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**École Nationale Supérieure d'Informatique et d'Analyse des Systèmes**  
Centre d'Études Doctorales en Sciences des Technologies de l'Information et de l'Ingénieur

## THÈSE DE DOCTORAT

# GAMIFICATION OF MOBILE HEALTH SOLUTIONS: CASES OF BLOOD DONATION AND POSTNATAL CARE APPS

Présentée par

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I, *Lamyae SARDI*, declare that this thesis entitled, 'Gamification of mobile health solutions: Cases of Blood donation and postnatal care Apps' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at ENSIAS, Mohamed V, Rabat.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- All the assistance received in preparing this thesis and all the main sources have been acknowledged.

Signed: *Lamyae Sardi*

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*“If you can’t fly then run, if you can’t run then walk, if you can’t walk then crawl, but whatever you do you have to keep moving forward.”*

*–Martin Luther king Jr*

# *Abstract*

Owing to the ubiquity of smartphones and their associated devices, a plethora of mobile health applications (mHealth apps) can now be found in the app stores. In such apps, gamification appears being an auspicious approach to improve user engagement, promote healthy behaviours, and motivate users to use mHealth apps over a long period of time. Over the last decade, gamification has gained growing interest among healthcare researchers and professionals, in that a variety of health-related interventions are being gamified. While most of these interventions support a priori pervasively gameful behaviours such as exercise, scant attention is paid to other health behaviours. The objective of this thesis is therefore to investigate the use of gamification principles in less pervasive health sectors such as blood donation (BD) and postnatal care (PNC). As a result, two gamified apps have been developed to: 1) aid in the recruitment and retention of motivated blood donors and 2) promote postnatal care, respectively. To build strong foundation for this research, a literature review has been conducted to scrutinize the use of gamification in health-related contexts. Moreover, an analysis of functionalities and features of available BD and PNC apps has been carried out to help elicit relevant requirements. Throughout the cycle of this research, several disciplines have been investigated to raise the quality and potential of these pilot apps including requirements engineering and software product quality.

A significant part of the research presented in this thesis was conducted in close cooperation between the Software Project Management research team of ENSIAS in Morocco and the Software Engineering Research Group of University of Murcia in Spain. The research on postnatal care was carried out under the PEER project 7-246 entitled: "Facilitating Access to Reproductive Health Services for Refugee Women in Morocco". This project is supported by the US Agency for International Development (USAID).

**Keywords:** Gamification, mHealth, Software Quality, ISO/IEC 25010, Requirements Engineering.

# Résumé

En raison de l'omniprésence des smartphones et des appareils qui leur sont associés, une pléthore d'applications de santé mobiles sont désormais disponibles dans les magasins d'applications. Dans ces applications, la ludification semble être une approche prometteuse pour améliorer l'engagement des utilisateurs, promouvoir des comportements sains et motiver les utilisateurs à utiliser les applications de santé mobiles sur une longue période. Au cours de la dernière décennie, la ludification a suscité un intérêt croissant parmi les chercheurs et les professionnels de la santé, dans la mesure où elle permet de ludifier diverses interventions liées à la santé. Alors que la plupart de ces interventions soutiennent a priori des comportements ludiques tels que l'exercice physique, les autres comportements de santé ne font guère l'objet d'une attention particulière. L'objectif de cette thèse est donc d'étudier l'utilisation des principes de ludification dans des secteurs de la santé moins envahissants tels que le don de sang et les soins postnatals. En conséquence, deux applications ludifiées ont été développées pour: 1) aider au recrutement et à la fidélisation de donneurs de sang et 2) promouvoir les soins postnatals, respectivement. Afin d'établir une base solide pour cette recherche, une analyse documentaire a été menée pour examiner l'utilisation de la ludification dans des contextes liés à la santé. En outre, une analyse des fonctionnalités et caractéristiques des applications pour le don du sang et les soins postnatals disponibles a été réalisée pour aider à déterminer les exigences pertinentes. Tout au long du cycle de cette recherche, plusieurs disciplines ont été étudiées pour améliorer la qualité et le potentiel de ces applications pilotes, notamment l'ingénierie des exigences et la qualité des produits logiciels. Une partie importante de la recherche présentée dans cette thèse a été menée en étroite collaboration entre l'équipe de recherche sur la gestion de projets logiciels de l'ENSIAS au Maroc et le groupe de recherche sur le génie logiciel de l'université de Murcia en Espagne. La recherche sur les soins postnatals a été réalisée dans le cadre du projet PEER 7-246 intitulé: "Faciliter l'accès aux services de santé reproductive pour les femmes réfugiées au Maroc". Ce projet est soutenu par l'Agence américaine pour le développement international (USAID).

**Mots clés:** Ludification, Santé mobile, Qualité du logiciel, ISO/IEC 25010, Ingénierie des exigences.

# *Resumen*

Debido a la ubicuidad de los teléfonos inteligentes y sus dispositivos asociados, ahora se puede encontrar una gran cantidad de aplicaciones móviles (apps) de salud en las tiendas de aplicaciones. En esas apps, la gamificación parece ser un enfoque auspicioso para mejorar la participación del usuario, promover conductas saludables y motivar a los usuarios a utilizar las apps de salud durante un largo período de tiempo. En la última década, la gamificación ha ganado un interés creciente entre los investigadores y profesionales de la salud, en el sentido de que se está modificando una variedad de intervenciones de salud. Si bien la mayoría de estas intervenciones apoyan a priori los comportamientos lúdicos generalizados, como el ejercicio, se presta escasa atención a otros comportamientos de salud. Por consiguiente, el objetivo de esta tesis es investigar el uso de los principios de la gamificación en sectores sanitarios menos omnipresentes, como la donación de sangre y la atención postnatal. Como resultado, se han desarrollado dos apps gamificadas para: 1) ayudar a la captación y retención de donantes de sangre y 2) promover la atención postnatal, respectivamente. A fin de sentar bases sólidas para esta investigación, se ha realizado un examen de la bibliografía para analizar el uso de la gamificación en contextos de salud. Además, se ha llevado a cabo un análisis de las funcionalidades y características de las apps de donación de sangre y de la atención postnatal disponibles para ayudar a obtener los requisitos pertinentes. A lo largo del ciclo de esta investigación, se han investigado varias disciplinas para elevar la calidad y el potencial de estas apps piloto como la ingeniería de requisitos y la calidad del software. Una parte importante de la investigación presentada en esta tesis se llevó a cabo en estrecha cooperación entre el equipo de investigación de Gestión de Proyectos de Software de ENSIAS en Marruecos y el Grupo de Investigación de Ingeniería de Software de la Universidad de Murcia en España. La investigación sobre la atención postnatal se llevó a cabo en el marco del proyecto PEER 7-246 titulado: "Facilitar el acceso a los servicios de salud reproductiva para las mujeres refugiadas en Marruecos". Este proyecto cuenta con el apoyo de la Agencia de los Estados Unidos para el Desarrollo Internacional (USAID).

**Palabras claves:** Gamificación, Salud móvil, Calidad del software, ISO/IEC 25010, Ingeniería de requisitos.

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# Abbreviations and acronyms

|               |   |
|---------------|---|
| <b>AA</b>     | <b>Apps' Accessibility</b>  |
| <b>AF</b>     | <b>App's Functionalities</b>  |
| <b>BD</b>     | <b>Blood Donation</b>   |
| <b>BP</b>     | <b>Behavioural Processes</b>  |
| <b>COPPA</b>  | <b>Children's Online Privacy Protection Act</b>                           |
| <b>DP</b>     | <b>Donation Point</b>   |
| <b>EC</b>     | <b>Exclusion Criteria</b>   |
| <b>EDPS</b>   | <b>Edinburgh Postnatal Depression Scale</b>                               |
| <b>EHR</b>    | <b>Electronic Health Record</b>   |
| <b>EP</b>     | <b>Experiential Process</b>   |
| <b>FAQ</b>    | <b>Frequently Asked Questions</b>   |
| <b>GDPR</b>   | <b>General Data Protection Regulation</b>                                 |
| <b>HIPAA</b>  | <b>Health Insurance Portability and Accountability Act</b>                |
| <b>i18n</b>   | <b>Internationalization</b>   |
| <b>IC</b>     | <b>Inclusion Criteria</b>   |
| <b>ICT</b>    | <b>Information and Communication Technology</b>                           |
| <b>JCR</b>    | <b>Journal Citation Reports</b>   |
| <b>MANOVA</b> | <b>Multivariate ANalysis Of Variance</b>                                  |
| <b>PHI</b>    | <b>Personal Health Information</b>  |
| <b>PHR</b>    | <b>Personal Health Record</b>   |
| <b>PNC</b>    | <b>PostNatal Care</b>   |
| <b>PPD</b>    | <b>PostPartum Depression</b>  |
| <b>PPH</b>    | <b>PostPartum Hemorrhage</b>  |
| <b>PRISMA</b> | <b>Preferred Reporting Items for Systematic Reviews and Meta-Analyses</b> |
| <b>QA</b>     | <b>Quality Assessment</b>   |
| <b>RE</b>     | <b>Requirements Engineering</b>   |
| <b>RQ</b>     | <b>Research Question</b>  |



|               |   |
|---------------|---|
| <b>SD</b>     | <b>Standard Deviation</b>                           |
| <b>SDT</b>    | <b>Self-Determination Theory</b>                    |
| <b>SE</b>     | <b>Software Engineering</b>                         |
| <b>SIREN</b>  | <b>SImple REuse of software requiremeNts</b>        |
| <b>SLR</b>    | <b>Systematic Literature Review</b>                 |
| <b>SQR</b>    | <b>Software Quality Requirements</b>                |
| <b>SRC</b>    | <b>Software Requirements Catalog</b>                |
| <b>SRS</b>    | <b>Software Requirements Specification</b>          |
| <b>SQuaRE</b> | <b>Software Quality Requirements and Evaluation</b> |
| <b>TPB</b>    | <b>Theory of Planned Behaviour</b>                  |
| <b>TRA</b>    | <b>Theory of Reasoned Action</b>                    |
| <b>TTM</b>    | <b>Trans-Theoretical Model</b>                      |
| <b>UA</b>     | <b>Users' Actions</b>                               |
| <b>UIA</b>    | <b>User Interface Aesthetics</b>                    |
| <b>UML</b>    | <b>Unified Modeling Language</b>                    |
| <b>UX</b>     | <b>User Experience</b>                              |

*To my parents ...*

# General Introduction

*“Gamification is design that places most emphasis on the human motivation in the process. In essence it is human focused design.”*

- Yu Kai Chou

The primary goal of this thesis is to gain deeper knowledge and understanding of gamification and its application for promoting healthcare services. This thesis also focuses on the requirements specification and software quality of mobile health applications (mHealth apps), particularly in the fields of blood donation and postnatal care. The major contributions of this thesis are: i) exploration of the state of research in the area of gamification in eHealth through a Systematic Literature Review, ii) analysis of functionalities and features of the available mHealth apps for blood donation and postnatal care, iii) design and implementation of two gamified mHealth apps for blood donation and postnatal care, respectively, iv) proposal of a comprehensive requirements catalog for the development of gamified mHealth apps.

This introduction is organized as follows: Section outlines the motivations for conducting this thesis. Section describes the major objectives of this thesis. Section portrays the research approaches used in this thesis and the thesis outline is presented in section .

## Motivations

Even in high-resource settings, Postpartum Hemorrhage (PPH) is recognised as one of the most frequent causes of maternal mortality and morbidity worldwide [1]. PPH is defined as the loss of lots of blood quickly which may cause a severe drop in blood pressure, and can lead, if not treated rapidly, to shock and death [2].

Generally happening after the placenta is delivered, mostly with a caesarian birth, PPH may also be caused by a lack of uterine tone, damage and tears to genital structures (cervix, uterus, vagina, etc), blood clotting disorders and placenta problems [3]. Some women are at

greater risk for PPH if they are obese, having quick or prolonged labor or had many previous births. In light of this, the immediate blood transfusions become necessary and life-saving, inducing therefore the importance of donating blood.

In spite of all the significant advances in the medical area, no real progress has been made to develop a substitute for blood [4]. Consequently, blood supplies are considerably outstripped by the immediate and crucial demand for transfusions [5]. Despite people awareness about the need for blood, 90% of people who are eligible to donate blood are not currently doing so. Non-donors provide different reasons for their non-willingness such as busy schedule, needle phobia and fear of catching disease [6]. Notwithstanding the fact that blood donation (BD) is considered a purely prosocial behaviour, altruism and empathy were portrayed among the less significant motivations driving the BD decision [7]. Recruiting and retaining voluntary, non-remunerated, safe and young blood donors pose an acute challenge for transfusion services and blood banks. Social networks and text messages have played a leading role in the search and recruitment of blood donors, respectively [8]. However, it has been affirmed that relying on social networks and text messages to broadcast the need of BD could be inefficient if the information is irrelevant to the potential donors.

User-friendly apps may, in fact, promote BD. Through geolocation services and push notifications, donors can be instantly informed of blood shortage in nearby locations. Besides, offering virtual and/or real rewards to donors can boost their motivation and enhance the retention rate of regular donors [9]. Considering that the individual is mostly driven by its intrinsic motivations [10], levelling and acquiring status can have a better influence on donors' engagement and loyalty. In spite of the large number of BD apps, there is a significant scarcity of BD apps that employ game elements to motivate users (i.e. donors or non-donors) and stand upon a well-founded understanding of the users' psychology.

While blood transfusions can save lives of thousands of women during postpartum, an optimal postnatal care (PNC) remains also highly important to avert neonatal and maternal deaths, as well as long-term complications. PNC is the care given to the mother and her newborn infant immediately after the birth and during the postnatal period which may last up to six months [11]. Effective counseling, well-founded. Vaginal care, targeted postpartum hygiene and nutrition, infant care and counselling on family planning and exclusive breastfeeding are the most preeminent pillars of PNC [12]. Along with its undoubtable benefit for both infant and maternal health, studies have shown that extended breastfeeding can substantially decrease the risk of postpartum anaemia [13]. Thus, the importance of delivering an appropriate PNC cannot be overstated. Nevertheless, PNC services tend to be poorly covered when compared with other reproductive health care services. The inadequacy and the underutilization of PNC services likely emanate from several factors ranging from poor education and poverty to limited access to healthcare facilities [14]. In order to palliate these problems and improve access to reproductive healthcare services and PNC in particular, numerous apps have been launched in the mHealth apps market [15]. However, most of these

apps overlook some crucial postnatal aspects and lack motivational and engaging elements. The dearth of gamified comprehensive apps for BD and PNC is the major motive to focus on these two health disciplines.

## Research objectives

The objectives of this thesis are highlighted by means of research questions (RQs). Correlated to the main RQ which represents the central focus of this research, these questions are answered throughout the chapters of this thesis. The principal purpose of this thesis is to apply gamification to blood donation and postnatal care, therefore, the main RQ is formulated as follows:

**Main RQ.** How can gamification be effectively employed in blood donation and postnatal care areas?

In order to answer this main RQ, it is necessary to address the following RQs:

**RQ1.** What is the current state of research on applying gamification in the eHealth realm? This RQ is answered in Chapter 2 through a Systematic Literature Review.

**RQ2.** What are the main functionalities and features of available apps for BD and PNC? This RQ is answered in Chapter 3.

**RQ3.** What is the compelling set of functionalities and gamification aspects to develop an effective BD app? This RQ is answered in Chapter 4.

**RQ4.** What are the functionalities and features essential to build a comprehensive gamified PNC app? This RQ is answered in Chapter 4.

**RQ5.** What are the most relevant quality aspects to include in gamified mHealth apps? This RQ is answered in Chapter 5.

**RQ6.** How to conduct an audit method to assess and improve gamified mHealth apps? This RQ is answered in Chapter 5.

## Research approaches

In order to gather all the elements and data essential to addressing the research objectives, two types of research approaches have been used; a Systematic Literature Review (SLR) to explore the applications of gamification in healthcare contexts and a survey to understand blood donors' behaviour.

## Systematic Literature Review

Each year, a considerable amount of research is produced, usually with discordant results. These inconsistencies across studies are mainly due to operational and methodological aspects. In such situations, it becomes difficult to decide which results are most reliable and replicable. Systematic reviews aim to resolve these issues by identifying, critically appraising and integrating all the relevant data and results from research about a particular problematic in a standardized and systematic way. Systematic reviews help giving objective and transparent overview of all evidence surrounding a particular RQ. Given their explicit methodology and their study design that reduces bias, systematic reviews are considered to be the highest quality evidence on a research topic and have the potential to provide the most important practical implications [16].

A systematic review is defined as a review using a systematic method to synthesize evidence on RQs with a detailed and comprehensive plan of study. The key steps for effectively conducting a systematic reviews are the following [17, 18]:

1. **Formulate the RQ(s).** The problem(s) to be addressed by the review should be specified in the form of clear, well-defined and structured questions. In clinical and health-related studies, the RQ should address four basic elements, known as PICO which stands for: Population, Intervention, Comparison and Outcome.
2. **Define the inclusion/exclusion criteria (IC/EC)** that will be used to determine whether or not a study will be included in the search. These study selection criteria should flow directly from the review questions.
3. **Select relevant studies.** The search for studies should be extensive in that multiple resources should be searched. all the studies found should undergo a rigorous screening using the selection criteria. Reasons for inclusion and exclusion should be recorded.
4. **Extract relevant data from included studies.** The objective of this stage is to read the full-text of the included studies and extract relevant data using a pre-determined data extraction form. At a minimum, data extraction form should include: Study Characteristics; with particular detail related to characteristics, Outcome Measures of interest, and Results to be used in data synthesis.
5. **Assess the quality of all included studies.** Selected studies should be subject to an in-depth quality assessment by use of design-based quality assessment checklists. This assessment will be used for exploring heterogeneity and identifying potential risk of various biases which will allow to gauge the quality of the evidence in a more refined way.
6. **Summarize the evidence.** Data synthesis consists of categorizing the findings and exploring commonalities and differences between studies.

7. **Interpret the findings.** This final step consists of clearly presenting the findings, including detailed methodology so that the review can be easily updated in the future with new research findings. A good interpretation of the findings will significantly help in objectively answering the RQ(s).

## Survey

Frequently present in politics, market, social, and psychological research, surveys are one of the most reliable ways to gather targeted information in which to draw conclusions and make important decisions [19]. A survey is a research approach that is based on the collection of information from a specific group or a representative sample of a particular group to gain specific information regarding knowledge, attitudes, or behaviours [20]. It can use quantitative and/or qualitative research strategies. Quantitative strategy is usually conducted through surveys with closed-ended questions whereas qualitative strategy consists of open-ended questions to explore more elaborate answers. When quantitative and qualitative strategies are paired, we talk about mixed strategy that allows a complete set of data to be gathered about the target audience to gain broader information about their demographic characteristics, experience, behaviours and attitudes [21]. Accordingly, there are several ways of administering a survey depending on multiple factors such as: Time, costs, coverage of the target audience, sensitivity of survey data and response accuracy. These administration modes can be summarized as follows [19]:

- **Interviewer-administered structured interviews** (e.g. Face-to-face interviews, telephone interviews, street intercept survey)
- **Self-administered questionnaires** (e.g. Web survey, Mail survey)
- **Mixed-mode surveys** (e.g. web survey followed by a shorter telephone interview for non-respondents).

In order to conduct an effective survey research, it is essential to perform the following steps [22]:

1. Develop a single clear and explicit RQ
2. Define the population and sample
3. Decide on the administration mode (e.g. face-to-face, online, mail)
4. Design the survey questions
5. Disseminate the survey and collect responses
6. Analyze the survey results

## 7. Report the results

Despite the simplicity of these steps, a number of surveys fail to obtain accurate results. Among the multiple challenges facing survey research, the rise of non-response is perhaps the most bothersome. The non-response can stem from the respondents' refusal or lack of cooperation, cultural and language barriers, or from the inadequacy and ambiguity of the survey's questions. Besides, missing the purpose, prompting respondents with leading questions and measuring too many factors can highly affect the efficiency and reliability of the survey research [23]. For a survey research to yield accurate results, it is therefore imperative to clearly define the purpose, know the target population and its preferences with regards language and technical aspects and design a short and convenient survey with relevant, unbiased and intelligible questions.

## Thesis outline

This thesis is organized as follows:

Chapter 1 provides some background on the most important topics of this thesis. It, first, introduces mobile health and gamification. Second, it describes the Trans-Theoretical Model (TTM) as the most relevant behaviour change theory applied in health settings. Moreover, Chapter 2 gives an overview of common software quality models that are principally used in the definition of quality requirements or in the measurement of the software product quality. The core activities involved in the requirements engineering process are also presented.

Chapter 2 presents the state-of-the-art research on gamification in e-health. An SLR has been conducted to investigate the domains of application, benefits and challenges of gamification in health settings. To this aim, substantial data have been extracted from a total of 46 primary studies in order to answer nine RQs. Subsequently, these studies were classified according to their research types, publication channels and trends, health disciplines and empirical types. Moreover, all data related to the game mechanics employed in the proposed gamified solutions, the challenges encountered and the perceived benefits of gamification have been retrieved from the selected studies.

Chapter 3 analyzes the functionalities and gamification aspects implemented in the BD apps available in app repositories. A quality evaluation of these apps using ISO/IEC 25010 quality model is also provided. The degree of impact of 37 BD apps' requirements on eight quality characteristics and their underlying sub-characteristics have been therefore assessed. Moreover, Chapter 4 explores a total of 48 PNC apps to identify the most predominant functionalities and technical features in relation to security, usability and internationalization.



Chapter 4 proposes two gamified health mobile solutions intended to promote BD and PNC, respectively. On the one hand, a stage-matched BD app has been developed to enhance the recruitment and retention of blood donors through combining gamification elements and TTM principles. On the other hand, a PNC solution has been developed in collaboration with Maternity les orangers in Rabat under a PEER research project. The requirements specification has therefore been carried out taking into consideration the functionalities presented in Chapter 3 and those catering the real needs of women in terms of PNC. This chapter also provides a gamification strategy to be implemented in the solution and an experiment design to perform an empirical evaluation of its overall quality.

Chapter 5 presents a reusable software requirements catalog for gamified mHealth apps. Multiple information sources including standards and international guidelines have been considered to discern the most relevant requirements regarding gamification, functional suitability, usability and security. Chapter 5 also outlines the phases of an audit approach to assess the compliance of apps with the requirements in the catalog. A BD and a PNC apps have been selected to validate the applicability of both the catalog and the audit method. An evaluation of these two apps has been provided by means of a checklist generated from the catalog.

Chapter 6 concludes this thesis. This chapter presents a summary of the main contributions of our research by highlighting the key findings. A list of potential directions for future works is also provided.

# Background

## 1.1 Introduction

This chapter presents the key concepts and the theoretical background for this thesis. Section 1.2 and Section 1.3 provide an overview of the trends, advantages and challenges associated with the advancement of mobile health technology and gamification. The most popular theories that help understand the change in people's health behaviour are described in Section 1.4. The remaining sections are concerned with Software Engineering; Section 1.5 presents the Software Quality Models applied in the contributions dealing with quality assessment of mHealth apps and Section 1.6 highlights the requirements engineering process.

## 1.2 Mobile health

Information and Communication Technologies (ICT) have proven to be a powerful prospect in promoting the fields of healthcare and allowing patient empowerment and disease management [24]. ICT have been efficiently used by patients and healthcare providers to facilitate communication, manage patient history and handle medical transcriptions, among others [25]. The new era of mobile technologies has revolutionized all fundamental human pursuits in that many sectors have been reshaped and tangibly improved such as education, finance and healthcare [26]. The features of mobile technologies that may make them particularly appropriate for providing individual level support to consumers relate to their popularity, their mobility, and their technological capabilities. The popularity of mobile technologies has led to high and increasing ownership of mobile technologies, which means interventions can be delivered to large numbers of people [27].

Referred to as mHealth, the use of mobile technologies to track and improve health outcomes is a rapidly expanding trend. mHealth is a term coined for the use of mobile and wireless devices to improve health outcomes. The Global Observatory for eHealth of the World Health Organization (WHO) defines mHealth as "medical and public health

practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices” [28]. mHealth is thus the new edge on healthcare innovation. It proposes to deliver healthcare anytime and anywhere, surpassing geographical, temporal, and even organizational barriers [29, 30]. Efforts to adopt health apps into medical and clinical practice has progressed significantly, leading to a steadily proliferation of the mHealth industry. There are now over 318,000 mHealth apps available at the top app stores worldwide, namely Google Play Store and Apple App store, accounting with more than 200 apps being added each day [31]. This staggering number is fuelled by a combination of factors including the increased penetration and ownership of smartphones, tablets and other mobile platforms, the high burden of chronic disease prevalence and the shift towards a patient-centric healthcare delivery [32]. Besides, the rising need for tracking daily activities, changing lifestyles and behaviours substantially results in the widespread use of mHealth apps [33]. In this respect, mHealth apps promise to empower patients and healthcare providers at different levels and through a myriad of ways including the ubiquitous access to accurate health information [32], consistent remote monitoring and vital signs self-management along with the startling treatment adherence support [33, 34]. Patients can remain under constant observation of expert physicians without being physically present at the hospitals. Another prevalent benefit of mHealth apps is shifted towards motivating positive health behaviour change which is considered as the most frequently targeted lever for reducing the burden of preventable disease and enhancing wellbeing [35, 36].

Despite these perceived advantages, the lack of regulation around the dissemination of mHealth apps raises concern about their quality and practices. In fact, there are many significant challenges that plague the implementation of mHealth apps, which can be categorized into issues with user experience, data security and privacy, and user engagement [37]. User experience (or usability) is considered a crucial part of design and development of apps for mHealth as it aims to reduce the risk of users having difficulty in using the application and it is one of the attributes that regulate the success of the app in the market [38, 39]. From user interface to app navigation, every element in the app must add value to the overall user experience. Besides simplicity and intuitive navigation, interactivity is another key element to include in design features to enhance the overall usability of the application [40]. In general, users prefer interactive systems which are simple, interesting and satisfying. Furthermore, mHealth solutions shall resonate with the health literacy level of the target audience to shrink the gap in knowledge between healthcare providers and potential users. Another prevalent concern for users of mHealth apps is information security and privacy issues. Undoubtedly, mHealth apps facilitate easier information sharing and a better patient experience, nonetheless, they often collect and manage a massive amount of health and sensitive data [37]. Per se, it is of great importance to develop apps that comply with security and privacy guidelines defined by data protection laws, such as the European Union’s General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability

Act of 1996 (HIPAA) in the US [41]. Vulnerabilities regarding privacy and security may result in infringing the confidentiality of users' data which can subsequently lead to financial losses, discrimination, stress and discontent [42]. Developers of mHealth apps can therefore enact some technical safeguards to ensure users' data protection and privacy. These include the implementation of policies and procedures that a) guarantee the identity of users and impede access to third parties through authentication and identification, b) establish measures that warrant the integrity and encrypt users' data both in transmission and while being stored.

Offering consumers easy to use, intuitive and secure mHealth apps constitute the departure point towards user engagement. Being tightly linked to the users' intention to continue using the app, user engagement is also considered a decisive factor in determining the success of mHealth apps [43]. User engagement defines the user's response to an interaction that stimulates and retains their attention. In addition to fulfilling their ultimate user-centered health care objectives through the provision of vital information and informed decision making tasks, mHealth apps must offer user-friendly features, reach a high level of transparency and include gamification techniques (e.g. rewarding systems, challenges, leaderboards, etc) in order to boost user engagement [43].

### 1.3 Gamification

The concept of "gamification" has become progressively popular over the last few years. Conceived in the digital media industry, gamification began to be adopted on a wide scale only in the second half of 2010 [44]. In fact, the first documented use dates back to 2008, under the word "funware", which was coined by Gabe Zichermann [45]. Gamification gained more notability through various books such as Jane McGonigal's "Reality is Broken" [46] and Gabe Zichermann's "Game Based Marketing" [47]. Zichermann has also developed a marketing guide based on game mechanics to create brand awareness and drive customer engagement [47]. As the term "gamification" was heavily contested within the video game and digital media industries, many designers originated new terms for their own practice to avoid the appearance of misconceptions about gamification [45]. Moreover, there has been much controversy surrounding the definition of "gamification" [44,45,48]. However, the most commonly accepted definition amongst those proposed was that of Sebastian Deterding who stated that "Gamification is the use of game design elements in non-game contexts" [44]. This signifies that rather than creating immersive, full-fledged games as in "serious games", gamification is intended to affect the users' behaviour and motivation by means of experiences reminiscent of games [49]. Nevertheless, the aforementioned definition is related to similar concepts such as serious games, playful interaction, and game-based technologies [44]. Serious games are games designed for non-recreational purposes, focusing therefore on areas as "serious" as economics, education, health, industry, military and politics [50]. The most widely conventional definitions of serious games follow the lead

set by Michael [51] and Stokes [52] by which serious games were regarded as either being “games that do not have entertainment, enjoyment or fun as their primary purpose” or “games that are designed to entertain players as they educate, train, or change behavior.” Unlike gamification, serious games appeared a long time before the proliferation of computer technologies [53]. The ancestors of serious games were mainly non-digital and started to emerge in a few domains, namely, education, military and politics [54].

Although serious games and gamification tend to be used for purposes other than their expected entertainment use, their implementations differ considerably. Whereas serious games sometimes called as ‘games with a purpose’ afford pure gaming experiences by means of gameplay rules, game engines and mechanics, gamification attempts to create experiences reminiscent of game through a combination of game mechanics and game experience design [55]. Rewards (e.g. points, achievement badges, and leaderboards) are perceived as a core gamification strategy for users who accomplish the requested tasks [56]. Some of the means used to promote competition are setting challenges and making the tasks visible to other users [56]. Another useful pillar of gamification is leveraging social networks to increase engagement and interaction among the users [57]. There are many additional meaningful gamification tactics, which enhance the persuasiveness of the gamified solution, such as narrative storylines, avatar-based self-representation and onboarding tutorials [58].

Gamification thus promises a dual improvement consisting of making the activities more pleasant while ensuring people’s long-term engagement with tasks perceived to be demotivating [59]. Basically, a range of emotional, cognitive and social benefits are ascribed to gamification [59]. Developing positive social relationships and promoting a feeling of integration are the key social benefits noted for gamification [60]. Social influence can also invoke a sense of competition to achieve a higher status on the ranking table yielding thereby numerous emotional skills such as auto-satisfaction, self-esteem and pride [61]. Moreover, there is a good evidence that gamification aid in cognitive development, as it stimulates the brain and promote knowledge acquisition [61]. It helps develop strategic abilities of the players as long as it enhances their working memory, visual attention and processing speed [62]. Typically, the various game mechanics potentially involved in gamification are regarded as an anchoring point for players to ensuring a flow of cognitive skills such as reaching a state of concentration, developing problem-solving skills and acquire a sense of goal-orientation [63]. The underlying idea of gamification is to harness people’s innate motivation alongside the natural desire to learn, socialize, master tasks, compete, record achievements, build status, participate in self-expression and have fun [64,65]. Appealing to these intrinsic motivators, the gamified technology employs rewards and competitive game features to induce user immersion in the app environment [35]. These incentives typically include earning points, achievement badges and virtual currency or new levels, challenges and progress bars [66]. The use of leader boards and making rewards visible to other users are ways of fostering user competition.

According to a research report, the gamification market size is projected to generate USD 30.7 billion by 2025 [67]. In the same way, a market study shows that the world-wide Serious Games market it is forecast to reach \$8.91 billion by 2025 [68]. Nevertheless, it is interesting to note that despite the oldness of the concept of serious games, gamification genuinely steps into the mainstream whereas serious games stay in much limited scale [69]. To illustrate this point, observe that gamification has already been applied in several domains, including education (e.g. to foster the engagement of students [50]), business (e.g. to engage employees and increase customers' loyalty [70]) and environmental sustainability (e.g. to inspire and provoke engagement in environmentally positive behaviors [71]). There has been considerable interest in applying gamification to the digital healthcare industry. This growing interest was to some extent spawned by the inequity of access to healthcare resources, the lack of adherence to treatment [72] and the increase in healthcare costs [73]. Electronic technology has effectively contributed to the rise of gamification in many industries. The advanced features of smartphone handsets such as inbuilt accelerometers, external sensors and GPS services have proven to be an especially useful vehicle for the seamless delivery of healthcare interventions in general, and gamified health interventions in particular [73]. The tremendous power of the technological advances have led innovation and creativity to become more attractive and tempting for researchers in various domains. The healthcare realm in particular has been positively affected, and highly advanced health-related systems have therefore been developed in order to promote healthy lifestyles and enhance overall wellbeing.

## **1.4 Health behaviour change theory**

Different theories and models of behaviour change have been applied to health contexts to assist in the design of behaviour change interventions. In this respect, six main theoretical perspectives to boost adherence to health behaviours have been identified (biomedical, behavioural, communication, cognitive, self-regulatory and stage perspectives) encompassing, each of them, different theories [74]. The most recurrently used theories are those within cognitive and stage perspectives. The cognitive perspective includes theories that consider attitudes and beliefs as the locus of the individual's behaviour. Of those theories, the Theory of Planned Behaviour (TPB) is the most widely cited and applied theory in predicting BD behaviour and intentions [75]. On the other hand, stage-based theories contend that individuals go through distinct stages as they learn and develop. The Trans-Theoretical Model (TTM) is the most prominent and widely applied among stage models [76].

### **1.4.1 Theory of Planned Behaviour (TPB)**

This theory evolved from the Theory of Reasoned Action (TRA) [77] which assumes that the intention to perform a particular behaviour acts as the best determinant and the most

consistent predictor of that behaviour [78]. Intention, in turn, is believed to be directly affected by attitude that includes the individual's positive or negative evaluations of the behaviour and subjective norms which reflect the individual's perception of the social pressure exerted on him for the performance of the behaviour [77,79]. Recognizing that the TRA omits the fact that behaviour may not always be function of voluntary control, Azjen [80] extended the theory to include the variable of behavioural control which reflects the ease or difficulty perceived in performing the behaviour. Conceptually, the perceived behavioural control is closely related to the notion of self-efficacy [81] since they are both concerned with the perceived ability to perform a behaviour [82].

Although the TPB has proved to be the most promising theory in predicting future blood donor behaviour [75], its predictive utility was generally improved by considering the incorporation of other constructs [83]. The extensions to the TPB include moral norm, anticipated regret, identity, self-categorization [84] donation anxiety and past behaviour, to cite but a few [85]. Nevertheless, many limitations have been levied against the use of TPB in the prediction of BD intention and behaviour. It has been shown that these theories tend to focus on single, discrete acts rather than on repeated acts [85]. Moreover, models of attitude structure as the TPB, appear to offer very little in the way of selecting the highly significant predictors to guide interventions' set up [75]. As a viable alternative to the TPB, researchers have begun to apply the TTM to conceptualize blood donation behaviour [86].

#### 1.4.2 Trans-Theoretical Model (TTM)

Originally, the TTM was developed to study nicotine addiction, it assesses the individuals' readiness to quit smoking and provide them with well-established strategies to move towards smoking cessation [87]. More recently, the TTM has been applied in distinct cultures and ethnicities [88,89] over numerous health behaviours [90] including exercise, dietary fat reduction, diabetes prevention, organ donation, etc. The TTM consists of two major components: Stages of Change and Processes of Change [75]. The temporal dimension of this model is construed by these five exclusive stages of change: Pre-contemplation, Contemplation, Preparation, Action and Maintenance [75]. Each of these delineates the actual readiness and willingness of individuals for change. For instance, Pre-contemplation is the stage in which people are not planning to take action in the foreseeable future because they are unaware of the reason to change. Whilst, individuals in maintenance stage are being more confident to maintain the desired behaviour and are less tempted to relapse. Ten processes of change have been suggested to facilitate the transition from one stage to the next and were classified into two categories: experiential and behavioural. Each of these processes of change intervenes uniquely at one transition. [91].

The experiential processes are used primarily for the early stage transitions and include:

- **Consciousness Raising:** Increase awareness and gain understanding about the be-

haviour change

- **Dramatic Relief:** Increase emotional experiences about the behaviour change
- **Environmental Reevaluation:** Realize how the behaviour change affects physical and social environment
- **Self-Reevaluation:** Assess how one feels with and without the behaviour change
- **Social Liberation:** Harness environmental and social opportunities with the behaviour change

The five behavioural processes used primarily for the later stage transitions include:

- **Self-Liberation:** Choose and commit to act or believe in the ability to change
- **Reinforcement Management:** Reward oneself or be awarded for making steps towards behaviour change
- **Helping Relationships:** Trust and accept the support of others that encourage the desired behaviour
- **Stimulus Control:** Avoid cues for unhealthy habits and stimuli that encourage alternative behaviours.
- **Counter Conditioning:** Substitute health behaviours and thoughts for the problem behaviour

Further, TTM was expanded to include two additional core constructs: Self-efficacy and Decisional balance. The application of self-efficacy has been found to have numerous implications in predicting blood donor behaviour. It is expected to increase as people progress through the stages [92]. However, it is particularly relevant at transition through the later stages [93]. Decisional balance reflects the individuals' relative importance of the cons and pros of changing a specific behaviour. Recent research suggested that the pros are likely to increase in the earlier stages (e.g. pre-contemplation to contemplation) whereas the progress from contemplation to action involved a significant decrease in cons [90]. As such, individuals in the later stages endorse more positive aspects of change and more negative aspects in earlier stages. Given that the behavioural change is a function of the increases and decreases of pros and cons, decisional balance is of practical significance in developing tailored interventions to predict and enhance blood donors' behaviour change.

## 1.5 An overview of Software Quality Models

The use of systems and software products for business or personal reasons is constantly growing. Health-related software products, for example, are becoming more popular and



widely claimed thanks to their tremendous importance in promoting healthcare. Subsequently, high-quality software products are essential to avoid the emergence of massive numbers of mistakes that may lead to potential fatal outcomes. Improving the quality of a software product can be achieved by defining the vital and desired quality characteristics associated with stakeholders' objectives and demands. The specification and definition of Software Quality Requirements (SQR) represents a crucial part of the Software Engineering process as it determines the overall quality of the software product. SQR started to gain increasing attention, the international research standardization project SQaRE (Systems and Software Quality Requirements and Evaluation) has, therefore, developed a consistent standard series ISO/IEC 250xx for the software product quality, evaluated from the users and stakeholders point of view as shown in Figure 1.1).

### 1.5.1 ISO/IEC 25010 quality model

The ISO/IEC 25010 is part of the SQaRE series of International Standards which was launched in 2011 to supersede the ISO/IEC 9126 that was technically revised and republished in 2001. ISO/IEC 9126 is an international standard for the specification and evaluation of software products quality [94]. The quality model proposed in ISO/IEC 9126 consists of two major sub-models: internal and external quality attributes, and quality in use attributes [95]. These models categorize software quality attributes into 10 characteristics which are decomposed into 24 related sub-characteristics. More than 250 measures are proposed to quantify these quality characteristics and sub-characteristics. The first sub-model identifies the quality of a software product through the following characteristics:

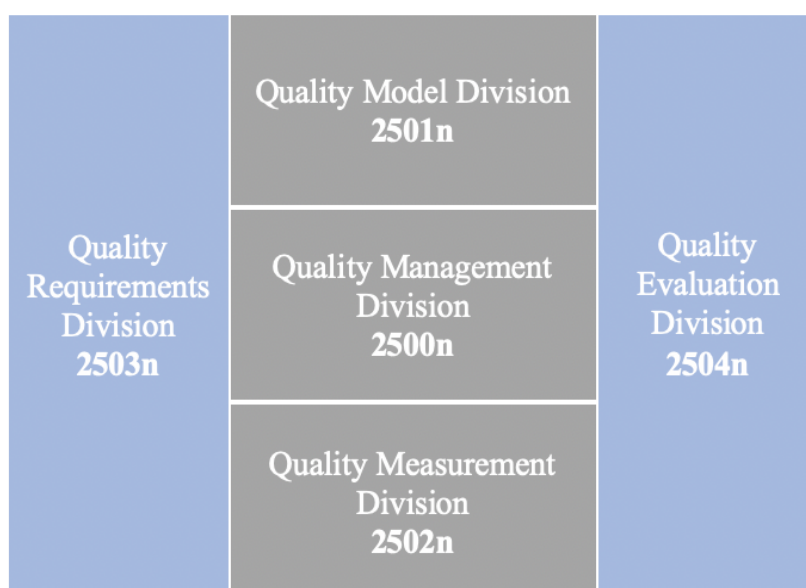


Figure 1.1: Organization of the SQaRE series of international standards.

Functionality, Reliability, Usability, Efficiency, Maintainability, and Portability. The 'quality in use' sub-model is hinged on a set of four characteristics, namely: Effectiveness, Productivity, Safety and Satisfaction which ISO/IEC 9126 suggests are indicative of the quality of the product from the user's point of view based on the combined influence of the attributes specified in the first sub-model. Nonetheless, the ISO/IEC 9126 model has been criticized for being ambiguous, difficult to understand and non-practical [96]. It provides metrics that are imprecise, completely merged and not well-founded [97]. Several additional weaknesses of the ISO/IEC 9126 have been identified [97], hence numerous refinements were proposed. For instance, 'security' and 'compatibility' became characteristics rather than sub-characteristics. New sub-characteristics were added to different characteristics such as maintainability and reliability. Moreover, the terminology was revised, thus some characteristics were renamed as for 'functionality' that was renamed 'functional suitability'. In ISO/IEC 25010 standard, software quality is divided into two broad dimensions: product quality and quality in use. On the one hand, the software product quality model is composed of eight characteristics [98]:

- 1) **Functional Suitability:** degree to which the software product provides functions that meet the stated and implied needs of its users.
- 2) **Performance Efficiency:** product's ability to provide appropriate performance, relative to the amount of resources used, under stated conditions.
- 3) **Reliability:** degree to which a software product maintains its level of performance under specified conditions for a stated period of time.
- 4) **Compatibility:** degree to which a system can perform its required functions efficiently, while sharing a common environment and exchange information with other systems.
- 5) **Usability:** degree to which a software's product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a particular context of use.
- 6) **Security:** degree to which a software product prevents unauthorized access to information and data.
- 7) **Maintainability:** degree of effectiveness and efficiency with which a software product can be modified.
- 8) **Portability:** degree of effectiveness and efficiency with which a system can be transferred from one hardware, software or other usage environment to another.

Each of these characteristics is composed of a number of sub-characteristics as shown in Figure 1.2. On the other hand, the quality in-use model relates to the outcome of interaction when a product is used in a particular context of use. The properties of quality in-use are categorized

into five characteristics, some of which are further subdivided into sub-characteristics as shown in Figure 1.3:

- 1) **Effectiveness:** accuracy and completeness with which users achieve specified goals.
- 2) **Efficiency:** resources expended in relation to the accuracy and completeness with which users achieve goals.
- 3) **Satisfaction:** degree to which user needs are satisfied when a product or system is used in a specified context of use.
- 4) **Freedom from risk:** degree to which a product or system mitigates the potential risk to economic status, human life, health, or the environment.
- 5) **Context coverage:** degree to which a product or system can be used with effectiveness, efficiency, freedom from risk and satisfaction in both specified contexts of use and in contexts beyond those initially explicitly identified.

### 1.5.2 ISO/IEC 2502n: Measurement of Software and System Product Quality and Quality in use

The ISO/IEC 25022:2016 and 25023:2016 are both part of the SQuaRE series of standards that form the Quality Measurement Division. They are primarily intended to be used together

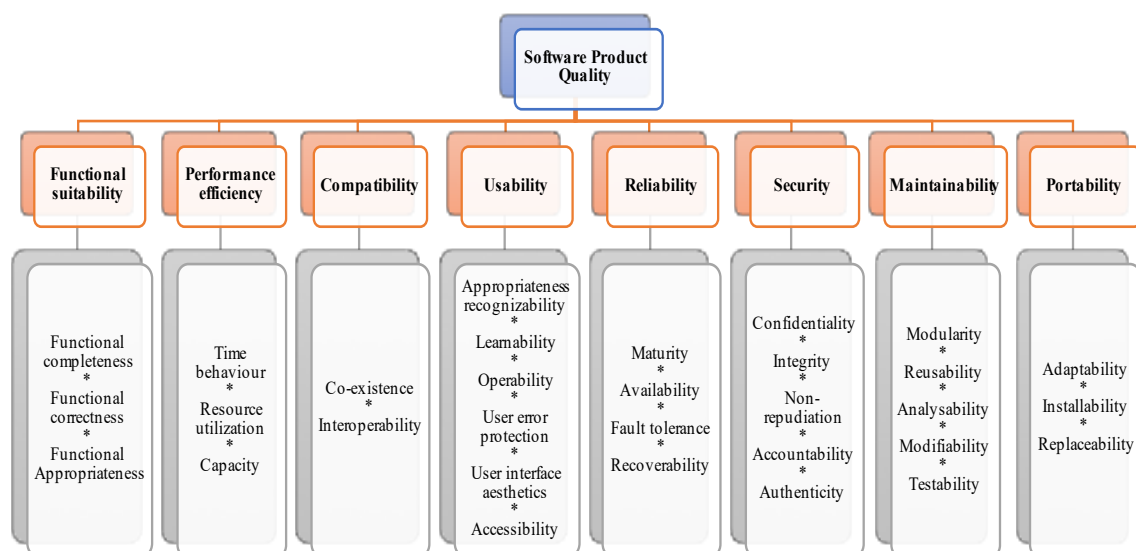


Figure 1.2: ISO/IEC 25010 Software Product Quality Model.

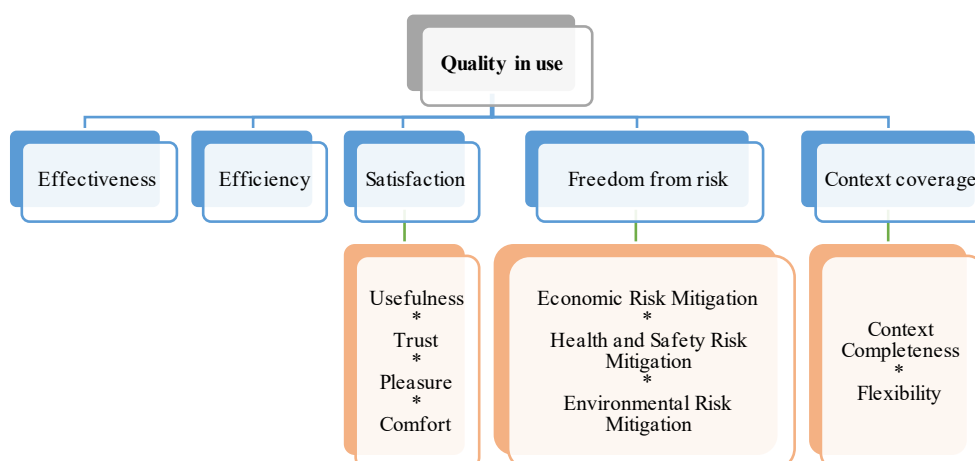


Figure 1.3: ISO/IEC 25010 Quality in use Model.

with ISO/IEC 25010, however they can also be used in conjunction with ISO/IEC 2503n and the ISO/IEC 2504n standards to address general needs with regard to product or system quality. The former aims to specify quality in use measures for the characteristics defined in ISO/IEC 25010 [99], whereas the latter describes a set of measures and provides guidance for quantitatively evaluating system and software product quality in terms of characteristics and sub-characteristics defined in ISO/IEC 25010 [100]. Both of these standards are the current revision of the following standards: ISO/IEC 9126-4 for quality in use metrics, ISO/IEC 9126-2 and ISO/IEC 9126-3 for external and internal metrics, respectively. Given that Product Quality measures and Quality in Use measures are tightly coupled (see Figure 1.4), the software quality is considered insufficient if either product quality or quality in use is absent.

### 1.5.3 ISO/IEC 25030: Software quality requirements

To ensure the quality of the software, it is paramount to specify the right software quality requirements that will be the bedrock of the desired quality of the final product [101]. The standard ISO/IEC 25030 uses the standard ISO/IEC 25020 to define which measures should be adopted for each characteristic and sub-characteristic identified in the standard ISO/IEC 25010 in order to specify the SQR. It is the only standard of SQuaRE Series that is dedicated to identifying and specifying system/software quality requirements. The application of this international standard can help ensure that SQR are clearly stated, correct and correspond to stakeholders' needs.

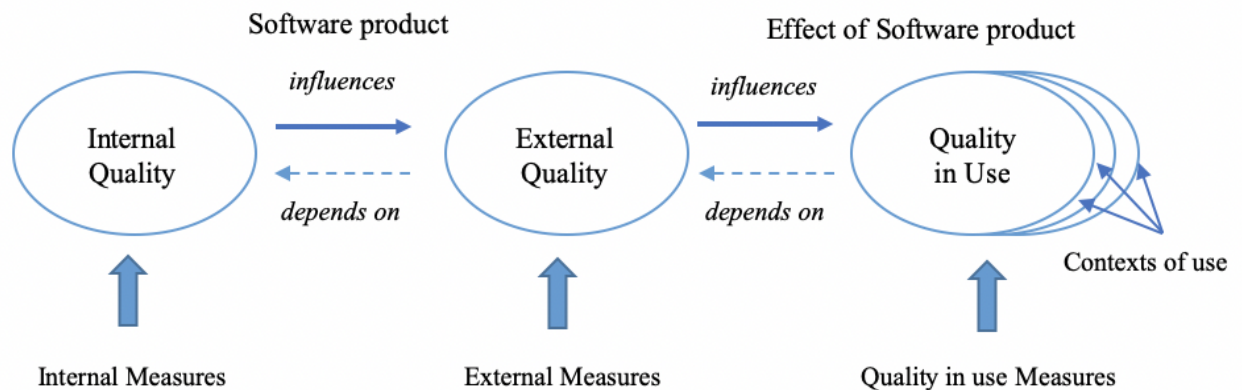


Figure 1.4: Relationship between quality measure types.

## 1.6 Requirements engineering

Requirements Engineering (RE) is a systematic approach, often used by software engineers to develop system requirements, which can serve as the basis for all other system development activities. It is an iterative and cooperative process of creating and maintaining a system requirements document [102]. The main purpose of RE is to discover a set of quality core system requirements that can be implemented into software development. The identified requirements must be clear, consistent, modifiable and traceable to produce a quality product. Requirements engineering is divided into two main groups of activities; namely, requirements development and requirement management. Requirements development covers activities related to identifying, capturing and validating a set of requirements and product characteristics that will achieve the stated business objectives, whereas requirement management includes activities dealing with traceability and verification. It also provides a way to keep track of changes in requirements.

### 1.6.1 Functional and non-functional requirements

A requirement can be defined as a description of the capabilities and characteristics that a software system must possess and the constraints under which it must operate, in order to satisfy stakeholder objectives and meet user needs [103]. Requirements are generally split into two types: Functional and Non-functional requirements.

- **Functional requirements**

These are the requirements that the end user specifically demands as basic facilities that the system should offer. Functional requirements are mandatory and developers must implement them to allow the system to function as it was intended. If the functional requirements are not met, the system will not work properly. Functional requirements are usually

represented or stated in the form of input to be given to the system, the operation performed and the output expected.

- **Non-Functional requirements**

Also known as quality attributes or non-behavioural requirements, non-functional requirements describe the general characteristics of a system that affect the user experience. Non-functional requirements are product properties and focus on user expectations. They do not affect the basic functionality of the system but determine how easy the system is to use, and judge system overall performance. Non-functional requirements basically deal with issues such as: Usability, Security, Flexibility and maintainability.

Functional and nonfunctional requirements can be formalized in the requirements specification (SRS) document. The SRS contains descriptions of functions and capabilities that the product must provide. In this respect, SRS documents are one of the most crucial deliverables in a software project in that they are necessary to both communicate and define requirements in a clear and concise way to ensure teams and individual stakeholders are on the same page regarding the software product.

## 1.6.2 Requirements development process

As shown in Figure 1.5, the requirements development process includes four generic activities: Requirements elicitation, requirements analysis, documentation of requirements, validation and verification of requirements [104].

1. **Requirements elicitation:** This phase starts with identifying stakeholders of the system and gathering raw requirements from them. This process aims to collect different viewpoints such as business requirements, user requirements, constraints, security requirements and standards, etc. There are a number of elicitation techniques to gather requirements or to collect the information from the stakeholders. Commonly used elicitation processes are the consultations with stakeholders through meetings or interviews.

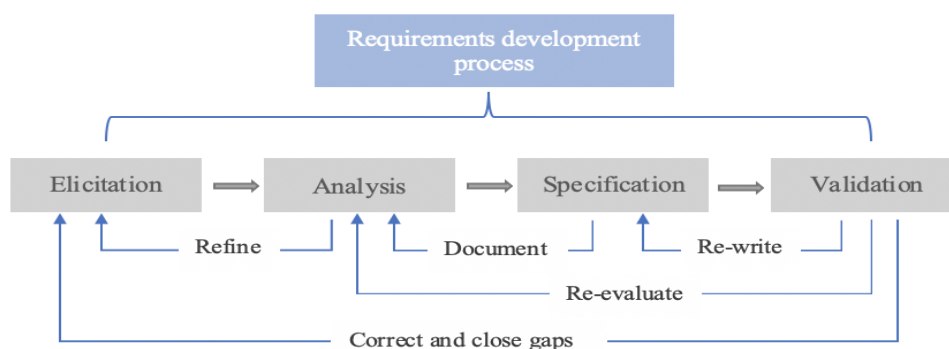


Figure 1.5: Requirements development process

2. **Requirements analysis:** This phase includes taking higher level requirements and delineating them down into appropriate level of detail. Requirements analysis involves searching for missing requirements and evaluating feasibility. It provides a feedback loop to refine the requirements gathered during the elicitation phase, get clarification, fill in missing details and resolve conflicting information. Negotiating priorities of the software requirements is also part of software requirements analysis. The analysed requirements need to be documented to enable communication with stakeholders and future maintenance of requirements and the system.
3. **Requirements documentation:** This involves capturing the information and structuring it into some form that can be used as a communication tool among the various project's stakeholders. A formal document, which contains a complete description of the external behavior of the software system is then prepared. Non-functional requirements are combined together with functional requirements into the software requirements specification. The documentation of requirements includes requirement identification (focus on the assignment of a unique identifier for each requirement) and requirement specification (complete description of the behaviour of the system or software to be developed).
4. **Requirements validation:** This phase ascertains that the correct requirements are stated (validation) and they are stated correctly (verification). On the one hand, validation is the process of ensuring that the requirements: 1) achieve stated business objectives, 2) meet the needs of stakeholders and are 3) clear and understood by the developers. It addresses each individual requirement to ensure that it is correct, clear, feasible, modifiable, necessary, prioritized, traceable and verifiable. The most common techniques for validating requirements are requirements reviews with the stakeholders, and prototyping. On the other hand, verification is the process of confirming that the designed and built product fully addresses documented requirements. It includes correctness, consistency, unambiguousness and understandability of requirements. Verification consists of performing various inspections, tests and analyses throughout the product lifecycle.

## 1.7 Conclusion

This chapter has provided some background for the research presented in this thesis. The important key concepts, including mHealth and gamification have been defined to set the scene for presenting the underlying scientific contributions. This chapter has also presented two main theories of behaviour change, namely, TPB and TTM, but it has given greater attention to the latter for its relevance in this research. Moreover, an overview of a few existing software quality models (e.g. ISO/IEC 25010, 25030) has been presented.

These models are used to support the evaluation of a software product quality or to guide further definition and elicitation of quality requirements. Further, this chapter has defined the two broad categories of software requirements and has briefly described the requirements engineering process ranging from elicitation to validation.



# Gamification in e-Health: A Systematic Literature Review

## 2.1 Introduction

Despite its novelty, gamification seems to be increasingly gaining in popularity in both research and practice. The health sector is one of many fields that have tremendously benefited from gamification principles. This chapter reports and discusses the findings of a systematic review conducted on a compilation of 46 relevant scientific papers about gamification in e-Health. The entire research design of this SLR is described in Section 2.2. The core results of the SLR are presented in Section 2.3 and are further discussed in Section 2.4 along with the potential implications of the results for researchers and practitioners in the e-Health field. Section 2.4 also discusses the threats to validity related to this SLR research.

## 2.2 Research methodology

This section gives an outline of research methods that were followed in this SLR. It provides the RQs, the search venues, the eligibility criteria and describes the data extraction strategy.

### 2.2.1 Research questions and search string

The goal of this SLR was achieved by identifying nine RQs. The corresponding rationale for each of these questions is presented in Table 2.1. The search strategy should be conducted thoroughly, as it directly affects the relevance and the completeness of the studies retrieved. In this SLR, the search for the papers was performed using the best-known digital libraries as regards the fields of software engineering and medical informatics: ACM, IEEE-Xplore, Springer, Wiley Interscience, ScienceDirect, PubMed and Google Scholar. In order to perform

Table 2.1: Research questions

| Research question  | Rationale   |
|--|---|
| Which publication channels are the main targets for gamification in e-Health?                        | To examine the different sources in which articles related to gamification in e-Health are being published            |
| How is the research focused on gamification in e-Health distributed over years and across countries? | To explore the temporal and geographic publication trends of gamification in e-Health                                 |
| How easy is it to find recognized papers?  | To discover how appropriate and relevant the articles found are   |
| In which health domains has gamification been investigated?  | To identify the health domains most frequently investigated in the studies  |
| What are the research types of the studies related to the gamification of e-Health?                  | To identify the main types of research used in studies on gamification in e-Health                                    |
| Are the studies in the area empirically validated?   | To determine whether research in the area has been validated through empirical studies                                |
| What game mechanics have been used in gamifying e-Health?  | To understand the different aspects of gamification in e-Health   |
| Which challenges are the most frequently encountered during gamification?                            | To explore the limitations and problems of gamification that are most frequently addressed in the existing literature |
| What are the benefits of using gamified e-Health?  | To discover the advantages and the positive outcomes of gamified e-Health   |

the automated searches in the digital libraries selected, the search string shown in Table 2.2 was structured in terms of the PICO criteria: Population, Intervention, Comparison and Outcome [105] and was divided into three parts so as to cover the entire scope of the study. As shown in Table 2.2, the Boolean “OR” was used to combine alternate terms in each part, while the Boolean “AND” was used to join the three major parts. The papers returned were obtained by applying the search string to the metadata (title-keywords-abstract) in each digital source. Further adaptation was needed to suit the search process of each library.

## 2.2.2 Inclusion and exclusion criteria

After removing duplicates, a set of IC and EC was formulated to evaluate and identify the most relevant studies of those retrieved. The selection process was conducted by the three authors, who considered the metadata in the papers, and each discrepancy that occurred was solved by screening the entire paper. The studies that satisfied at least one of the following criteria were included:

**IC1.** The paper focuses on the use of gamification in e-Health.

Table 2.2: Search string

| Scope               | String  |
|---------------------|---|
| <b>Software</b>     | (App* OR framework* OR system* OR electronic*) AND                |
| <b>Health</b>       | (*health* OR *PHR* OR *EHR* OR medic* OR clinic* OR patient*) AND |
| <b>Gamification</b> | (gamif* OR “game elements” OR game* OR “game mechanics”)          |

**IC2.** The paper evaluates gamified e-Health applications or serious games for end-users.

**IC3.** The paper provides empirical evidence regarding the impacts and outcomes of gamifying e-Health.

The studies that met at least one of these EC were discarded:

**EC1.** Papers not written in English.

**EC2.** Papers published before 2000 or after December 2015.

**EC3.** Papers published in the form of an abstract (one or two pages), tutorial or poster.

**EC4.** Papers dealing with gamification in any domain other than health and those that only mention the concept of gamification without providing further research.

### 2.2.3 Quality assessment

In order to limit any possible bias while conducting this SLR, all the selected papers underwent a quality assessment (QA) carried out by means of a set of closed questions which were used to evaluate the relevance and quality of the papers' contents. The QA questions were formulated according to a previous SLR [106] and are described as follows:

**QA1.** Does the paper present a detailed description of the game elements employed?

The possible answers were "Yes (+1)", "No (+0)" and "Partially (+0.5)".

**QA2.** Does the study present empirical results? The possible answers were "Yes (+1)" and No "(+0)".

**QA3.** Are the limitations of gamification addressed explicitly? The possible answers were "Yes (+1)" and No "(+0)".

**QA4.** Does the paper discuss the benefits of gamification? The possible answers were "Yes (+1)" and No "(+0)".

**QA5.** Has the study been published in a relevant journal or conference proceedings? This QA question was rated by considering the CORE 2014 [107] and Journal Citation Reports 2014 (JCR); rankings of conferences and journals, respectively. The possible answers to this question were:

– for conferences, workshops, and symposia:

- \* (+1.5) if it is ranked CORE A
- \* (+1) If it is ranked CORE B
- \* (+0.5) If it is ranked CORE C
- \* (+0) If it is not in the CORE ranking

- for journals:
  - \* (+2) If it is ranked Q1
  - \* (+1.5) If it is ranked Q2
  - \* (+1) If it is ranked Q3 or Q4
  - \* (+0) if it has no JCR ranking
- for others: (+0)

**QA1** scores partially when the paper does not provide details about the game elements employed in the application. The differentiation made as regards the score for question **QA5** is owing to the fact that it is usually more complicated to publish in ranked journals than in conferences or symposia. The highest QA score that could be given to a paper was 6, (i.e., the total score is an integer between 0 and 6).

#### **2.2.4 Data extraction strategy and analysis method**

The RQs listed in Table 2.1 were answered by designing a data extraction form which was filled in for each of the selected papers. Using a structured sheet, data were extracted by one reviewer and subsequently checked for accuracy by the other two authors. All the information extracted is described below.

**RQ1:** Publication source and channel of each paper should be extracted.

**RQ2:** In order to analyze the temporal and spatial evolution of publications in the area, the papers should be distributed over years and the authors' nationalities should be represented.

**RQ3:** The ranking of the publication sources should be considered so as to investigate the pertinence of the papers.

**RQ4:** The health topic should be obtained in order to identify the exact domain to which gamification has been applied.

**RQ5:** This question deals with the nature of the research reported in each paper. A research type can be organized into the following categories [108]:

- Solution proposal: A paper in this category proposes a solution to a problem. The solution can be either new or a significant extension to an existing technique.
- Evaluation research: Techniques are implemented in practice and an evaluation of the technique is conducted.
- Review: Multiple research studies or papers are investigated and/or critically analyzed.
- Other: e.g. Experience papers, opinion papers, philosophical papers, etc.

**RQ6:** Empirical research studies can be classified in the following categories [109]:

- Experiment: A highly-controlled empirical method that commonly uses students as subjects.
- Case study: An observational study that tracks projects in their real-life context.
- Survey: This method involves collecting quantitative data from a sample of the population to be studied, usually by means of questionnaires and interviews.

**RQ7:** The game mechanics should be extracted from each paper so as to identify those most frequently used in the healthcare sector. A commonly leveraged framework of game mechanics consists of the following game components [65]:

- Points: “the heart of any gaming system”, which quantify users’ participation and performance.
- Badges: these mark the completion of goals and are frequently assigned upon accumulating points.
- Leaderboards: these visually display where users stand with regard to their peers.
- Challenges and quests: these provide users with a guided path in order to perform a prescribed set of gameplay actions.
- Levels: these serve to indicate the users’ progress in the gamified experience over time (e.g. Progress bars).
- Feedback: this is the constant process of returning information to users about their actions within the game in realtime.

**RQ8:** Information about possible obstacles should be analyzed in order to determinate how gamification in the health area could be hampered.

**RQ9:** The salient findings should be considered so as to investigate the impact of gamifying e-Health.

The synthesis process aims to synthesize the relevant information extracted from the selected papers in order to answer the RQs. Besides using descriptive statistics, the results were graphically represented to help interpret them. The data extracted for the RQs ranging from RQ1 to RQ7 are presented in Tables 2.3 and 2.4.

## 2.3 Results

This section describes the results of the SLR conducted to answer the RQs presented in Table 2.1. The selection process was performed between December 2015 and January 2016. As shown in Figure 2.1, a total of 562 papers were returned from the database searches by using the search terms described in Table 2.2 After removing duplicates and papers that met

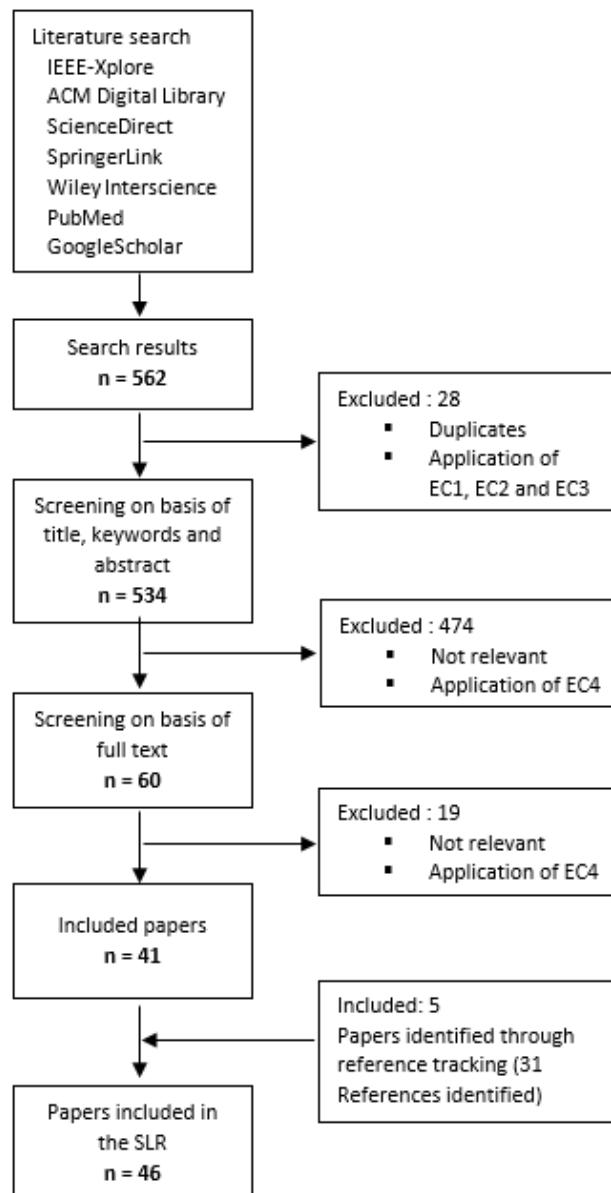


Figure 2.1: PRISMA flow diagram of the selected studies

the first three EC, 534 papers were left and underwent a screening based on their metadata (Title, keywords and abstract). Of 534 papers, 474 were excluded after the application of EC4. The remaining 60 papers were evaluated by considering their full texts. 19 articles were discarded and 41 articles focusing on both gamification and serious gaming in e-Health were selected after applying EC4. Five more articles were identified after checking the reference list of each selected study (snowballing technique). A total of 46 papers were, therefore, eventually included in this SLR. The papers included are detailed in Table 2.5, along with their QA scores.

RQ1. Which publication channels are the main targets for gamification in e-Health?

Table 2.3: Data extracted from the selected papers on gamification of e-Health for RQ1, RQ2, RQ3 and RQ4

| Paper | Type | RQ1   | RQ2   | Pub. year | Author' Country | RQ3   | RQ4  |
|-------|------|-------|---|-----------|-----------------|-------|--|
|       |      | P. Ch | Pub. name abbr.                             |           |                 | Rank. | Health Topics                                      |
| [110] | GA   | J     | J Med Internet Res                          | 2012      | Canada          | Q1    | Diabetes Management                                |
| [111] | GA   | J     | J Med Internet Res                          | 2015      | USA             | Q1    | Rheumatoid Arthritis self-management               |
| [112] | GA   | J     | J Med Internet Res                          | 2013      | Canada          | Q1    | Pain assessment for adolescents with cancer        |
| [113] | GA   | J     | J Med Internet Res                          | 2014      | USA             | Q1    | Fitness  |
| [114] | SG   | J     | Games Health J                              | 2015      | Canada          | Q3    | Physical Activity                                  |
| [115] | SG   | J     | Games Health J                              | 2012      | USA             | Q3    | Nutrition  |
| [116] | SG   | J     | Games Health J                              | 2015      | Netherlands     | Q3    | Mental Health (Anxiety)                            |
| [117] | GA   | J     | Comput Hum Behav                            | 2015      | Finland         | Q1    | Fitness/ Exercise                                  |
| [118] | GA   | J     | Comput Hum Behav                            | 2014      | Finland         | Q1    | Exercise   |
| [119] | SG   | C     | SeGAH                                       | 2011      | Netherlands     |       | Diabetes management                                |
| [120] | SG   | C     | SeGAH                                       | 2011      | Portugal        |       | Mental Health                                      |
| [121] | SG   | C     | SeGAH                                       | 2011      | Canada          |       | Alzheimer Disease management (training)            |
| [122] | SG   | C     | SeGAH                                       | 2011      | Italy           |       | Mental Health                                      |
| [123] | SG   | C     | SeGAH                                       | 2013      | Italy           |       | Stroke Rehab                                       |
| [124] | SG   | C     | SeGAH                                       | 2013      | Netherlands     |       | Obesity management                                 |
| [125] | GA   | C     | ICTH'15                                     | 2015      | England         |       | Diabetes Self-management                           |
| [126] | GA   | C     | ICTH'15                                     | 2015      | Greece          |       | Exercise (CVD rehabilitation)                      |
| [127] | GA   | C     | PervasiveHealth'12                          | 2012      | USA             |       | Physical Activity                                  |
| [128] | GA   | C     | PervasiveHealth '14                         | 2014      | Portugal        |       | Exercise (Stroke rehabilitation)                   |
| [129] | SG   | C     | ACE'14                                      | 2014      | Portugal        | B     | Stroke Rehab                                       |
| [130] | SG   | C     | ACE'14                                      | 2014      | Portugal        | B     | Mental Health (Phonological disorders)             |
| [131] | GA   | C     | IDC'13                                      | 2013      | USA             |       | Fitness  |
| [132] | GA   | J     | INVENT                                      | 2015      | Sweden          |       | Mental health                                      |
| [133] | GA   | J     | Clin Psychol Sci                            | 2014      | USA             |       | Mental health                                      |
| [134] | GA   | C     | ITAG'14                                     | 2014      | England         |       | Mental health                                      |
| [135] | SG   | C     | WH'15                                       | 2015      | USA             |       | Mental Health (Anxiety)                            |
| [136] | GA   | C     | DUXU  | 2014      | Portugal        |       | Chronic Disease, Hygiene, Nutrition, Exercise      |
| [137] | GA   | J     | EntCom                                      | 2015      | Israel          |       | Physical Activity, Nutrition, Chronic Disease      |
| [138] | GA   | J     | Health Inform                               | 2014      | Canada          | Q3    | Fitness, Chronic Disease Management                |
| [139] | GA   | C     | NordiCHI '10                                | 2010      | Finland         |       | Physical Activity                                  |
| [140] | GA   | J     | Pers Ubiquit Comput                         | 2014      | Austria         | Q2    | Physical Activity                                  |
| [141] | GA   | S     | Chinese CHI'14                              | 2014      | USA             |       | Fitness  |
| [142] | GA   | J     | Prod Pediatr Cardiol                        | 2014      | England         |       | Exercise (Congenital heart disease rehabilitation) |
| [143] | GA   | C     | HCII'14                                     | 2014      | Ireland         |       | Fitness/Exercise                                   |
| [144] | GA   | C     | COLCOM                                      | 2014      | Colombia        |       | Exercise (Lower member)                            |
| [145] | GA   | C     | BHI   | 2014      | Spain           |       | Behaviour Treatment for Childhood Obesity          |
| [146] | GA   | C     | CSCWD                                       | 2014      | Brazil          | B     | Nutrition  |
| [147] | GA   | S     | ISCSS'10                                    | 2015      | Canada          |       | Fitness/ Exercise                                  |
| [148] | SG   | C     | ICVR  | 2011      | Austria         |       | Chronic Pain Rehab                                 |
| [149] | SG   | C     | SouthCHI                                    | 2013      | Germany         |       | Physical Activity                                  |
| [150] | SG   | C     | DH'15                                       | 2015      | USA             |       | Nutrition  |
| [151] | SG   | C     | 121st ASEE Annual Conference and Exposition | 2014      | USA             |       | Physical Activity for CP children                  |
| [152] | SG   | C     | ENBENG                                      | 2014      | Portugal        |       | Neurological disease Rehab                         |
| [153] | SG   | C     | EPE'14                                      | 2014      | Portugal        |       | Physical Activity Rehab                            |
| [154] | GA   | C     | IWAAL                                       | 2014      | Ireland         |       | Alzheimer's Disease Prevention                     |
| [155] | SG   | C     | BioRob                                      | 2012      | USA             |       | Rehab (Cerebral Palsy)                             |

\* SG: Serious Game, GA: Gamified App.  
J: Journal, C: Conference, S: Symposium.

Table 2.4: Data extracted from the selected papers on gamification of e-Health for RQ5, RQ6 and RQ7

| Paper | RQ5                         | RQ6                     | N   | Methods of data collection       | Duration | RQ7 |   |     |   |   |
|-------|-----------------------------|-------------------------|-----|----------------------------------|----------|-----|---|-----|---|---|
|       | Research Type               | Empirical Research Type |     |                                  |          | F/R | P | C/Q | S | O |
| [110] | Solution Proposal           | Case Study              | 20  | Questionnaire, interviews        | 12 weeks | x   |   | x   |   |   |
| [111] | Evaluation Research         | Experiment              | 157 | Questionnaire                    | 4 months | x   |   | x   |   |   |
| [112] | Solution Proposal           | Case Study              | 18  | Interviews, questionnaire        | 15 days  | x   |   |     |   | x |
| [113] | Review                      | None                    |     |                                  |          | x   | x | x   | x | x |
| [114] | Evaluation Research         | Case Study              | 54  | Questionnaire                    | 2 weeks  | x   | x | x   | x | x |
| [115] | Evaluation Research         | Experiment              | 16  | Interviews                       |          | x   | x |     |   |   |
| [116] | Evaluation Research         | Case Study              | 42  | Questionnaire                    | 8 weeks  | x   |   | x   |   | x |
| [117] | Review/ Evaluation Research | Survey                  | 200 | -                                | -        | x   |   | x   | x |   |
| [118] | Evaluation Research         | Survey                  | 195 | -                                | 5 months | x   |   | x   |   |   |
| [119] | Solution Proposal           | Experiment              | 9   | Questionnaire                    | -        | x   | x |     |   |   |
| [120] | Solution Proposal           | None                    |     |                                  |          | x   | x | x   |   |   |
| [121] | Solution Proposal           | None                    |     |                                  |          | x   | x |     |   |   |
| [122] | Solution Proposal           | None                    |     |                                  |          | x   |   |     |   |   |
| [123] | Solution Proposal           | None                    |     |                                  |          |     |   |     |   |   |
| [124] | Evaluation Research         | Survey                  | 53  | -                                | -        | x   | x |     |   | x |
| [125] | Solution Proposal           | None                    |     |                                  |          | x   | x |     |   | x |
| [126] | Solution Proposal           | Case Study              | 6   | Interviews                       | -        | x   | x |     |   | x |
| [127] | Solution Proposal           | Experiment              | 23  | Interviews, questionnaire        | 4 weeks  | x   | x | x   | x | x |
| [128] | Solution Proposal           | Case Study              | 1   | (Observation)                    | -        | x   |   |     |   |   |
| [129] | Evaluation Research         | Experiment              | 10  | Logs                             | -        | x   | x |     |   | x |
| [130] | Solution Proposal           | Survey                  | 12  |                                  |          | x   | x |     |   |   |
| [131] | Solution Proposal           | None                    |     |                                  |          | x   |   |     |   | x |
| [132] | Solution Proposal           | None                    |     |                                  |          | x   |   |     |   | x |
| [133] | Evaluation Research         | Experiment              | 38  | Questionnaire                    | 2 hours  | x   |   |     |   | x |
| [134] | Solution Proposal           | None                    |     |                                  |          | x   |   |     |   |   |
| [135] | Evaluation Research         | Experiment              | 22  | Questionnaire                    | 30 min   | x   |   |     |   |   |
| [136] | Review                      | None                    |     |                                  |          | x   | x | x   | x | x |
| [137] | Review                      | None                    |     |                                  |          |     |   |     |   |   |
| [138] | Review                      | None                    |     |                                  |          | x   | x | x   | x | x |
| [139] | Solution Proposal           | Experiment              | 37  | Online questionnaire, interviews | 1 week   | x   |   | x   | x | x |
| [140] | Evaluation Research         | Experiment              | 59  | Interviews, logs                 | 10 days  | x   |   | x   |   |   |
| [141] | Solution Proposal           | Experiment              | 36  | Interviews                       | 12 days  | x   | x | x   |   |   |
| [142] | Evaluation Research         | Case Study              | 1   | (Observation)                    | 6 months | x   |   | x   |   |   |
| [143] | Evaluation Research         | None                    |     |                                  |          | x   | x |     |   |   |
| [144] | Solution Proposal           | Survey                  | -   | -                                | -        | x   |   |     |   | x |
| [145] | Solution Proposal           | None                    |     |                                  |          | x   |   | x   |   | x |
| [146] | Solution Proposal           | None                    |     |                                  |          |     |   |     | x | x |
| [147] | Solution Proposal           | Experiment              | 5   | Questionnaire                    | -        | x   |   | x   |   |   |
| [148] | Evaluation Research         | Case Study              | 6   | Questionnaire                    | 4 weeks  | x   |   |     |   |   |
| [149] | Evaluation Research         | Experiment              | 71  | Interviews                       |          | x   | x |     |   |   |
| [150] | Solution Proposal           | Survey                  | 82  |                                  | 14 weeks | x   | x |     |   | x |
| [151] | Evaluation Research         | Experiment              | 21  | Questionnaire                    |          |     |   |     |   | x |
| [152] | Evaluation Research         | Experiment              | 3   | Questionnaire                    |          | x   | x |     |   |   |
| [153] | Solution Proposal           | Survey                  | 160 |                                  |          | x   | x | x   |   |   |
| [154] | Solution Proposal           | Experiment              | 146 | Logs, daily self-report          | 6 months | x   | x |     |   |   |
| [155] | Solution Proposal           | None                    |     |                                  |          | x   |   | x   |   |   |

\* F/R: Feedback/Reward, P: Progress bar, C/Q: Challenges/Quests, S: Socialization and O: Others. Information not specified is marked as “-”.



The selected papers are distributed throughout a varied range of publication channels. Of the publication sources identified, three journals are repeated. Four papers were published in the Journal of Medical Internet Research [110–113], three were published in Games for Health Journal [114–116] and two papers were published in the Journal of Computer Human Behavior [117, 118]. Similarly, four conferences were recurrently identified. Six papers were published in the IEEE International Conference on Serious Games and Applications for Health in its first [119–122] and third edition [123, 124]. Moreover, two papers were published in the International Conference on Current and Future Trends of Information for the year 2015 [125, 126], whilst two more were published in the Pervasive Health conference in different years: 2012 [127] and 2014 [128]. Two additional papers were drawn from the International Conference on Advances in Computer Entertainment Technology of the year 2014 [129, 130]. Around 63% of the selected papers were published in conferences, 33% were presented in journals and only 4% in symposia. Table 2.6 lists the publication sources of all the selected studies, their types and the number of papers per publication source.

RQ2. How is the research focused on gamification in e-Health distributed over years and across countries?

Figure 2.2 presents the publication evolution of the selected papers between 2010 and December 2015. Most of the research was conducted during the past two years (2014–2015) reaching a peak in 2014 (20 articles). Figure 2.2 also shows the publication trend of empirical studies. The publication trends of research on gamified apps and Serious games in e-Health were mostly similar. Figure 2.3 displays the nationality of the first author of each of the selected papers. This figure provides clear information on the spatial distribution of the studies tackling gamification and serious gaming in e-Health. A total of 16 nationalities was identified, of which American, Portuguese and Canadian researchers were the most dedicated to gamification in e-Health. However, there seems to be a progressive spread of interest in the field across the world.

RQ3. How easy is it to find recognized papers?

The relevance of the selected papers can be evaluated through the ranking of their publication sources. In this study, there are five different journals ranked as Q1, Q2 and Q3 in the JCR 2014 ranking. Although there are 21 conferences, only two of them are ranked as B in the CORE 2014 ranking: The International Conference on Computer Supported Cooperative Work in Design (CSCWD) and The International Conference on Advances in Computer Entertainment Technology.

RQ4. In which health domains has gamification been investigated?

As depicted in Figure 2.4, the most recurrently studied health topic for both gamified apps and serious games in e-Health is chronic disease management/rehabilitation. Some of these health conditions are Cancer, Alzheimer's disease, Stroke and Obesity. For example,

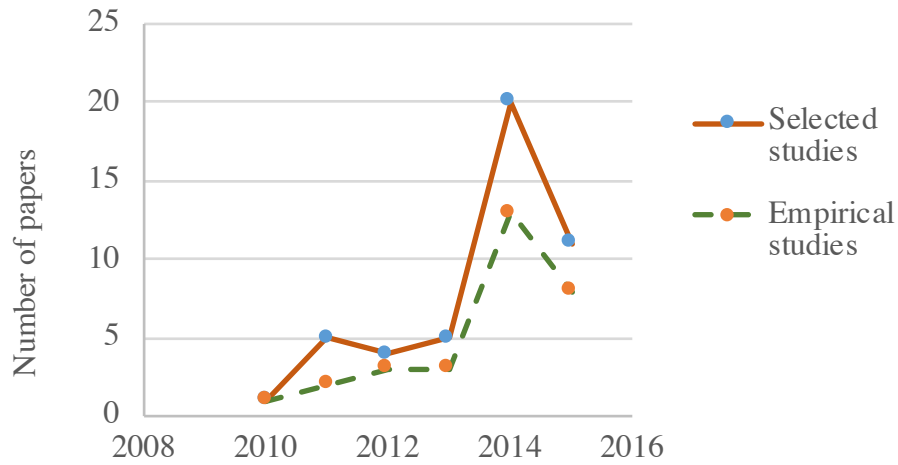


Figure 2.2: Distribution of the selected papers over time.

Cafazzo et al. [110] presented a gamified mHealth app aimed at self-monitoring blood glucose in adolescents with type 1 diabetes. Imbeault et al. [121] made use of Artificial Intelligence and game mechanics to create a serious game specifically intended to provide cognitive training for patients suffering from Alzheimer. While only two papers focused on designing serious games to promote physical activity, a total of 13 papers investigated the gamification of physical activity. For instance, Keung et al. [131] integrated gamification elements into a fitness app intended to motivate young people to exercise outdoors.

Three other studies focused on harnessing gamification techniques in mental health-related applications [132–134] five papers presented serious games focusing on mental

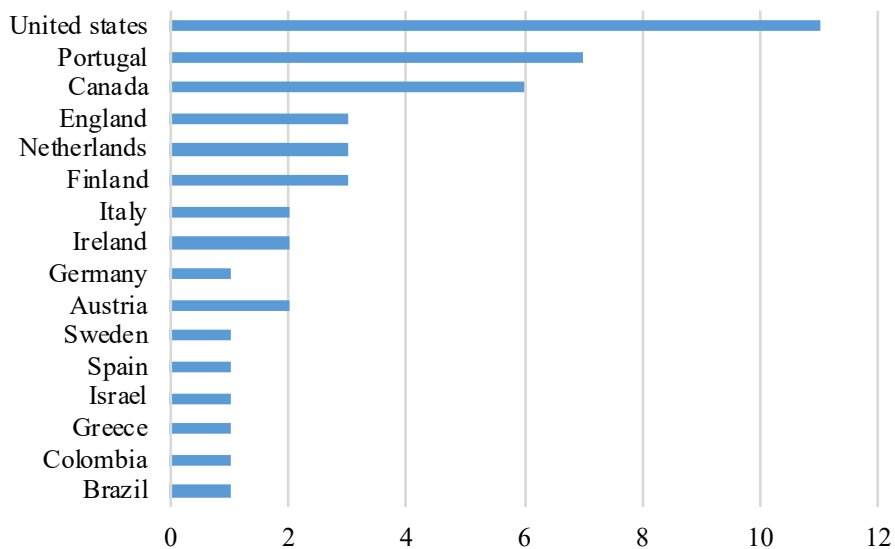


Figure 2.3: Number of studies per country

disorders, particularly, in children [116, 120, 122, 130, 135]. The remaining two papers tackling serious games in e-Health were nutrition-related and presented m-Health interventions to increase children’s vegetable consumption [115] and improve their nutritional outcomes [116], respectively. Nutrition was also identified in a paper written by Pereira et al. [136], in which an app was developed to persuade users to change their bad eating habits through a collaborative gamified experience. While most the papers investigated gamification in a single health domain, three papers [136–138] reviewed gamified applications related to multiple health domains including nutrition, hygiene, physical activity and chronic disease management.

RQ5. What are the research types of the studies related to the gamification of e-Health?

Figure 2.5 shows the three research approaches that were identified in this SLR. Besides five reviews, around 35% of the selected papers were solution proposal studies and 13% were undertaken to evaluate existing or new gamified e-Health applications. Even though the majority of the research was found in the category of solution proposals, the reviews identified have relied mainly on gamified e-Health applications retrieved from apps stores, namely App Store and Google Play store, which are not therefore reported in literature. Besides reviewing the existing gamified exercise application, Hamari, J. & Koivisto, J. investigated the role of social influence on changing behavior through the evaluation of an application called “Fitocracy” [117]. By contrast, evaluation research (22%) was slightly more dominant than solution proposals (19%) for serious gaming in e-Health. However, no review was identified for this context in this SLR.

RQ6. Are the studies in the area empirically evaluated?

As depicted in Figure 2.5, most of the selected papers were empirically evaluated through case studies, experiments and surveys. No type of evaluation was provided in 35% of the studies. In about 33% of the papers, experiments were performed with students, patients or

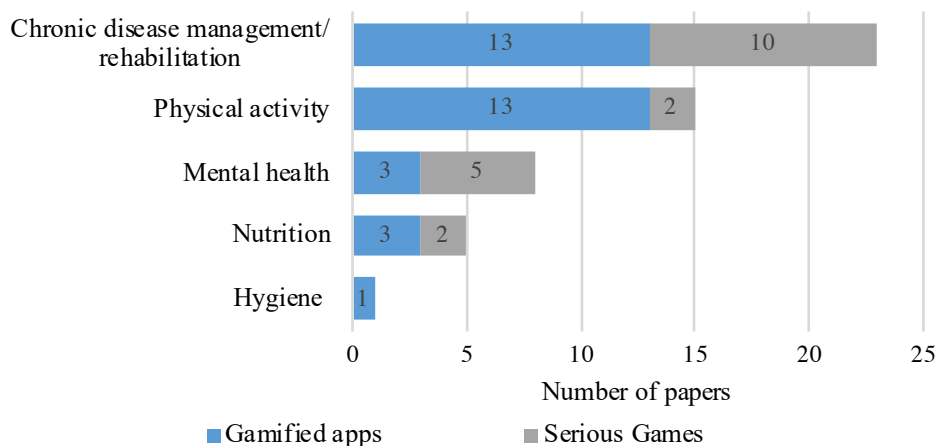


Figure 2.4: Health topics studied in the selected papers

Table 2.5: Quality assessment results of the selected papers on gamification of e-Health

| Paper | Pub. Year | Pub. Channel | Pub. name abbr.                             | Quality assessment |     |     |     |     | Score |
|-------|-----------|--------------|---|--------------------|-----|-----|-----|-----|-------|
|       |           |              |   | QA1                | QA2 | QA3 | QA4 | QA5 |       |
| [114] | 2015      | J            | Games Health J                              | 1                  | 1   | 1   | 1   | 1   | 5     |
| [118] | 2014      | J            | Comput Hum Behav                            | 1                  | 1   | 1   | 0   | 2   | 5     |
| [113] | 2014      | J            | J Med Internet Res                          | 1                  | 0   | 1   | 1   | 2   | 5     |
| [111] | 2015      | J            | J Med Internet Res                          | 1                  | 1   | 0   | 1   | 2   | 5     |
| [117] | 2015      | J            | Comput Hum Behav                            | 1                  | 1   | 0   | 1   | 2   | 5     |
| [110] | 2012      | J            | J Med Internet Res                          | 1                  | 1   | 0   | 1   | 2   | 5     |
| [112] | 2013      | J            | J Med Internet Res                          | 1                  | 1   | 0   | 1   | 2   | 5     |
| [140] | 2014      | J            | Pers Ubiquit Comput                         | 1                  | 1   | 1   | 0   | 1.5 | 4.5   |
| [116] | 2015      | J            | Games Health J                              | 1                  | 1   | 0   | 1   | 1   | 4     |
| [130] | 2014      | C            | ACE'14                                      | 1                  | 1   | 0   | 1   | 1   | 4     |
| [138] | 2014      | J            | Health Inform                               | 1                  | 0   | 1   | 1   | 1   | 4     |
| [127] | 2012      | C            | PervasiveHealth'12                          | 1                  | 1   | 1   | 1   | 0   | 4     |
| [119] | 2011      | C            | SeGAH                                       | 0.5                | 1   | 1   | 1   | 0   | 3.5   |
| [149] | 2013      | C            | SouthCHI                                    | 0.5                | 1   | 1   | 1   | 0   | 3.5   |
| [129] | 2014      | C            | ACE'14                                      | 1                  | 1   | 0   | 0   | 1   | 3     |
| [124] | 2013      | C            | SeGAH                                       | 1                  | 1   | 0   | 1   | 0   | 3     |
| [150] | 2015      | C            | DH'15                                       | 1                  | 1   | 0   | 1   | 0   | 3     |
| [136] | 2014      | C            | DUXU  | 1                  | 0   | 1   | 1   | 0   | 3     |
| [142] | 2014      | J            | Prod Pediatr Cardiol                        | 1                  | 1   | 0   | 1   | 0   | 3     |
| [141] | 2014      | S            | Chinese CHI'14                              | 1                  | 1   | 0   | 1   | 0   | 3     |
| [144] | 2014      | C            | COLCOM                                      | 1                  | 1   | 0   | 1   | 0   | 3     |
| [139] | 2010      | C            | NordiCHI '10                                | 1                  | 1   | 0   | 1   | 0   | 3     |
| [154] | 2014      | C            | IWAAL                                       | 1                  | 1   | 0   | 1   | 0   | 3     |
| [152] | 2015      | C            | ENBENG                                      | 0.5                | 1   | 0   | 1   | 0   | 2.5   |
| [148] | 2011      | C            | ICVR  | 0.5                | 1   | 0   | 1   | 0   | 2.5   |
| [151] | 2014      | C            | 121st ASEE Annual Conference and Exposition | 0.5                | 1   | 0   | 1   | 0   | 2.5   |
| [147] | 2016      | S            | ISCSS'10                                    | 0.5                | 1   | 0   | 1   | 0   | 2.5   |
| [146] | 2014      | C            | CSCWD                                       | 0.5                | 0   | 0   | 1   | 1   | 2.5   |
| [115] | 2012      | J            | Games Health J                              | 0                  | 1   | 0   | 0   | 1   | 2     |
| [123] | 2013      | C            | SeGAH                                       | 1                  | 0   | 1   | 0   | 0   | 2     |
| [122] | 2011      | C            | SeGAH                                       | 1                  | 0   | 0   | 1   | 0   | 2     |
| [120] | 2011      | C            | SeGAH                                       | 1                  | 0   | 0   | 1   | 0   | 2     |
| [137] | 2016      | J            | EntCom                                      | 0                  | 0   | 1   | 1   | 0   | 2     |
| [126] | 2015      | C            | ICTH'15                                     | 1                  | 1   | 0   | 0   | 0   | 2     |
| [125] | 2015      | C            | ICTH'15                                     | 1                  | 0   | 0   | 1   | 0   | 2     |
| [145] | 2014      | C            | BHI   | 1                  | 0   | 0   | 1   | 0   | 2     |
| [131] | 2013      | C            | IDC'13                                      | 1                  | 0   | 0   | 1   | 0   | 2     |
| [133] | 2014      | J            | Clin Psychol Sci                            | 1                  | 1   | 0   | 0   | 0   | 2     |
| [135] | 2015      | C            | WH'15                                       | 0.5                | 1   | 0   | 0   | 0   | 1.5   |
| [153] | 2014      | C            | EPE'14                                      | 0.5                | 1   | 0   | 0   | 0   | 1.5   |
| [128] | 2014      | C            | PervasiveHealth '14                         | 0.5                | 1   | 0   | 0   | 0   | 1.5   |
| [155] | 2012      | C            | BioRob                                      | 1                  | 0   | 0   | 0   | 0   | 1     |
| [132] | 2015      | J            | INVENT                                      | 1                  | 0   | 0   | 0   | 0   | 1     |
| [134] | 2014      | C            | ITAG'14                                     | 0                  | 0   | 0   | 1   | 0   | 1     |
| [143] | 2014      | C            | HCI'14                                      | 1                  | 0   | 0   | 0   | 0   | 1     |
| [121] | 2011      | C            | SeGAH                                       | 0.5                | 0   | 0   | 0   | 0   | 0.5   |

\* The abbreviation "Pub." stands for Publication  
J: Journal, C: Conference, S: Symposium.

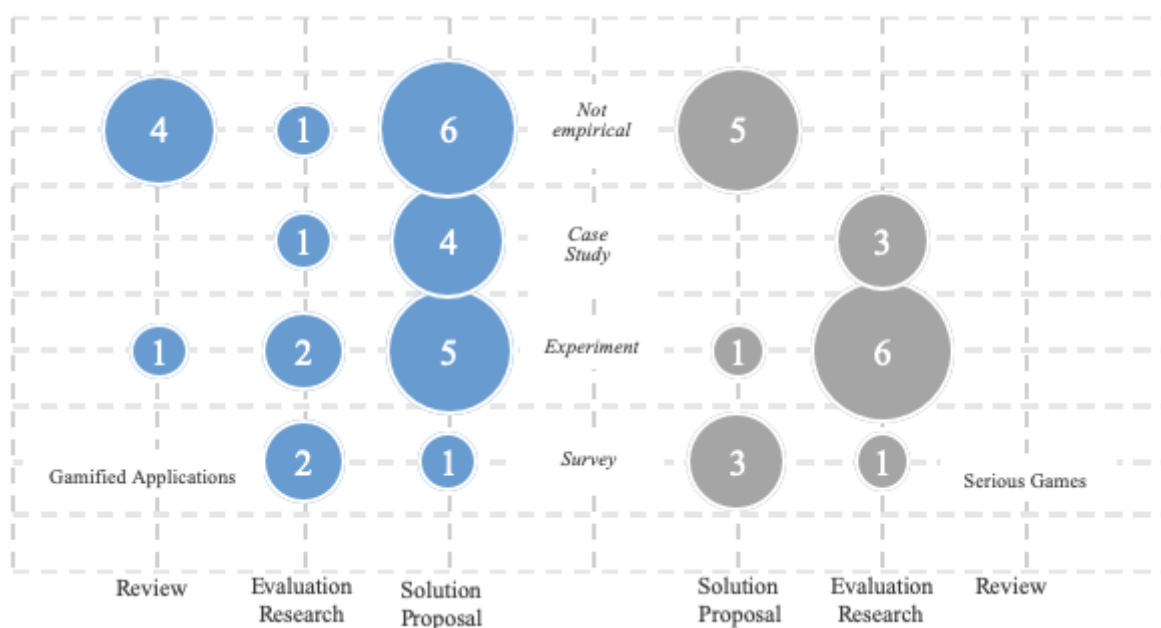


Figure 2.5: Research types and empirical methods

acquaintances who complied with a certain number of conditions, such as being experienced in the use of mobile devices [139], being of a certain age (20–50) [127] or even being able to speak and read English [112]. In nine evaluation research papers on gamified applications and serious games, the participants recruited were asked to sign a consent form prior to involvement in any phase of the study [111, 112, 114, 116, 127, 129, 135, 140, 141] and in some of them, they received a gift as compensation for their participation [117, 127, 141]. In around 17% of the selected papers, the authors conducted case studies to evaluate e-Health gamified applications and serious games in real-life context. Of the five papers on gamified applications that conducted case studies, two reported a single-patient-led study [128, 141]. For instance, in one paper a 44-year-old woman with complex congenital heart disease evaluated a gamification-based exercise monitor over a period of 6 months [142]. The patient managed the system by herself during the entire study period. The outputs were consecutively analyzed and interpreted by the researchers. In order to collect data after the completion of experiments or case studies, authors mostly relied on audio-recorded structured/ semi-structured interviews and questionnaires. Logs were also used to gather data about the sequencing of activities and time spent of them by the different participants [129].

Moreover, two papers evaluated the effectiveness of the gamified e-Health application by respectively implementing logs, along with interviews or daily self-reports [140, 143]. Almost 200 participants were involved in two surveys on gamified apps [110, 118] conducted by researchers, while one paper did not state the precise number of participants [144]. However, it did state that a small group of participants was recruited to perform the survey. As for

surveys that were conducted in serious games' studies, the least number of respondents was of 12 participants [130]. Figure 2.6 shows that the number of participants involved in the empirical processes in both gamified applications and serious games ranges from one to 200 participants. In six studies [111, 118, 127, 137, 141, 142], users tried out the gamified applications over a long period ranging from one to six months. Accordingly, the longest evaluations of gamified applications reported in the selected papers lasted 6 months [142, 143], whereas the longest period stated in studies evaluating serious games was of two months during which children diagnosed with ADHD played a serious game at home over four periods of two weeks [116]. Figure 2.7 depicts the duration (in hours) of all the empirical studies reported in the papers.

RQ7. What game mechanics have been used in gamifying e-Health applications?

As shown in Figure 2.8, various game mechanics were employed in the selected papers. However, feedback and rewards were the most frequently used incentives in gamifying e-Health applications and games. About 93% of the selected papers reported the integration of an automatic real-time feedback system and/or a variety of collectible virtual rewards such as badges and points. Miloff et al. [132] used preloaded and personalized rewards consisting mostly of outing and pampering suggestions. In the same way, different reward systems were implemented in almost 95% of the investigated serious games.

Social interaction received significant attention among gamified applications; more than half (16 papers) of the selected papers reported the usage of an embedded social context in the application via leaderboards or instant messaging system. Zuckerman and Gal-Oz [140] employed a social comparison element in the form of a leaderboard which ranked users in function of their accumulated points. Moreover, social interaction in terms of communication has been identified in nine studies about gamified applications [110, 117, 118, 139, 141–143, 145, 146]. While some applications enabled users to communicate locally (within the application) [110] with their peers, others handled social media support [127, 147] by ensuring an instant connection with the best-known social networks (e.g. Facebook, Twitter). On the other hand, social interaction was less frequently employed in serious games. Garde et al. [114] brought

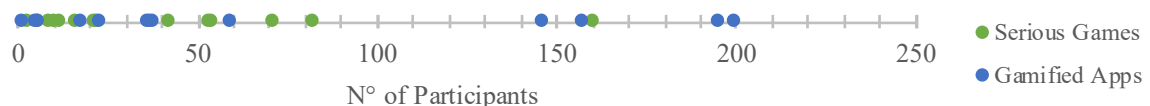


Figure 2.6: Number of users involved in the empirical studies

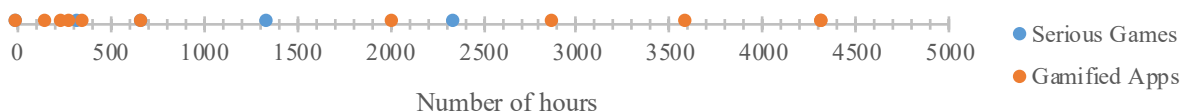


Figure 2.7: Duration of the empirical studies (in hours)

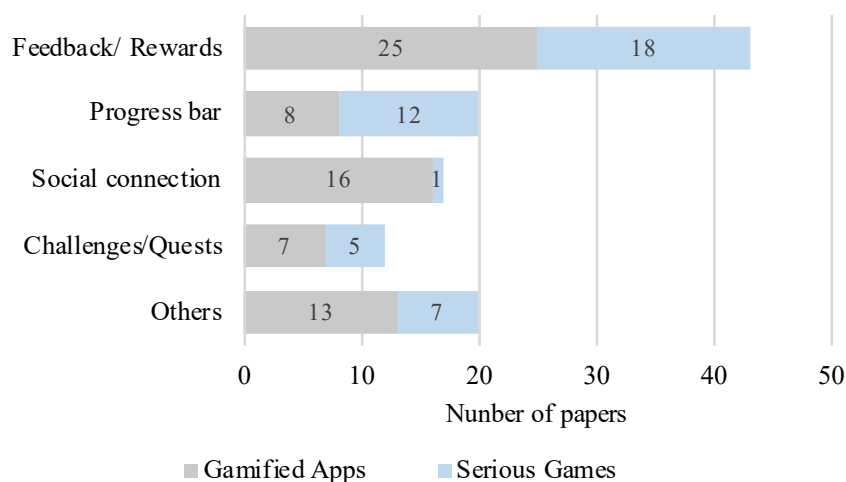


Figure 2.8: Distribution of gamification elements in the selected papers

to play a variety of game mechanics including those for social engagement, progression and scheduling. In this SLR, social interaction was achieved by the competition between teams of players through collection of rewards, thereafter, team members could see their ranking on leaderboard. Another gamification technique reported in 29% of the selected papers on gamified applications consists of progress bars that help users visualize their performance and keep track of their progress.

Challenges and quests were pinpointed in seven studies [113, 117, 125, 138, 139, 146, 148]. Although, most of these studies did not provide details about this category of gamification elements, it may be surmised that challenges could take place among the users of the application in a collaborative mode (group of users) or in single mode.

The serious games investigated in 59% of the selected studies afforded a sense of progression to the users through levels and missions [129, 148–150]. In addition to the aforementioned gamification techniques, a variety of other game elements was investigated. Trophies, ribbons and medals were integrated to award users upon the completion of a task or after leveling-up [127, 142]. Additional incentives were implemented in serious games such as prizes [151] and in-game currency [116]. In accordance with the findings of the selected studies, gamification techniques were extended to audible modules; sound effects, notifications/alerts, congratulatory messages and video-taped acknowledgments were also identified in the selected studies [112, 120, 145]. Moreover, personalized avatars and animated characters were used to represent the users [123, 124, 132]. Keung et al. [131] included a narrative context in their gamified fitness application in which the user is asked to perform a set of workouts so as to progressively unlock the storylines.

RQ8. Which challenges are the most frequently encountered during gamification?

Only ten of the selected studies discussed the problems encountered in gamifying e-

Table 2.6: Publication source in the studies included in the SLR

| Publication source   | Type       | References | # | %     |
|--|------------|------------|---|-------|
| IEEE International Conference on Serious Games and Applications for health   | Conference | [119–124]  | 6 | 13.04 |
| Journal of Medical Internet Research   | Journal    | [110–113]  | 4 | 8.69  |
| Games for Health Journal   | Journal    | [114–116]  | 3 | 6.52  |
| Conference on Advances in Computer Entertainment Technology  | Conference | [129,130]  | 2 | 4.35  |
| Computers in Human Behavior  | Journal    | [117,118]  | 2 | 4.35  |
| International Conference on Current and Future Trends of Information and Communication Technologies in Health-care | Conference | [125,126]  | 2 | 4.35  |
| Pervasive Health   | Conference | [127,128]  | 2 | 4.35  |
| Progress in Pediatric Cardiology   | Journal    | [142]      | 1 | 2.17  |
| Health Informatics Journal   | Journal    | [138]      | 1 | 2.17  |
| Entertainment Computing  | Journal    | [137]      | 1 | 2.17  |
| International Conference on Computer Supported Cooperative Work in Design  | Conference | [146]      | 1 | 2.17  |
| Clinical Psychology Science  | Journal    | [133]      | 1 | 2.17  |
| Personal and Ubiquitous Computing  | Journal    | [140]      | 1 | 2.17  |
| International Conference on Design, User Experience and Usability  | Conference | [136]      | 1 | 2.17  |
| Human-Computer Interaction International Conference  | Conference | [143]      | 1 | 2.17  |
| International Work-conference on Ambient Assisted Living   | Conference | [154]      | 1 | 2.17  |
| Interaction Design and Children  | Conference | [131]      | 1 | 2.17  |
| Interactive Technologies and Games Conference  | Conference | [134]      | 1 | 2.17  |
| IEEE International Conference on Biomedical and Health Informatics   | Conference | [145]      | 1 | 2.17  |
| Nordic Conference on Human-Computer Interaction  | Conference | [139]      | 1 | 2.17  |
| Internet Interventions   | Journal    | [132]      | 1 | 2.17  |
| IEEE Colombian Conference on Communications and Computing  | Conference | [144]      | 1 | 2.17  |
| The Second International Symposium of Chinese CHI  | Symposium  | [141]      | 1 | 2.17  |
| International Symposium on Computer Science in Sports  | Symposium  | [147]      | 1 | 2.17  |
| IEEE Portuguese Bioengineering Meeting   | Conference | [152]      | 1 | 2.17  |
| International Conference on Virtual Rehabilitation   | Conference | [148]      | 1 | 2.17  |
| Conference on Wireless Health  | Conference | [135]      | 1 | 2.17  |
| American Society for Engineering and Education Annual Conference and Exposition                                    | Conference | [151]      | 1 | 2.17  |
| The International Conference on Human Factors in Computing and Informatics   | Conference | [149]      | 1 | 2.17  |
| International Conference on Digital Health   | Conference | [150]      | 1 | 2.17  |
| International Conference and Exposition on Electrical and Power Engineering  | Conference | [153][89]  | 1 | 2.17  |
| IEEE RAS & EMBS International Conference on Biomedical Robotics and Bio-mechatronics                               | Conference | [155]      | 1 | 2.17  |

Health applications and serious games. The majority of these studies have mentioned a particular weakness, stating that motivating users by means of game elements may not be sustained in the long run if the gamification solution is not continuously improved [114, 118, 124, 127, 139, 140]. Another considerable limitation reported in five studies was that some game mechanics did not provide additional information that may help users clearly define their level of performance [119, 127, 136, 138, 140] and did not capture the nuances of content and target users. To put it simply, some game mechanics lacked a certain form of



customization to match the health purposes of the application and to be fully adapted to target groups. In this respect, two studies about serious games reported that incorporating game mechanics is unlikely to be equally suited to people of all ages [114,149]. Although it was not massively investigated, cheating can be perceived as a considerable problem that may undermine gamified e-Health applications [136]; users may input wrong data to obtain rewards and move up the comparison scale. Table 2.7 presents the main limitations and challenges that might seriously hinder the efficiency and effectiveness of implementing game mechanics in both gamified e-Health applications and serious games.

RQ9. What are the benefits of using gamified e-Health applications?

Several studies discussed the benefits of implementing game mechanics in gamified e-Health applications and serious games. The gameplay afforded in these e-Health interventions may positively affect users' emotional experiences and foster their satisfaction and self-esteem [122,125,131,137]. One important advantage of the use of game mechanics is that it was perceived to highly motivate users to change their health behaviors and stay engaged with the application [125,149,150]. Although it was noticed that gamification may fail to keep the users involved, many studies considered that game elements can be of great assistance in yielding a regular use of the application [110,112]. Moreover, the game mechanics help stimulate users' willingness to continue using the gamified applications or serious games [119]. Another advantage that was recurrently identified was that of promoting the gameplay and making the application more entertaining and easy to use and intelligible, especially for children and the elderly. All the benefits drawn from the selected papers are summarized in Table 2.8.

## 2.4 Summary and discussion

This section discusses the results obtained and provides implications for practice and directions for further research in the area of gamification in e-Health.

RQ1. Which publication channels are the main targets for gamification in e-Health?

According to the findings reported in Section 2.3, a great insight has been gained as regards gamification in e-Health, as it was investigated in different publication channels including conferences and journals. Nevertheless, the majority of the papers selected in this SLR were published in journals and conferences focusing on medicine and health research and/or those that are related to computer interactions. The difference perceived in the number of journals in comparison with the number of conferences as publication venues can be explained by the fact that publishing in journals is generally more complicated than publishing in conferences; this distinction was made clear in the quality assessment phase.

Table 2.7: Limitations of gamification in e-health

| Limitations and challenges  | Supporting studies        |               |
|---|---------------------------|---------------|
|   | Gamified apps             | Serious games |
| Effectiveness of the gamification solution can lessen when relying on only one game element.  | [136,156]                 |               |
| There is no unified framework with which to evaluate gamification principles and outcomes.  | [113,137,140]             |               |
| Users might feel motivated and excited about the gamification elements but the interest declines over time.   | [113, 118, 127, 139, 140] | [110,120,145] |
| Gamification elements are sometimes perceived to be meaningless and not helpful in terms of the system's healthcare purposes.                         | [127,136,138,140]         | [119]         |
| Gamification solutions are not user-centered as they overlook the traits and demographic characteristics of potential users.                          | [118,136,137,140]         | [114,149]     |
| Some rewards were judged to be irrelevant or exaggerated.   | [127,138]                 | [115,119]     |
| Gamified health solutions do not integrate health professionals in their development, which may reduce their performance and lower their credibility. | [136,137]                 |               |
| Cheating may increase as users might work to achieve higher levels solely for the sake of rewards.  | [136]                     |               |
| There is a significant lack of controls between the elements of gamification, and various elements were therefore viewed as a single one.             | [140]                     |               |

RQ2. How is the research focused on gamification in e-Health distributed over years and across countries?

Although we planned to include studies published during the entire past fifteen years, we eventually obtained solely those published throughout the last five years (2010 – 2015). From the second half of 2010, the concept of gamification took off in many areas, particularly those of industry and education. However, the surge of interest in gamification in e-Health only started at the beginning of 2014. In comparison, the current wave of serious games started to gain some momentum in the minds of many researchers by the year 2002, yet various games were designed for serious purposes before this date [54]. Nevertheless, the reader may note the slight decrease in 2015, which can be justified by the time period in which this SLR was conducted. The number of studies that were published in 2015 may, therefore, be biased to a certain extent. There were no surprises as regards the geographical distribution of research on gamification and serious games in e-Health. Most of the papers that have been published in the area are written by authors from the United States of America [111, 113, 131, 133, 141], Portugal [120, 128–130, 136, 152, 153], Canada [110, 112, 138, 147], Netherlands [116, 119, 124], England [125, 134, 142] and Finland [117, 118, 139]. A smaller frequency of contributions has been made by other European countries such as, Ireland [143, 154], Italy [122, 123], Spain [145], Greece [126], Sweden [132] and Austria [140], and by Latin America countries, namely Colombia [144] and Brazil [146]. Although many studies were discarded to meet the IC of this ISLR, there was little to no frequency of contributions from Asian and African countries. This spatial inequity could be explained by the development that has occurred at the level of e-Health in countries across the world. The most highly developed countries were, therefore, obviously the first to tackle this area and make fruitful contributions in order to enrich it.

RQ3. How easy is it to find recognized papers?

Even though conferences and symposia outnumbered journals in this study, the majority of the journals identified were highly recognized. Of the five journals ranked as JCR, three of them are interested in Medicine and Health informatics. The focus areas of the three additional JCR journals include cyber-psychology and ubiquitous computing. Regarding conferences, only two conferences were found in the CORE 2014 ranking and their scopes include, among others, collaborative approaches in healthcare systems, gamification and interaction design for games. The percentage of recognized papers (30%) indicates that gamification and serious games in the e-Health area are considered to be maturing disciplines. As can be inferred from the QA we performed, the papers included were neither perfect nor improper in terms of quality and relevance. However, most of the selected studies obtained scores in the range of [3,6]; seven studies received scores equal to 5 and there were seven studies whose scores were equal to either 1 or 1.5.

RQ4. In which health domains has gamification been investigated?

Gamified applications and serious games were designed for a variety of health topics, yet there was a slight difference perceived between the major health topics investigated in both areas. Chronic disease management and rehabilitation was the most frequently investigated health domain in the selected studies on both gamification and serious games. Whereas several studies were found in the area of gamified physical activity interventions, very few research studies addressed serious gaming in this topic. Physical activity, as it was defined in

Table 2.8: Advantages of gamification in e-health applications

| Benefits/advantages  | Supporting studies   |   |
|--|--|---|
|  | Gamified apps  | Serious games                                 |
| Sustains users' engagement with the tool.  | [110, 112, 117, 118, 126, 131, 134, 136, 137, 143, 145-147, 154] | [120, 123, 149, 150]                          |
| Increases users' compliance with health interventions and improves their ability to self-manage their conditions and adherence to treatment. | [111, 112, 125, 133, 138]  | [124, 130]                                    |
| Provides positive emotional states and elevates users' satisfaction and self-esteem.   | [110, 112, 117, 128, 136, 137, 139, 145, 147]                    | [122]   |
| Game mechanics allow intrinsic and extrinsic users' motivation to be increased.  | [110, 111, 113, 125, 127, 128, 134, 140-145]                     | [116, 119, 120, 122, 130, 149]                |
| Makes health activities fun, enjoyable and understandable.   | [112, 125, 134, 137, 139, 140, 143, 144]                         | [114, 115, 120, 123, 130, 148, 149, 151, 152] |
| Promotes healthy behavior and reinforces the users' efforts to change their behavior.  | [110, 113, 117, 125, 127, 134, 136, 137, 145, 146, 154]          | [124, 148, 150]                               |
| Social support was perceived to be appealing and crucial as regards increasing social skills.  | [111, 136, 139, 141, 146]  | [114]   |

this study, encompasses both fitness and exercise for people who are not ill. Papers reporting prescribed exercise for patients with chronic disease, as in [142], were considered in the category of chronic disease management and rehabilitation. Chronic disease management and rehabilitation therefore embody specialized healthcare dedicated to help patients regain strength after illnesses [125] and provide those living with long-term conditions with tools to manage their health and improve their wellbeing [110]. Some of the health conditions that the papers in this category dealt with are Stroke, Diabetes, Alzheimer's disease and Cardiovascular disease. Mental health also held the interest of researchers in both areas (gamification and serious gaming); a total of eight papers discussed the design of gamified applications and serious games dedicated to people suffering from mental disorders. These papers concentrated particularly on two major health conditions, namely Anxiety [132, 133, 135] and Attention Deficit Hyperactivity Disorder (ADHD) [116, 134]. ADHD is defined as a mental disorder that is marked by a pattern of behavioural symptoms including inattention, hyperactivity and impulsivity [134]. Two papers presented serious games intended to minimize intellectual deficiency and to improve the phonological competencies in children, respectively [120, 130]. In addition, there were five papers concerning nutrition and personal hygiene [115, 136, 137, 146, 150]. These studies reported that their objective was to change eating and hygiene habits and bolster the ability to adopt healthy lifestyles [115, 136, 146].

Bearing in mind the various health domains that were investigated in the selected studies, there would appear to be a growing interest in the use of gamified health interventions and serious games in the treatment, rehabilitation and management of chronic disease patients. In this respect, gamified healthcare applications can ease the burden and provide motivation to the patients by creating a therapeutic game-like environment [138]. Persevering with regular healthy activities such as completing a course of medication, maintaining an exercise routine or sticking to a healthy diet can be a struggling and demoralizing experience. With the help of gamified tools and platforms, these activities become more enjoyable and easier to keep on with. Similarly, gamified e-Health applications provide a means to assist patients with mental health problems and disorders such as anxiety, stress and depression. Beyond raising awareness and understanding of these mental health issues, gamified tools can deliver cognitive therapies to reduce stress or tune out negativity and anxiety by displaying avatars and offering rewards, among others [133]. In a similar vein, serious games for health entertain and promote better delivery of health care services. The use of tailored games can serve the purpose of raising patients' willingness to manage their disease or condition and increasing their medical adherence. It also provides an opportunity to motivate patients to persevere in long-term treatments. Gamification and serious gaming are therefore highly promising in the matter of reducing problems with treatment adherence [157] and boosting engagement with healthcare interventions.

RQ5. What are the research types of the studies related to the gamification of e-Health?

The most prevalent research type is solution proposal, which accounts for 54% of the selected papers. This implies that the design and development of gamified e-Health applications and serious games are significantly expanding among researchers in the areas of healthcare and pervasive technologies. The second most frequent research type in the selected studies is evaluation research. About 35% of the papers analyzed conducted an evaluation of pre-implemented gamified e-Health interventions and full-fledged serious games. Some of them additionally provided a set of benefits and drawbacks of the usage of these interventions. However, this result denotes that evaluation research into gamification and serious gaming in e-Health is, to some extent, scarce. Indeed, researchers do not focus primarily on evaluating the existing applications but alternately concentrate their efforts on proposing new solutions to enhance the area in question. This is mainly owing to the complexity and difficulties inherent to the evaluation of healthcare systems. In order to conduct thorough health-related experiments, it is currently necessary to obtain permissions and extensive consents from various parties, which renders the evaluation even more difficult. Furthermore, five reviews [113, 117, 136–138] were included in this study. A dozen gamified applications related to healthcare and wellbeing were examined from different perspectives, such as design challenges in terms of functionality and privacy [136, 137]. Nevertheless, there was no relevant review of health serious games identified in this study.

RQ6. Are the studies in the area empirically validated?

Empirical investigation is a crucial process in scientific research. Having qualitative data and measurements to hand can facilitate the decisions made about the efficiency and reliability of the systems evaluated [158]. There is a wide range of existing empirical methods. The selected papers in this study relied principally on experiments (33%), which were performed mainly by students who showed their willingness to participate in the evaluation. Recruiting participants from universities, hospitals or through acquaintances was a commonly adopted strategy when seeking prospective contributors. Five papers [110, 112, 126, 128, 142] carried out case studies to assess the effectiveness of the gamified e-Health applications. Within this category, it was noted that two case studies [128, 142] were performed by a single patient who was observed during a long period of time. Consequently, these findings can hardly be considered as being based on scientific evaluation.

Research studies on serious games also used case studies to explore the impact of these games on the improvement of participant's condition by gathering quantitative data. Furthermore, surveys were endorsed in 15% of the selected papers. With the exception of two papers [130, 144], surveys were driven by a large sample of respondents and were launched upon the completion of the project. With regard to data collection methods, researchers essentially opted for questionnaires and audio-recorded interviews that were later transcribed for better analysis. Around 35% of the studies did not include an empirical validation. Empirical evidence about gamification and serious gaming in e-Health applications is therefore

progressively emerging [159].

However, gamification has not yet attained the mainstream of any academic discipline. According to various studies on gamification [66,160], there is a serious lack of research that provides well-founded and rigorous empirical evidence of the motivation process driven by the core elements of gamification. Several studies therefore reported the need for more substantial research and empirical data on the effectiveness of the gamification elements incorporated into diverse contexts such as enterprises [63], education [50] and journalism [161]. In a like manner, it was noted that there is a dearth of studies speculated about serious games that did not include high-quality empirical evidence concerning positive impacts and outcomes of serious gaming [162].

RQ7. What game mechanics have been used in gamifying e-Health applications?

A multitude of game mechanics are being integrated into gamified e-Health applications and serious games. The majority of the selected studies reported the usage of a combination of game mechanics to encourage users to engage with the application. Of the gamification elements most frequently used, we found feedback, rewards, progression and social features. Most of the studies incorporated a basic game-like feature that rewards users with numerical values for an action or a combination of actions. This point-scoring system was generally associated with achievement rewards such as badges, trophies and medals upon accumulating a certain amount of points. Apart from these virtual rewards, some researchers opted for more personalized rewards [132]. For instance, the pain assessment application for adolescents with cancer [112] rewarded its users with a congratulatory video-recorded acknowledgment upon accomplishing the assessments. Moreover, children were rewarded real-world prizes such as a jump rope and a Frisbee after the completion of the game's nutritional activities [150]. Providing instant-feedback was also perceived as a helpful mechanism as regards informing users about their current progress and alerting them to changes in their status. Feedback was mainly represented in the form of visual popups [126] (e.g. textual measures, informative messages) or audible notifications (sound effects) [144].

Serious games also provided constant auditory, visual or textual feedback which directly react to the patient's actions and inform on their performance and results [129,148]. It has been pointed out that the adjustment of the real-time feedback is crucial, because the game needs to provide a feedback appropriate to the level of the patient [121]. Feedback should therefore be dynamic and adaptable. Several studies emphasized the positive effect of socialization on the users' engagement with the gamified applications. Whilst some applications implemented a socialization component that interacts with the best-known social networks [125] (e.g. Facebook, Twitter), a private social platform was created in other applications to allow users to communicate with their peers and receive support from them [110]. Another aspect of socialization was that of leaderboards. This is based on status, which leads to greater visibility for the users. This implies a social comparison, which encourages the users of

applications, especially those related to physical activity, to surpass their fellows [140]. Another competition setting was that of creating a collaborative platform on which users can perform the application's activities as part of a small group, which ultimately helps people enhance their physical accomplishment [141]. Although not highly valued in serious games, social interaction, as presented in two studies [114,116] consisted on the setup of an in-game social community of players where they can communicate and support each other in order to generate competition between them and stimulate a prosocial behavior.

As in the gamified applications, the players were able to see each other's rank and current status on a leaderboard. In addition, serious games made an extensive use of leveling-up and progression mechanics. To advance levels, the players had to perform challenges of a gradual increasing complexity [114,120]. On the contrary, progress bars and challenges were found to be the least commonly used game mechanics in the selected studies on gamified applications. However, users who participated in the evaluation of applications that employ these mechanics expressed positivity about and satisfaction with them. They stated that challenges allowed them to complete a particular set of actions within a time limit, but they suggested that this mechanism might be more effective if they could set personalized challenges by themselves [139]. Moreover, a mobile fitness application called BonnyBolt was based on a fictitious storyline in which users were asked to explore the different episodes of the storyline while exercising. This quest appeared to be significantly engaging for young users [131]. Some studies reported the usage of further gamification elements. For instance, users of a wellness application [139] were disposed to track their progress instantly on a virtual map. This analogy was considered to be helpful as it added more tangibility to the achievements.

The effectiveness of some game mechanics in comparison with others is mainly owing to their role in simultaneously yielding enjoyment, competition and self-evaluation [163]. Social features, rewards and progress tracking were therefore demonstrated to be powerful mechanics in producing positive effects on users. In line with the studies conducted on gamification in non-health-related contexts such as education [164] and software engineering [165], there is a similarity in terms of the most frequently used game mechanics. In fact, tracking and monitoring progress help users stay focused on their goals and avoid dwelling on negativity [163]. Pointsification is the core component of gamification, particularly in progress visibility and leaderboards. Users' progress is mostly fueled by the amount of points collected, which are then used to provide a ranking on leaderboards. However, points could be less appealing and insignificant in terms of gratification. Users tend to prefer receiving badges [165] for their multiple functions. Beyond advertising one's achievement, badges can provide instructions that help users shape their activities and diversify their participations [156]. Besides encouraging self-improvement, social features are designed to create a competitive environment in which users can effectively engage to achieve extrinsic motivations. Nevertheless, these positive effects can be undermined from the perspective of

users. For example, users may actually feel disheartened if they are not able to surpass their fellows or they realize that they do not have in-app friends to connect with [163]. As long as there are different perceptions about the potency of the game mechanics, more research is needed to understand, exactly, how these gamification elements trigger motivation in order to implement them more appropriately.

RQ8. What are the research types of the studies related to the gamification of e-Health?

Although the number of studies investigating the limitations of gamification in e-Health is relatively scarce, it was noted that the implementation of gamification techniques in the e-Health realm is a critical and demanding process. The authors of the selected papers addressed several challenges that could undermine the potential success of gamification and serious gaming. One of the major challenges is related to the long-term viability of the gamification effects on the applications' users. Researchers argue that the noticeable short-term effect on users' motivation and engagement is unlikely to be sustained, as the users' interest and enthusiasm in the game-like features seems to decrease in the long run [114, 134, 139]. Moreover, some game mechanics (e.g. points, badges) did not provide a tangible health-driven meaning in terms of the user's competence and health skills [140], and they were sometimes wrongly located on the application's display. In this respect, the participants in the evaluation of a nutritional serious game [115] did not understand the purpose of the partitioned progress bar along with the number associated to it.

A direct, simple and clear set of instructions would thereby be essential to avoid confusions and optimize users' gameplay experience. Furthermore, it was stated that some gamification applications offer a valuable reward for an activity that does not require a significant endeavor and/or vice versa [113]. Regardless of their functionality in a game-context, gamification elements were sometimes falsely mixed-up as there was no apparent control between them [140]. To effectively alleviate these challenges, it is necessary to design game elements for meaningful in-system purposes by providing them in response to efforts that users consider important. It is also significant to assign informative content to the game elements in order to make them easily intelligible and not confusing [166]. In addition, building an entire gamified solution on the basis of a single gamification element can reduce the effectiveness of the solution and therefore lead to a straightforward failure [136]. Because fun and motivation are not a "one-size-fits-all" proposition, a game element that seems motivational for one individual may not be persuasive for another. This also holds true for serious gaming as it was emphasized in different studies [114, 149] that there is a crucial need to understand the gaming forms which motivate and engage players [149]. This knowledge may therefore help designers create adaptive games that offer slightly different modes of play for different player types. Moreover, in order to trigger users' motivation through gamification, it is important to allow them to experience a sense of communion, autonomy and competence [167].

Gamified solutions should encompass a well-structured and varied rollout of game



elements if these motivational needs are to be realized. Another important issue is that most gamified solutions and serious games are not user-centered since they disregard the demographic characteristics of the targeted users to a significant extent [159], thus failing to provide an appropriate solution to the cohort in question. In this respect, researchers suggest bearing in mind the varied demographic traits and considering children and elderly cohorts to a much greater extent [136]. Besides the lack of a standardized methodology with which to assess the potency of gamification [137], there is a paucity of healthcare professionals' involvement in the design and development of the gamified e-Health solutions, which diminishes their credibility and respect among patients [136].

RQ9. What are the benefits of using gamified e-Health applications?

Despite the challenges that were judged to hamper the potential of gamification in the e-Health realm, the majority of the selected studies have demonstrated the positive effects that the user can still attain while using gamified e-Health interventions and serious games. The major advantage of gamification in the health context is, perhaps, that of ensuring users' regular engagement and increasing their immersion into the e-Health solution [123, 127, 145]. Indeed, gamification seeks to take playful aspects of gaming experiences in order to restructure a typically boring activity into something enjoyable, competitive and engaging [134, 146]. This implies motivating users to deliberately stick to the application's activities [125]. Similarly, the use of visual aesthetics and game mechanics in serious games promotes the gameplay and the interaction with the players while yielding a great level of enjoyment and entertainment [122, 151]. Besides providing extrinsic motivation (rewards, feedback), gamification is also intended to help users experience positive emotional states such as satisfaction, relatedness and self-esteem [134, 136, 137]. This results in the inducement of positive changes in users' behavior that are beneficial for their overall health and wellness [126].

Furthermore, gamification was perceived as a successful means to provide a certain type of assistance to patients with chronic conditions by improving their adherence to medication and treatment plans [111]. On the other hand, serious games were appreciated and were seen as a good method to help people induce positive behavioural change in people living with chronic conditions thanks to the powerful integrated game design [122, 124]. From a social perspective, gamification has a huge potential as regards improving communication and bilateral encouragement among users by means of social-sharing (e.g. posts) and instant messaging [114, 141].

### **2.4.1 Implications of the results**

The findings of this SLR have implications for both researchers and practitioners working in the area of gamification applied to e-Health. Researchers need to pay considerable attention to the motivational side of the gamified applications and serious games. Extrinsic

and intrinsic motivation should be tuned up to yield a permanent engagement with the application. Moreover, the findings of this review show that the majority of the studies reported evaluations during a short period of time, which actually diminished the accuracy of the results. The gamified applications and serious games, especially those dealing with therapy and prevention, must therefore undergo empirical evaluations that span longer periods so as to better explore the long-term viability of the game mechanics being integrated. In addition, patients diagnosed with the health condition in question should be involved from the first stage of the development of the application or the game. Since the seriousness of the application might be alleviated owing to the game-like features, receiving medical approval can reassure the users about the effectiveness of the application from the health outcome perspective. Practitioners, for their part, need to examine the gamified applications and serious games rigorously in order to lessen the eventual loopholes that enhance the users' ability to cheat, i.e., seeking rewards while being oblivious to the actual health outcome. It may be worth involving experienced game-designers in the whole process of building the e-Health solution so as to draw on their expertise for the purpose of implementing game-mechanics that are properly thought through and well balanced. Furthermore, practitioners need to bear in mind the importance of ensuring security and privacy to the extent that the users' personal health data are fully protected.

#### 2.4.2 Study limitations

As with any review, this study has a number of considerations that may limit the soundness of the conclusions drawn. These biases have been divided into four kinds of threats to validity, which are described below:

- **Construct validity:** The most obvious bias that could affect the validity of the conclusions of this study is the incompleteness of the search and the selection of the studies. Although the trial search was performed in the major digital libraries related to computer science and medicine, relevant studies that investigate gamification and serious gaming in e-Health may have been missed. In an attempt to mitigate this bias, the Google Scholar database was first used to retrieve the potentially relevant studies that are not indexed in the selected sources. Second, the reference lists of the papers included were checked to identify any further relevant studies. Although the PICO criteria were used to obtain a rich collection of elements for the search string, it was impossible to ensure that the search was totally exhaustive. Additional terms related to 'gamification' and 'serious game' could have been used to make the search more comprehensive through performing a rigorous search strategy as reported in [168]. Moreover, since the search was performed only on the metadata of papers (i.e., Title, Abstract and keywords), it is probable that some papers that did not include a reference to validation in their metadata were systematically rejected. Another issue that arose

during the screening phase was that some papers had a potentially valid content, but an irrelevant abstract could have led to their exclusion.

- **Internal validity:** Bias during the data extraction phase may have affected the accuracy of the data extracted. To alleviate this threat, the data items to be extracted in this study were discussed by the three authors until an agreement was reached. Since the extraction of data was conducted by just one reviewer, there is a risk of making mistakes, thus, causing substantial inconsistency in the outcomes. In fact, single data extraction process can potentially raise the rate of extraction errors such as inadequacies, incomplete data and omissions [169]. It is true that most of the systematic reviews do duplicate the data extraction process by having at least two reviewers performing the extraction independently as recommended in PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [170], however, there are many reviews which included single data extraction with double checking and did yield significant results as in [106, 171]. Single data extraction offer a pragmatic approach to complete the review to time and cost when the double process is not feasible. All data extraction details are shown in Tables 2.5 and 2.6 to allow the reader to verify the reliability and accuracy of the information extracted. Another limitation of this study is the absence of the assessment of risk of bias in included studies that consist of evaluating the methodological features of each individual study and assessing the applicability of their findings. This restriction could plausibly influence the overall strength of the body of empirical evidence.
- **Conclusion validity:** Conclusion validity is concerned with biases regarding the existence or absence of relationships which may lead to incorrect conclusions being reached. In order to mitigate this threat, any phase of the study during which disagreements among the authors were likely to occur was thoroughly conducted and discussed until a consensus was reached. Besides the textual description, the results were plotted using various charts. This helps enhance the traceability between the data extracted and the conclusions.
- **External validity:** External validity is related to the ability to generalize. The validity of the conclusions drawn holds solely for the context of this study. This threat is not, therefore, applicable.

## 2.5 Conclusion

This chapter presents the main results of a SLR on gamification in eHealth. From an initial set of 562 papers retrieved from seven main publication sources, 46 studies presenting gamified applications and serious games in eHealth were selected as primary studies for the SLR. Data were extracted from these papers and then synthesized against nine predefined

RQs, including publication source and trend, research type, empirical type, gamification elements, advantages and challenges of gamification in e-Health. The results showed that gamification and serious gaming began to attract researchers' attention in e-Health realm only in the second half of the year 2010, with a peak year in 2014. The principal research types identified were solution proposals and research evaluations. Roughly half of the papers did not provide any type of empirical evidence. There is obviously a need for further empirical evaluations to provide a rigorous validity of gamification's effectiveness in e-Health. Another interesting result is that the most frequently investigated health domains in literature are chronic disease management and physical activity. Concerning game mechanics, most of the studies reported that rewards, feedback and socialization aspects are recurrently employed to gamify e-Health. Moreover, the results obtained allowed us to address the benefits and the issues of gamification in the e-Health realm. The findings of this chapter sheds light on the importance of thoroughly investigating the potential pitfalls of gamification in eHealth in order to harness the full potential of this powerful design discipline.

# Analysis of functionalities of mobile applications for blood donation and postnatal care

## 3.1 Introduction

Mobile technology appears to be promising in improving access and efficiency in health care delivery [26]. Consequently, the mHealth app market has been expanding steadily over the last few years with the adoption of new technologies and new workflows that are transforming healthcare [172]. BD and PNC are among the several health domains that have harnessed the mobile technological advances in that a panoply of apps are increasingly being released to the public. The structure of this chapter is as follows: Section 3.2 analyses the functionalities and identifies the gamification techniques employed in the gamified BD apps available in four app repositories. Section 3.3 proposes a comprehensive set of requirements for gamified BD apps drawn out from literature and existing apps on the market. Moreover, this section analyses the influence of these requirements on SPQ characteristics using the ISO/IEC 25010 standard. Section 3.4 reviews and analyses features and functionalities of the pool of PNC apps that are currently available in the two most widely used smartphones applications stores: Apple app store and Google Android play store. Section 3.5 presents the conclusions of this chapter.

## 3.2 Review of gamified blood donation mobile applications

BD is one of the most valuable contribution that an individual can make towards the society. In spite of the significant advances in medical area, no real progress has been made to develop a substitute for blood [173]. This induces the importance of donating blood. In fact,

there is a surge demand for blood supplies and blood products [5] each year which are used in different situations ranging from severe childhood anaemia to cancer therapy depending on the country's incomes [174]. Despite the people's awareness about the need for blood, 90% of people who are eligible to donate blood are not currently doing so [175]. Non-donors provide different reasons for their non-willingness such as busy schedule, needle phobia and fear of catching disease [176]. Given this critical situation, many studies investigated how mobile technology can boost potential donors' motivation through a multitude released BD apps. Social networks and text messages have played a leading role in the search and recruitment of blood donors, respectively [8]. However, it has been affirmed that relying on social networks and text messages to broadcast the need of BD could be inefficient if the information is irrelevant to potential donors [177]. Therefore, the BD apps must be developed with in-built geolocation services and push notifications to instantly inform the donor of blood need in nearby locations [177].

One of the critical issues that is encountered in BD is the ageing population of most countries which implies the blood centres to mobilize in order to recruit more blood donors among youth as well as improving their retention [178]. In this regards, as the young interaction with mobile devices and game world is significantly high [179], the usage of gamification techniques in BD apps could be of great help. Actually, gamification lies in applying game mechanics and dynamics in non-game contexts [45]. A myriad of domains such as marketing and recruitment have adopted gamification as a strategy to enhance user's loyalty and improve user's motivation [180]. In BD area, gamification can enhance the retention rate of donors and motivate the non-donors to start donate through offering proper incentives [9]. Rewarding the blood donors takes several forms. A donor can earn points for each blood unit donated which can be redeemed for material rewards (e.g. gift cards, T-shirt, keychain). Considering that the individual is mostly driven by its intrinsic motivations [10], levelling and acquiring status can have a better influence on donors' engagement and loyalty.

### **3.2.1 Methodology**

This sub-section describes the methodology used to search for, select and analyse the gamified BD apps.

#### **A. Review and protocol**

A set of recommendations set out by PRISMA [181] has been used to address the search for gamified BD apps. Prior to the beginning of the search, a review protocol was developed which sets out the methods of the review including RQs, eligibility criteria and data extraction.

#### **B. Research questions**

In order to guide this review, three RQs were formulated according to a previous

study on BD apps [182]. Table 3.1 shows the RQs addressed in this study and their motivations.

### C. Eligibility criteria

The following inclusion criteria (IC) have been used to select the BD apps:

- Free or Paid BD apps available in app repositories.
- Apps for human Blood Donation.
- Apps that are gamified.

IC1 selects the BD apps that are available under the four mobile platforms (iOS, Android, Windows Mobile and Blackberry). IC2 selects the apps that focus only on human BD, hence discarding those for pets or those that focus on general health. IC3 assesses the presence of gamification elements in the apps. In this respect, applications were evaluated through their descriptions and screenshots.

### D. Search strategy

The study sample was identified through systematic searches in the following apps repositories: Apple App store, Google Play, Windows Mobile Store and Blackberry App World. The apps were identified in June 2016. Search terms were defined using PICO (population, intervention, comparison and outcome) [105] criteria. The population considered is that of blood donors; the intervention consisted on gamified apps for BD and the outcomes encompasses all existing outcomes regarding gamified BD apps. The ‘comparison’ criterion is overlooked since this review does not aim to prove evidence regarding gamified BD apps not providing alternatives. The search string is defined as follows: *Blood AND (donat\* OR give OR bank OR network OR help OR need\*)*.

### E. Selection process

The selection process went through the following main steps:

1. Entering the search terms in the aforementioned mobile app stores to identify candidate apps.

Table 3.1: Research questions

| ID  | Research Questions  | Motivation  |
|-----|---|---|
| RQ1 | Which BD apps are currently available in app stores and what types of BD apps have been selected? | To identify the BD apps that are available in app repositories and the areas of BD that are covered by the selected apps. |
| RQ2 | What are the functionalities and features proposed in the installed BD apps?                      | To study the common functionalities and characteristics as regards BD apps.   |
| RQ3 | How gamification has been employed in the selected apps?  | To analyse which gamification strategies are mostly used in the BD apps.  |

2. Screening and assessment of the apps using eligibility criteria as shown in Figure 3.1.
3. Installing the selected apps in appropriate devices. Since the apps designed for iOS were also compatible with both iPhone and iPad, an iPad 2 was used to explore them. Whereas the apps for android were installed to a Samsung GALAXY Note 2 and the windows app was installed on Nokia Lumia 635 smartphone.

The activities described above were carried out between June and July 2016 by one author. Any discrepancies were resolved through discussion by the rest of authors. Figure 3.1 illustrates the selection process of the apps for each app repository. Ten gamified BD apps were selected from a total of 801 apps identified.

#### F. Data extraction

Data extraction process was performed by the first author through a designed form and was reviewed by two other authors. A set of data items was extracted for each selected BD app. These data items were analysed to show:

- ID. The first letter refers to the source of the app; G represents an Android app available in Google Play, the letter A refers to an iOS app which is available in Apple App Store while the Windows apps are pointed out with the letter W.
- Name of the App.
- Type of BD App. The following eight types were identified [183].
  - Find donors. Apps which help the user find potential blood donors.
  - Find centres. Apps which help the used find nearby centres/ hospitals to donate blood.

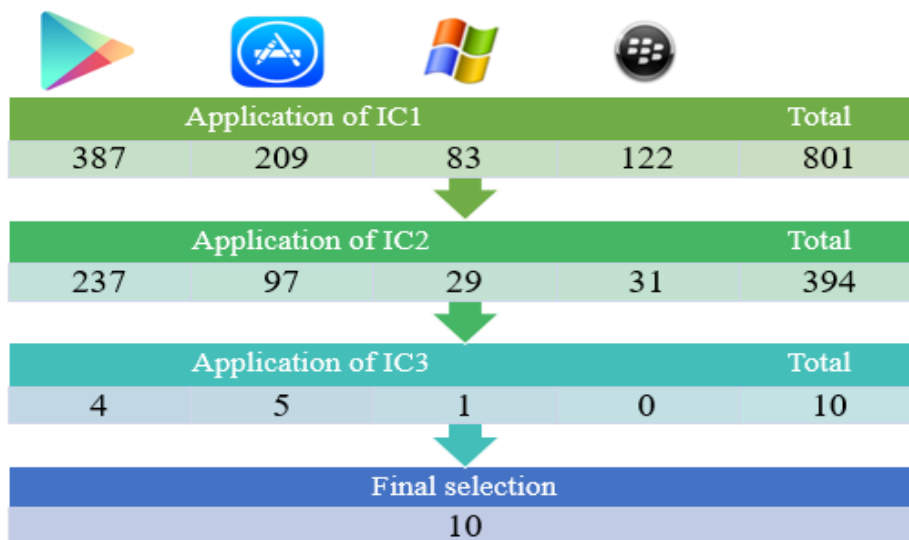


Figure 3.1: PRISMA digram of the selected gamified BD apps



Table 3.2: Characteristics questions of the gamified BD apps

| ID | Question  | Motivation   |
|----|---|--|
| Q1 | Does the application use an authentication method?                          | <b>Privacy.</b> To pinpoint the authentication method used to access the data in the application.  |
| Q2 | Does the application support multiple languages?                            | <b>Internationalization.</b> To identify the languages used in the BD application.   |
| Q3 | Is the application geographically restricted?                               | <b>Internationalization.</b> To analyse the intended users of the BD applications.   |
| Q4 | Is the application connected to a specific medical institution?             | <b>User communication.</b> To discover whether the user receives BD-related data from a specific medical institution.  |
| Q5 | Is the application integrated with Facebook, Twitter or other social media? | <b>Social Media.</b> To examine whether the application provides users with the possibility to share BD information via social network.                                      |
| Q6 | Does the application use maps to show localizations?                        | <b>Localization.</b> To inspect whether it is easy to localize donors or centres in the BD applications.   |
| Q7 | Does the application include notification feature?                          | <b>User communication.</b> To investigate whether the user receives notifications from the application and to precise the types of notification included in the application. |
| Q8 | Does the application include information about the BD process?              | <b>Recommendations.</b> To determine whether the user can access recommendations and tips related to BD process in the application.  |

- Eligibility. Apps which determine whether or not the user is eligible to donate based on their health condition and the date of their last BD.
  - Blood Types. Apps which provide information on the different blood groups.
  - Blood Calculation. Apps which estimate the user’s blood type based on their parental blood types.
  - Records. Apps which record and list out the user’s donation history.
  - Related to a centre. Apps that offer to the user useful information related to a medical institution (e.g. hospital, laboratory ...).
  - General Information. Apps which give general information on the BD process.
- App repository link to the App.
  - Developer and Country of origin.
  - Current version.
  - Latest update.
  - Number of installs.
  - Number of raters.
  - User rating. It is scored out of 5.

A list of 8 functionality items was also extracted and evaluated for each of the gamified BD apps installed. These characteristics questions along with their rationales are presented in Table 3.2. The way in which this questionnaire was written was inspired by previous studies [182,184]. The extracted data and characteristics corresponding to each selected app are listed in Tables 3.3 and 3.4.

### 3.2.2 Results and discussion

This section describes and discusses the results related to the data extraction process. The extracted data along with the characteristics of the BD apps selected are presented in table 3.3. The search for the gamified BD apps was performed in June 2016. A total of 10 gamified BD apps were selected from the 801 apps identified. As depicted in Figure 3.1, eligibility criteria were applied separately to apps for each app repository. In the screening phase, 407 of 801 apps were discarded as they were not intended for human BD. Only 10 apps appeared to be eligible in terms of incorporating gamification elements and were, consequently, selected for further evaluation in this study.

**RQ1.** Which BD apps are currently available in app stores and what types of BD apps have been selected?

Among the four app repositories, Apple App store was the app store that offered most BD apps (5 apps) followed by Google Play Store (4 apps). In contrast, the number of BD apps available for Windows and Blackberry devices was less significant. Only one BD app was identified in Windows Phone Store and no app was found relevant in Blackberry app store. This could be owing to the fact that Android and iOS are the most used operating system worldwide [185]. The total of these apps contains duplicates. Actually, three apps are available in more than OS, Android/iOS platform and Android/Windows respectively and were hence included because the features they offer may differ between the corresponding mobile platforms. No restriction was made on the category in which the app figures within the app store in order to include most available gamified BD apps. The small number of the apps selected could be explained by the fact that gamification is a novel discipline in health area in general and BD in particular. Hence, incorporating game mechanics in BD apps has not been put heavily into practice. Around 70% of the apps selected have been updated

Table 3.3: Extracted data from the selected BD apps

| ID | App Name                          | BD Type          | Link  | Developer/ Country                          | Current version | Latest update | Category         | #Installs   | Rating | #Raters |
|----|-----------------------------------|------------------|---|---|-----------------|---------------|------------------|-------------|--------|---------|
| G1 | Blood Donor                       | E, FD, FC, GI, R | <a href="https://goo.gl/lhjDXS">https://goo.gl/lhjDXS</a> | The American National Red Cross, USA        | 1.3             | 23-Sep-15     | Medical          | 100k - 500k | 4,1    | 2658    |
| G2 | Daruj krev s VZP                  | FC, GI           | <a href="https://goo.gl/WxscET">https://goo.gl/WxscET</a> | eMan s.r.o, CZE                             | 1.0.1           | 02-Jul-12     | Medical          | 1k - 5k     | 2,6    | 79      |
| G3 | Blood donor+                      | FC, E, R         | <a href="https://goo.gl/grMk4j">https://goo.gl/grMk4j</a> | SmartMobe Solutions, USA                    | 1.0.1           | 08-Jun-15     | Social Media     | 500 - 1k    | 4,6    | 31      |
| G4 | Bloodstore                        | FC, FD           | <a href="https://goo.gl/g050ta">https://goo.gl/g050ta</a> | Pseudo Labs, IND                            | 1.1             | 02-Jun-14     | Health & Fitness | 10 - 50     | N/A    | N/A     |
| A1 | Blood Donor by American Red Cross | E, FD, FC, GI, R | <a href="https://goo.gl/N9c3ai">https://goo.gl/N9c3ai</a> | The American National Red Cross, USA        | 1.3             | 23-Sep-15     | Medical          | N/A         | 4,3    | 222     |
| A2 | Blood Donor +                     | FC, E, R         | <a href="https://goo.gl/h7NYFP">https://goo.gl/h7NYFP</a> | SmartMobe Solutions, USA                    | 1.0.1           | 19-Jun-15     | Medical          | N/A         | N/A    | N/A     |
| A3 | Central Blood Bank                | E, FC            | <a href="https://goo.gl/zO3394">https://goo.gl/zO3394</a> | The institute for Transfusion Medicine, USA | 1.0.3           | 15-Jun-16     | Medical          | N/A         | N/A    | N/A     |
| A4 | The Blood Center Mobile           | FC, RC           | <a href="https://goo.gl/twya3K">https://goo.gl/twya3K</a> | The Blood Center, USA                       | 1.3             | 17-Sep-12     | Health & Fitness | N/A         | N/A    | N/A     |
| A5 | Red Cross Connection              | FD, FC           | <a href="https://goo.gl/zWw0AB">https://goo.gl/zWw0AB</a> | Singapore Red Cross Society, SGP            | 4.0.11          | 01-Apr-16     | Utilities        | N/A         | N/A    | N/A     |
| W1 | BloodStore                        | FC, FD           | <a href="https://goo.gl/ULRbqD">https://goo.gl/ULRbqD</a> | Pseudo Labs, IND                            | -               | -             | Health & Fitness | N/A         | 4,0    | 2       |

Table 3.4: Summary results of the assessment of the gamified BD apps

| ID | App name                          | Q1  | Q2  | Q3  | Q4  | Q5  | Q6  | Q7  | Q8  |
|----|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| G1 | Blood donor (American)            | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| G2 | Give Blood with VZP               | No  | No  | Yes | No  | No  | Yes | No  | Yes |
| G3 | Blood donor+                      | Yes | No  | Yes | No  | Yes | Yes | Yes | Yes |
| G4 | BloodStore                        | Yes | No  | Yes | No  | Yes | Yes | Yes | No  |
| A1 | Blood Donor by American Red Cross | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| A2 | Blood donor+                      | Yes | No  | Yes | No  | Yes | Yes | Yes | Yes |
| A3 | Central Blood Bank                | Yes | No  | Yes | Yes | Yes | Yes | Yes | No  |
| A4 | The Blood Center Mobile           | Yes | No  | Yes | Yes | Yes | Yes | Yes | Yes |
| A5 | Red Cross Connection              | Yes | No  | Yes | No  | Yes | No  | Yes | Yes |
| W1 | BloodStore                        | Yes | No  | Yes | No  | Yes | Yes | Yes | No  |

between 2014 and 2016. The G2 and A4 apps have been ultimately updated in 2012 whether because the app is stable and has a good functionality compliance or the app is no longer serving. Table 3.3 shows the latest date of update and the current version of each selected gamified BD mobile app. Among the eight aforementioned types of the BD apps, finding centres is the most recurrent type identified in all the selected apps. They help users to find nearby blood drives and donation centres, thus, bridging the gap between blood donors and patients in-need. Five apps of those considered help users to find donors. These apps help meet the constant need of blood by providing an additional support to laboratories and blood banks, especially in emergency situations [186]. The BD eligibility apps selected in this study calculate the eligibility date of the next donation and provide a set of criteria to help the users find out whether they are eligible to donate or not. Considering the World Health Organization (WHO) guidelines on donor suitability for BD [187] the main eligibility criteria focus on the lower and upper age limit (18, 65 years old), weight limits (at least 45–50 kg) and vital signs (Pulse, body temperature and body pressure). As depicted in table 3.3, all the apps selected cover more than one type to achieve the utmost efficiency. These apps were counted separately for each type. Around 30% of the apps that combine different types offer the users general information about the process of donating blood. Only Blood donor+ and Blood donor by the American Red Cross apps in their both iOS and Android versions allow the users to maintain a personal record of their BDs. Nonetheless, no app from those selected was attributed to Blood types and Blood calculation types. This is likely due to the fact that these activities do not need further incentives as they are considered personal and are not a matter of general interest. Figure 3.2 shows the types of the gamified BD apps.

**RQ2.** What are the functionalities and features proposed in the installed BD apps?

This question was discussed by considering the results obtained after installing the ten selected apps and answering the questions presented in table 3.1. The eight aforementioned characteristics were evaluated for each selected BD app. The reader may note that installation problems were not taken into account in order to yield an overview of the existing set of gamified BD apps in repositories. However, no significant issue was encountered during the

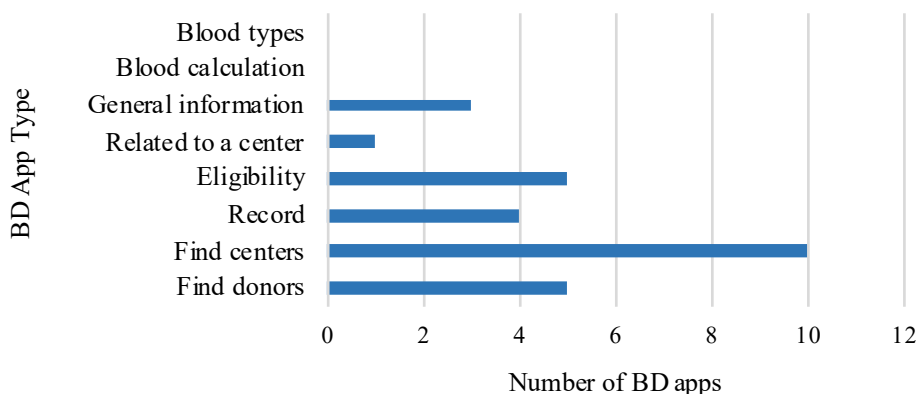


Figure 3.2: BD type of the selected apps

Table 3.5: Authentication methods in BD apps

| Authentication method         | ID       |
|-------------------------------|----------|
| Login                         | G1 A1 W1 |
| Social network login          | G3 A2 A4 |
| Login or Social Network login | G4 A5    |
| Login + Center ID             | A3       |

installation of the apps.

**Authentication Method.** Around 90% of the apps require the user to provide credentials to identify them which can be accomplished in many ways. Table 3.5 presents the authentication methods employed in the BD apps installed. The Daruj krev s VZP is the only app that provided open access and did not require any login. In the G1, A1 and W1 apps, the user is required to create an account using an email address whereas a social network login particularly Facebook or Twitter is requested in the G3, A2 and A4 apps. The possibility of choosing between a normal login and a social network login is provided by two apps namely G4 and A5. Using a social login in the majority of the apps installed facilitate the access to the app. In order to access the content of Central Blood Bank app, the user can enter the app as a guest although most of the features would not be usable. To harness the app to the utmost, a specific centre ID is needed to create a login account when registering for the first time. This condition shrinks the number of the app’s users as it is only accessible for the adherents of the centre. However, it helps to lessen making random and anonym accounts by non-good willing people who may access sensitive details of the users [188]. Thanks to technological advances, the authentication methods are becoming more sophisticated and not easily broken which can crowd out the social and traditional login, still however widely used in the apps.

**Multiple Languages.** Perhaps one of the actual challenges of the apps is the globalization. Building an app in multiple languages promotes its integration in the international market. However, English remains the most recurrent language supported by the majority of the

apps as it is considered to be a universal language [189] mainly because it is the most spoken language worldwide owing to the British and American world economic, political and military domination aspects. In fact, it is supported in 9 of the apps selected beside Dutch, French, German, Romanian, Russian, Spanish and Traditional Chinese in A1 and G1 apps. Although donating blood is frequently made in the surrounding areas [190], developing a BD mobile app with a multiple languages support could be necessary to widen the target users of the app living in the country or area in question. The other language that was identified in the installed apps is Czech available in the Daruj krev s VZP app.

**Geographical Restriction.** All of the installed apps are dedicated to a specific country. Although there is no restriction during the installation nor the authentication, some of the features such as finding blood banks or donors could be without interest if the user is not located in the targeted area of the app. Four of the apps selected are intended to the people of USA, while five are for countries of Asia namely Singapore, India and Nepal. The remaining app is dedicated to people from Czech Republic. Considering the types of the BD apps selected, their geographical limitation for usage is evident as it would not be plausible to provide BD services at a worldwide scale.

**User Communication with Medical Institutions.** Among those selected, five apps are related to medical institutions. G1 and A1 apps which are the same app developed for Android and iOS smartphones by the American Red Cross, provide details about nearby Red Cross blood drives to schedule appointment. Similarly, the A5 app is linked to the Red Cross of Singapore and gives information about convenient blood banks' location that are ready to accept the donation, among others. However, both apps do not inform the user of any personal blood-related detail after donating. The A3 and A4 are the only apps that are directly connected with a third party. The Central Blood bank app can only be accessed using a particular ID that can be requested at the blood bank which means that the user could receive a feedback after the donation. The A4 app is connected to the blood centre of New Orleans in USA, the user could receive BD test from a laboratory in USA after donating blood, stating whether the user is eligible or not to give blood in the future. The gap between the clinical information of patients and blood banks should be systemically bridged in order to better exploit the usage of blood according the diagnoses of the patient which can be retrieved from different sources (e.g. electronic medical record) [5,9].

**Integration with Social Networking Portals.** All the apps selected allow the user to share information via social networks except the G2 App. Facebook is the most predominant social network that is incorporated into the BD apps followed by Twitter. Apart from the G3 and A2 apps which are the same app developed for Android and iOS platforms, the BD apps are integrated with more than one networking site such as Twitter, Instagram, YouTube or others. The American Red Cross Apps for BD allow the users to share achievements through the available social platforms on their devices. Sharing BD information in social networks can be of great help in recruiting new donors, thus increasing the number of voluntary

donors among youth in an efficient and economical way [191]. Also, there is evidence that people tend to give a huge importance to their relationships, consequently, they become more motivated to act in a way that maintains their social status [192]. Owing to the fact that social influence shapes the one's behaviour [9], a deeper investigation on the factors impacting donors' behaviour change has to be carried out to increase the recruitment and retention of blood donors.

**Geolocation.** Geolocation is a paramount feature that should be integrated in mobile apps as it helps the users search for precise locations using maps that illustrate the most direct routes and other navigational data [193]. Nowadays, GPS services for emergency or Location-Based Services are one of the advanced handsets that any smartphone has included which makes the delivery of information goes seamlessly and rapidly. Around 90% of the apps examined are developed with a built-in geolocation feature. Donors and centres' locations are displayed on a map that can be visualized and optimized based on the real-time location data of the user to identify the nearest centres or donors. Since GPS services operates with users' personal information, malicious implications as well as privacy and anonymization concerns can be major issues that need to be addressed to prevent the misuse of data [188].

**Notifications.** Apart from the G2 App, all the apps installed provide the users with notification feature. The user can be notified in different ways. Among those investigated, a notification can be an instant alert that the user receives about blood shortage in nearby locations or a reminder of a donation appointment or the date on which the next donation is possible. Users can also receive push notifications for upcoming nearby campaigns and receive instant invitation to donation events. Notifications are a powerful tool that gets users' attention in a disruptive manner. However, these notifications may become annoying and intrusive if they convey irrelevant and interesting messages, thus leading to negative perceptions about the app.

**BD Recommendations.** To ensure the safety of BD for both donors and recipients, volunteer donors must be evaluated to check their eligibility according to the guidelines determined by the WHO [187]. Countries may adapt these guidelines to the characteristics of their population. All the apps installed provide BD recommendations to the users except three apps; G3, A3 and W1. These recommendations mostly focus on explaining the BD process and eligibility requirements. In addition, users are given tips and guidelines on how to stay comfortable and safe throughout the donation process. In order to decrease wait times at blood drives and streamline the donation experience, the users of some of the apps installed such as A1, A3 and G1 are requested to complete an online health history questionnaire prior to arriving at the donation centre. Users should complete the questionnaire by visiting the official websites of the apps [194, 195] from their personal computer and present it at the blood drive whether printed or scanned to be evaluated.

**RQ3.** How gamification has been employed in the selected apps?

Gamification stands on applying game mechanics and dynamics in non-game settings. There is evidence that this technique is able to engender motivational drivers of human behaviour in non-game applications [196] by leveraging the users' natural desire for competition, status and achievement, among others [197]. This is accomplished through providing non-monetary incentives and rewards upon performing some actions within the application. These intrinsic rewards mostly consist on social recognition, appreciation and accomplishment feelings [198]. In fact, gamification seizes its essence through using a mixture of motivational affordances such as points, badges and leaderboards. Almost 80% of the apps considered in this study focus on badges and rewards as gamification elements to incentivise BD. The users of A1 and G1 apps are able to acquire badges depending on their donations' type and frequency.

The Blood donor app allow the donors to create or join teams and track its ranking on a national leaderboard. Additionally, through the award-winning engine WeWin, partnered retailers offer the users of this app diverse array of extrinsic rewards (e.g. coupons, promo codes) to boost their donations. In the android app Daruj krev s VZP, users can visualize their donation and sharing's mark upon which they can receive badges (silver, gold, diamond). This is also the case of the Android (G3) and iOS (A2) versions of Blood Donor+ app that award various badges to blood donors (Silver, Gold, Diamond, Platinum) alongside the champion and lifesaver badges. Nevertheless, no further information on the rewards is provided within this application. In both android (G5) and windows (W1) versions of the Bloodstore app, users are awarded points so as to recognize the most devoted donors. While in the A3 app, the points are redeemed for gift cards or items that are available in the online store of the blood bank such as T-Shirt and prepaid cards. The total of the awarded points differs according to the donation type. Donors can choose not to redeem their points for external rewards and have the option to donate them to other partnered non-profit-organisations. Alike the American Red Cross app, the red cross of Singapore through its app (A5) rewards the donors an augmented reality video thanking them for their selfless act. In addition, the loyal donors can be rewarded with special offers and discounts from the partnered merchants. Besides, the app confers status to users such as Heroglobin and pacemaker according to the number of lives they have helped save through their donation. The A4 offers external items such as exclusive T-shirts and Free tickets to attend upcoming events in the current month. Additional gifts (e.g. smart TV) could be awarded to users by drawing lots. Given that the secret of behaviour's change using gamification lies in intrinsic incentives, financial or extrinsic rewards could generate a straightforward users' engagement and loyalty towards the application. However, research [199] shows that excessive cash-rewards are not correlated with progress and performance and can therefore deflect users' motivation.

### 3.2.3 Limitations of the study

There are four notable limitations to this review. Firstly, the search string used to pinpoint the gamified BD apps may not have covered all the terms relevant to the study. To alleviate this threat, PICO criteria were used however no gamification-related term was used in order to avoid obtaining games in the results. Secondly, the app repositories do not allow advanced searches due to their limited functionalities thus widening ineffectively the number of search results. Thirdly, as the apps were finally selected after reviewing their screenshots and description, relevant apps could have been missed. Lastly, the steady proliferation of mobile apps is such that the results of this study will no longer portrays the current availability of the apps.

## 3.3 Quality evaluation of gamified blood donation apps

The use of gamification in BD has significantly increased during the last decade, therefore, diverse gamified mobile solutions intended for blood donors have emerged in research and practice. Typical inherent requirements should be taken into consideration prior the development of fully-fledged BD apps. Hence, it is necessary to apply SE processes to assure the development of secure, high-quality BD apps. Besides the specification of functional requirements, eliciting SQRs represents a crucial part of the SE process as it determines the overall quality of the software product.

### 3.3.1 Related work

This subsection draws an overview of studies that approaches the assessment of the quality characteristics of m-health apps. Investigators and experts used a myriad of methods to evaluate the quality of health-related software products. Several studies prioritized usability as a referential concept for quality evaluation [183,200,201]. Reynoldson et al. evaluated apps for pain self-management using quality assessment criteria and testing usability with potential users [200]. A study by Ouhbi et al. reported a QA of a total of 133 free BD apps using a questionnaire concerning the compliance of these apps with mobile OS usability guidelines [183]. In the same vein, Zapata et al. assessed the accordance of 24 mobile Personal Health Records with iOS and Android usability guidelines [201]. Another study aimed at the examination of multiple parameters around the quality of the most popular dietary weight-loss mobile apps available to the public using comprehensive quality assessment criteria [202]. Moreover, a study was about proposing a rating tool to provide a multidimensional measure of the quality indicators of m-Health apps [203]. Furthermore, papers within the evaluation of the quality of mobile apps used software quality models proposed by the series of ISO/IEC standards. Table 3.6 summarizes the main findings of some selected papers on the quality evaluation of health software products based on ISO-models.



### 3.3.2 Requirements of gamified BD apps

This subsection summarises the main requirements of a gamified BD apps considering system features and gamification aspects. The requirements elicitation phase was processed through reviewing related literature and evaluating the existing solutions in app repositories [9, 178, 204–208]. The extraction was, particularly, based on studies targeting BD apps such as: 1) the study by Foth et al. that proposes a design implications of a BD system based on their research findings on the necessary features for a BD application [178], and 2) the study by Yuan et al. in which the authors determined the most relevant functions of BD app to potential users besides investigating the degree of receptiveness of donors toward mobile apps [204]. Several studies focusing on gamification in BD solutions were also reviewed. For instance, Domingos et al. presents the design of a gamified BD app that facilitates the interaction between users and blood centres [205]. Another study by Sabani et al. which focuses on integrating gamification elements into iOS BD apps to encourage donors and help end blood shortage [206]. Furthermore, the findings of a previous review on gamified BD apps were used to extend the list of system requirements and gamification techniques [209]. Given that the results of the aforementioned review were obtained in 2016, a similar search was performed between August and September 2017 following the same search procedure in order to update the pre-obtained list of gamified BD apps. Two more apps were found relevant on the market. Nine apps, of which five on Android and four on iOS were therefore included in the current study as depicted in Table 3.7.

The main requirements of gamified BD apps were selected and regrouped in four clusters: App's accessibility, donor's personal information, user's actions and app's components.

- **App's accessibility**

App's accessibility is one of the important factors to consider when developing apps. It gathers a bunch of requirements related to the availability of the app for users either before or after installation. The accessibility requirements are as follow: **AA1**. The operating system (OS) type. This requirement regards the app's availability in the well-known app repositories (iOS, Android, Blackberry, Windows Phone). **AA2**. The OS version. Given that new features are consistently added to the OS, new versions are being launched accordingly. Although it is not necessary to upgrade the OS, the user might be obliged to perform the upgrade to be able to install a specific app. Hence, the AA2 concerns the compatibility of the app with OS version. **AA3**. Cost. In app repositories, there are free and paid apps. Although paid apps have high value content and features, free apps are the most popular because users are less willing to purchase apps. In-App Purchases (IAPs) remain a prominent alternative for users seeking low price but advanced features. **AA4**. Language. Several apps provide the possibility to change the language from an in-app setting or by adjusting the phone's selected language. **AA5**. Geographical limitation. It is important to define whether the app should have a restricted availability for users in certain countries, or should be accessible from all

Table 3.6: Overview of the application of ISO standards to evaluate the quality of health software products

| Ref.  | Software Product                   | Standard                        | Description  |
|-------|------------------------------------|---------------------------------|--|
| [210] | General Health mobile environments | ISO/IEC 9126                    | <ul style="list-style-type: none"> <li>• An analysis process based on the External Quality Model ISO/IEC 9126 has been proposed and applied to six quality characteristics.</li> <li>• A significant influence of limitations of mobile technologies (variable bandwidth, Limited Autonomy, etc.) was identified for Reliability, Usability, Portability and Efficiency.</li> <li>• The model used was not valuable for assessing the Maintainability and Portability characteristics, additional external should therefore be supplied to attributes of these characteristics.</li> </ul> |
| [211] | Mobile Personal Health Records     | ISO/IEC 25010 (Product Quality) | <ul style="list-style-type: none"> <li>• A quality evaluation of Mobile Personal Health Records was performed applying ISO/IEC 25010 model.</li> <li>• A checklist containing 30 quality characteristics and a compilation of 51 mPHR requirements was established.</li> <li>• The degree of influence on quality characteristics was calculated and analysed for each mPHR requirement.</li> </ul>  |
| [212] | MPHRs for pregnancy monitoring     | ISO/IEC 25010 (Product Quality) | <ul style="list-style-type: none"> <li>• A framework for evaluating the software product quality of mPHRs for pregnancy monitoring was designed using ISO/IEC 25010 model.</li> <li>• A set of mPHRs pregnancy monitoring requirements was extracted from literature and existing mobile apps.</li> <li>• The impact of these requirements was calculated for each software product quality characteristic and sub-characteristic.</li> </ul>  |
| [213] | Online HealthAwareness System      | ISO/IEC 25010 (Quality-in-use)  | <ul style="list-style-type: none"> <li>• A model based on the ISO/IEC 25010 standard was developed for assessing quality in-use of e-Ebola Awareness System.</li> <li>• A total of five quality in-use attributes (Effectiveness In Use, Efficiency In Use, Satisfaction In Use, Flexibility In Use and Safety In Use) were captured by usability testing, observation and attitudinal questionnaire.</li> <li>• Considering the analysis, the e-Ebola online portal has, to some extent, a good level of quality in-use.</li> </ul>   |

over the world. **AA6**. Internet access. This requirement indicates whether the app require internet connection to function. Building an app that works in both online and offline mode is considered as an effective feature.

- **Donor’s personal information**

Mobile apps usually require users to offer up a certain amount of information to get the full experience with the app. Unregistered donors are therefore requested to create a user profile that contain their following personal details (PD): **PD1**. Full name, **PD2**. Gender, **PD3**. Date of birth, **PD4**. Email, **PD5**. Address, **PD6**. Phone number.

- **User’s actions**

User’s actions (UA) constitute a set of inherent actions that should be specified in the requirements document. It should be indicated whether the user can or cannot perform these actions: **UA1**. Be authenticated using login credentials, **UA2**. Add information, **UA3**. Modify information, **UA4**. Delete information. **UA5**. Share information, **UA6**. Upload images.

- **App’s components**

Table 3.7: Details about the gamified blood donation mobile applications

| Application name                  | OS      | Latest Update | Free/Paid | App URL   |
|-----------------------------------|---------|---------------|-----------|---|
| Blood Donor by American Red Cross | iOS     | 31-Jul-17     | Free      | <a href="https://goo.gl/MHVm9x">https://goo.gl/MHVm9x</a> |
| Blood donor +                     | Android | 23-Jun-17     | Free      | <a href="https://goo.gl/grMk4j">https://goo.gl/grMk4j</a> |
| Red Cross Connection              | iOS     | 05-Apr-17     | Free      | <a href="https://goo.gl/72L6tL">https://goo.gl/72L6tL</a> |
| Central Blood Bank                | iOS     | 14-Jul-17     | Free      | <a href="https://goo.gl/zO3394">https://goo.gl/zO3394</a> |
| Blood Store                       | Android | 02-Jun-14     | Free      | <a href="https://goo.gl/4a48XA">https://goo.gl/4a48XA</a> |
| Blood Donor                       | Android | 29-Aug-17     | Free      | <a href="https://goo.gl/EcjM7U">https://goo.gl/EcjM7U</a> |
| Simply Blood -Find Blood Donor    | Android | 10-Jul-17     | Free      | <a href="https://goo.gl/92kG1u">https://goo.gl/92kG1u</a> |
| MSBD Mai Sewa Blood Donor         | Android | 18-Jul-17     | Free      | <a href="https://goo.gl/SzbKGg">https://goo.gl/SzbKGg</a> |

This block of requirements includes both the service-oriented features and the common gamification elements of BD apps.

– **App’s functionalities**

App’s functionalities (AF) define the requirements related to the characteristics of the app. It contains: **AF1**. Search and geolocation of local blood drives and nearby donation centres. **AF2**. Search for blood donors. **AF3**. Blood calculation. This feature provides users with their estimated blood type considering their relatives’ blood types. **AF4**. Connection with blood centres. **AF5**. Scheduling and management of donation appointments. **AF6**. Push notifications for BD events. The donor may receive alert messages for blood campaigns and for special blood shortage. **AF7**. Reminders. These help users remember their scheduled appointments or their next date of eligibility to donate blood. **AF8**. Information on blood, its types and the BD process. These can help donors make their BD experience as safe and pleasant as possible. **AF9**. Social media. Users can share BD experience on social media sites, to raise awareness and encourage others to donate. **AF10**. Donation history. Users can keep track of the history of their BDs. **AF11**. Blood donors’ teams. Users can create/join a team of donors to **AF12**. In-App FAQ (Frequently Asked Questions) section that improve user’s experience.

– **Gamification elements**

This sub-block identifies the gamification aspects implemented in the app. It includes: **GE1**. Points. Users can earn points after each donation. **GE2**. Special incentives when donating upon emergency blood shortage calls. **GE3**. Status. Users obtain a new status every time they reach a BD milestone. **GE4**. Rewards for referring others. **GE5**. Tracking of donations’ progress. **GE6**. Points redeeming for real-world items. **GE6**. Users’ ranking on leaderboard to encourage friendly competition. **GE7**. Visualization of achievements including collected badges, points earned and lives saved. These characteristics are further subdivided into sub-characteristics that can be measured internally or externally. The internal quality measures are static attributes used to measure inherent properties of a software work product that are typically available during development. The external quality measures, for their part, are

dynamic attributes that are used to address properties related to the execution of the software product in the system environment in which it is intended to operate. The other sub-model of the IEC/ISO 25010 ‘quality in use’ relates to the outcome of human interaction with the software and has five characteristics, which are further divided into a set of sub-characteristics. This sub-model is not tackled in this study.

### 3.3.3 Analysis of requirements impact on gamified BD apps

This subsection describes the analysis process used to measure the impact of the requirements defined for gamified BD apps on software product quality. It also presents an illustration example to better understand the process as shown in Figure 3.3. The analysis process was founded on that of previous studies [210–212], but was readjusted to the field of gamified BD to answer the following RQ:

**RQ.** What influence do requirements of gamified BD apps have on SPQ?

The analysis process consisted on carrying out three steps:

#### **Step 1. Analysis of the product quality characteristics and sub-characteristics.**

The ISO/IEC 25010 was analysed in order to understand the meaning of each external characteristic and sub-characteristic. In conjunction with this standard, the ISO/IEC 25023 standard was used to grasp the definitions of the quality measures used for quantitatively evaluating system and software product quality in terms of characteristics and sub-characteristics.

#### **Step 2. Checklist of gamified BD apps’ requirements using ISO/IEC 25010 SPQ model.**

The two first authors built a checklist to determine the potential impact of each pre-identified requirement on external sub-characteristics of the product quality model. There were no discrepancies between the authors during the process. The checklist was revised and verified by the third author in a way that respects the following instruction: A SPQ sub-characteristic is considered to be affected by a requirement if the variables used in the calculation of the external metric are affected by this requirement.

#### **Step 3. Calculation of the degree of impact of gamified BD apps’ requirements on SPQ.**

Three degrees of impact are calculated.

- (i).  $DI(EC,B)$ : degree of impact of a block of requirements B on an external characteristic EC. This degree is calculated according to the following equation:

$$DI(EC,B) = \frac{\sum DI(EC,R)}{N(R)}$$

where  $DI(EC,R)$  is the degree of impact of a requirement R on an external characteristic

EC and  $N(R)$  is the total number of requirements in the block B.

- (ii).  $DI(EC, R)$ : degree of impact of a requirement R on an external characteristic EC. This degree is calculated according to the following equation:

$$DI(EC, R) = \frac{N(EsC, R)}{N(EsC)}$$

where  $N(EsC, R)$  is the number of the sub-characteristics of the external characteristic EC that are affected by the requirement R and  $N(EsC)$  is the total number of the sub-characteristics comprised in the external characteristic EC.

- (iii).  $DI(EsC, B)$ : degree of impact of a block of requirements B on a external sub-characteristic EsC. This degree is calculated according to the following equation:

$$DI(EsC, B) = \frac{\sum DI(EsC, R)}{N(R)}$$

where  $DI(EsC, R)$  is the degree of impact of a requirement R on an external sub-characteristic EsC, and  $N(R)$  is the total number of requirements in the block B.

$N(EsC)$  and  $N(R)$  are obtained from the checklist established in step 2. After that the calculation of these degrees was performed, the results were classified into five groups as shown in Table 3.8.

With the aim to illustrate the analysis process described above, we present the following example that focus on calculating the degree of impact of the block AF which contains twelve

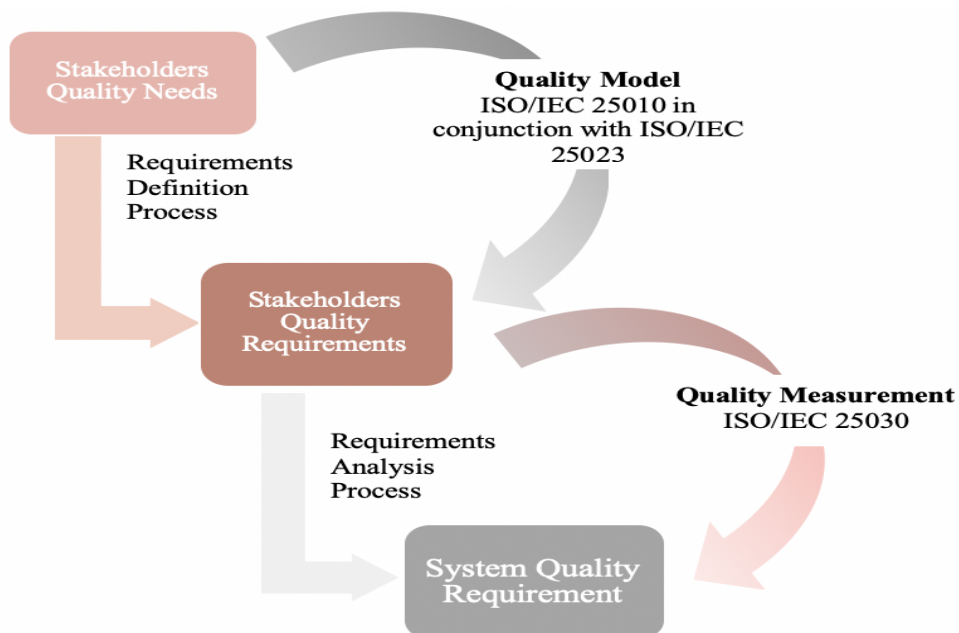


Figure 3.3: Software quality requirement definition and analysis process

requirements, on Functional Suitability (FS) characteristic. In order to calculate  $DI(FS, AF)$ , we proceed with calculating the degree of impact of each requirement of the block AF on Functional Suitability following this equation:

$$DI(FS, AF) = \frac{\sum_{i=1}^{i=12} DI(FS, AF_i)}{12}$$

As depicted in table 3.9, the requirements AF8 and AF9 affect solely the Appropriateness sub-characteristic, thus their degrees of impact are:

$$DI(FS, AF_8) = DI(FS, AF_9) = 1/2$$

The remaining requirements influence both sub-characteristics: Appropriateness and Accuracy. For instance,

$$DI(FS, AF_1) = \frac{2}{2} = 1$$

The degree of impact of the whole block of requirement AF on Functional Suitability is therefore:

$$DI(FS, AF) = \frac{1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + \frac{1}{2} + \frac{1}{2} + 1 + 1 + 1}{12} = \frac{11}{12} = 0.92$$

On the other hand, we calculate the degree of impact of the block AF on the Accuracy sub-characteristic (Ac) using the following equation:

$$DI(Ac, AF) = \frac{\sum_{i=1}^{i=12} DI(Ac, AF_i)}{12}$$

From the checklist, we notice that Accuracy is not affected by only two requirements AF8 and AF9, hence,

$$DI(Ac, AF_8) = DI(Ac, AF_9) = 0$$

and

$$\begin{aligned} DI(Ac, AF_1) &= DI(Ac, AF_2) = DI(Ac, AF_3) \\ &= DI(Ac, AF_4) = DI(Ac, AF_5) \\ &= DI(Ac, AF_6) = DI(Ac, AF_7) \\ &= DI(Ac, AF_{11}) = DI(Ac, AF_{12}) \\ &= 1. \end{aligned}$$

Therefore,

$$DI(Ac, AF) = \frac{1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 0 + 0 + 1 + 1 + 1}{12} = \frac{10}{12} = 0.83$$

Table 3.8: Classification of the degrees of impact

| Degree's value | Group     |
|----------------|-----------|
| 0.9 – 1        | Very high |
| 0.7 – 0.89     | High      |
| 0.4 – 0.69     | Moderate  |
| 0.2 – 0.39     | Low       |
| 0 – 0.19       | Very low  |

Considering the classification given in Table 3.8, the results show that the degree of impact of App's features block on Functional Suitability  $DI(FS,AF)$  is very high while the degree of impact of the same block AF on the Accuracy sub-characteristic  $DI(Ac,AF)$  is high.

### 3.3.4 Results

As an attempt to answer the RQ defined for this study, this subsection presents the results of the impact analysis of gamified BD apps' requirements on SPQ characteristics. The checklist presented in table 3.9 comprises 30 external sub-characteristics and a total of 37 requirements specified for gamified BD apps. As shown in Figure 3.4, The block AA has the lowest degree of impact on software quality characteristics. Compatibility and Maintainability are the least influenced by the blocks of requirements among eight quality characteristics as their degrees can be described as low and very low. Functional Suitability is moderately influenced by AA and PD blocks. All the blocks have low to very low degree of impact of Security characteristic. Transferability is only influenced by AA block with a low degree. UA, PD, AF and GE blocks have a moderate degree of influence on Operability and a very high degree of impact on Performance Efficiency. For Functional Suitability and Reliability characteristics, the degree of impact of blocks UA, AF and GE is very high. Figure 3.5 presents the degree of impact of each requirement of gamified BD apps on the external characteristics. Functional Suitability is the only characteristic that is influenced by all the requirements. 91% of requirements affect the Operability characteristic. Performance Efficiency is influenced by 86% and Reliability by 84%. For Maintainability and Security, the impact is measured

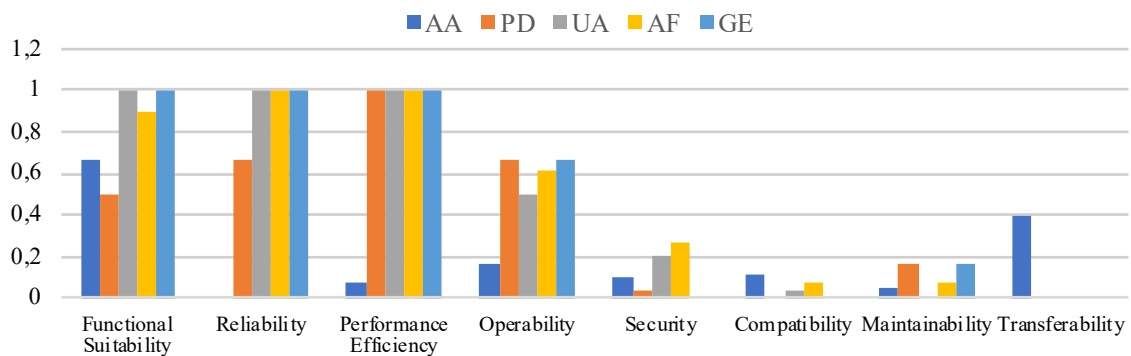


Figure 3.4: Degree of influence of gamified BD apps' requirements on external quality characteristics

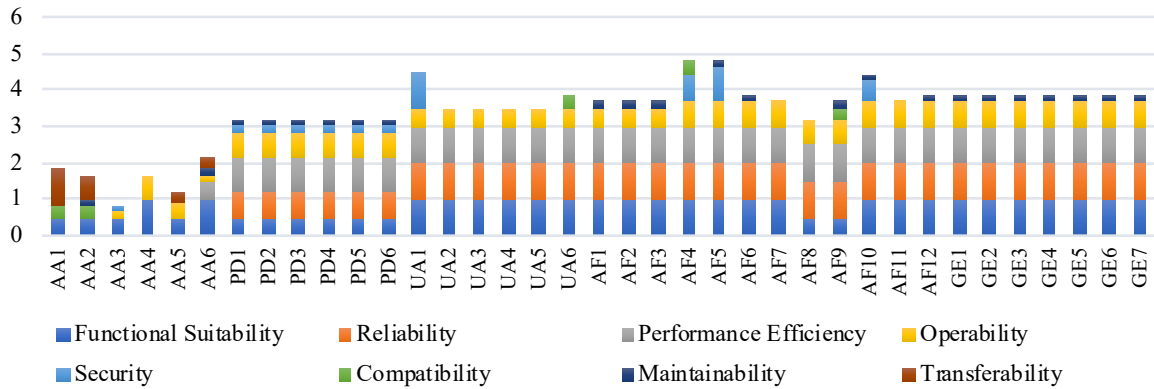


Figure 3.5: Degree of influence of the block of requirements on external quality characteristics

considering 54% and 35% of the requirements, respectively. The lowest degrees of impact are obtained for Compatibility (16%) and Transferability (11%). The requirements AF4 and AF5 have the most impact on software quality followed by UA1 and AF10. In contrast, AA3 is the requirement that have the least influence on the quality characteristics. Detailed insight into the impact of the blocks of requirements on each external sub-characteristic is illustrated in Figure 3.6. Appropriateness is the only sub-characteristic that is affected by the whole range of requirements. Whereas, none of the requirements has an impact on three sub-characteristics of Maintainability, namely Analyzability, Changeability and Testability in addition to one Compatibility sub-characteristic (Replaceability). Confidentiality is the most affected Security sub-characteristic. PD, UA, AA and GE blocks have an equal degree of impact on Performance Efficiency sub-characteristic. Among Operability’s sub-characteristics, Technical accessibility and Appropriateness recognizability are the most affected by all the blocks of requirements. Maintainability is roughly influenced through Modularity sub-characteristic. Learnability, Reusability and Modification stability are only influenced by one requirement: AA3, AA2 and AA6, respectively.

### 3.3.5 Discussion and implications

This study lists a set of requirements of gamified BD apps that were drawn out from literature and from the existing gamified BD solutions in app repositories. Among this compilation of requirements, (AF1) Search and geolocation of donations centres, (AF2) Search for blood donors were the features that are predominantly included in the gamified BD apps. One important aim of developing a mobile app in the area of BD is facilitating communication between blood donors, recipients, and donation centres [214]. All the requirements underwent the analysis process described in subsection 3.3.3 in order to obtain their degrees of impact on the external quality characteristics. With the exception of the OS version (AA2) and cost (AA3), all the requirements can be considered as software quality requirements. After performing the impact analysis, the blocks UA, AF and GE were found to have an important



impact on the quality characteristics. Considering the UA block, UA1: to be authenticated is the requirement that mostly affect software product quality, followed by UA6: Upload images.

Security and privacy constitute an essential part of apps development, particularly mHealth apps that store several data regarding patients' health status [215]. Improper implementation of security information can have severe repercussions on users and stakeholders alike. Authentication (UA1) represents a crucial source of security shortcomings and has therefore a notable impact on SPQ. A secure authentication can be achieved through adding another layer of security over the user credentials, this can include one of the three authentication' classes, such as asking a secret question, using a smart card or implementing biometric authentication [216].

With regard to the requirements considered as apps' features, connection with donation centres (AF5) is one of the AF block requirements to have a great influence on SPQ. One of the most interesting aspects of the mHealth sphere is its ability to promote communication across the healthcare sector from caregivers and patients. Nonetheless, the lack of a standardized and efficient form of data exchange is one of the most critical issues encountered by health apps' developers [217]. Scheduling appointments (AF4) is another aspect of connecting to donation centres. The possibility of tracking donations history (AF10) is another requirement that threaten the software product quality of apps as it implies privacy issues. Lastly, a notable and equal impact on SPQ was identified for all the requirements of gamification elements block (GE).

Although the application of gamification to BD apps has various benefits, it can be rendered ineffective if poorly implemented. Using gamification mechanisms that do not

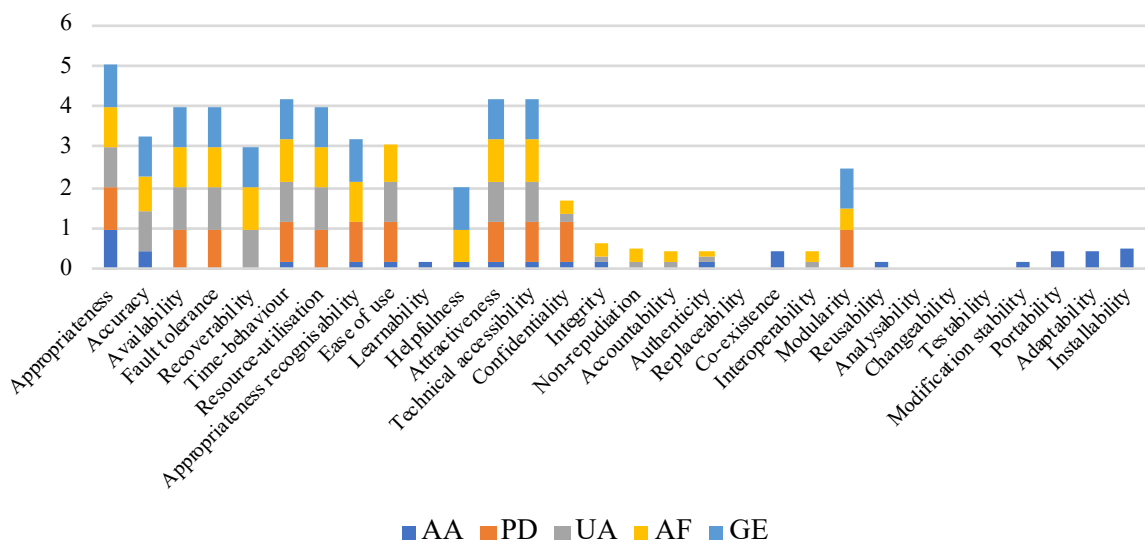


Figure 3.6: Degree of influence of each block of requirements on the external sub-characteristics

mesh the audience's need and burdening the app with a plethora of gamification elements are some of the problems that negatively impact the overall quality of the software product [136]. Moreover, the results show that along with Functional Suitability, Reliability and Performance Efficiency are the external characteristics which are highly affected by requirements of BD apps. Frequent disconnection and limited energy autonomy are some of the limitations of mobile environments that have significant influence on Reliability characteristic [210]. Whereas Performance Efficiency is affected by limited storage capacity and lower bandwidth. On that account, it is critical to take into consideration these limitations at requirements elicitation phase. According to the checklist, Operability sub-characteristics were fairly affected by gamified BD requirements. The limitation of user smartphone interface is one of the obstacles that may be encountered by Operability characteristics [210].

This study has identified a range of requirements for gamified BD apps, which developers and evaluators can translate to SQR for the assessment of software product quality. SPQ evaluation can be undertaken during or after the development or acquisition process. The requirements of gamified BD apps for external quality characteristics should be quantitatively described in the SQR. The checklist established in this study on the influence of BD requirements on quality characteristics may be of significant use to developers of gamified BD apps. Stakeholders could take advantage of the suggestions made in this study to draw up the essential requirements that help augment the overall quality of gamified BD apps.

### **3.4 Review of mobile applications for postnatal care**

The postnatal (or postpartum) period is the most critical, yet the most neglected phase in the lives of mothers and newborn infants. Beginning immediately after childbirth, the postnatal period and usually extends for about six weeks as the mother's body returns to its pre-pregnant state. Yet, some evidence indicates that the postnatal period is a continuity of three distinct phases of which the third one lasts up to six months following delivery [11]. The postnatal period marks an important transition in the lives of parents as it brings about major changes in parental roles, responsibilities, and identities. During this period, parents are supposed to make physical, psychological and social re-adjustments to restore balance in their lives [218]. While most expecting mothers focus on potential risks involved during pregnancy and up to delivery, few closely consider the risks afterward. In fact, the postnatal period poses substantial health risks for both mothers and newborn infants and is the period when most maternal and infant mortalities and morbidities occur. According to recent estimates by the World Health Organization, upwards of 303,000 women died as a result of pregnancy and child birth-related complications and approximately 2.7 million newborn babies died after birth in 2015 [219].

Given that maternal health and newborn health are closely linked, interventions targeting maternal care can likely also improve fetal and neonatal health [220]. Providentially, most

Table 3.9: Checklist of the impact of gamified blood donation apps requirements on software product quality characteristics

| Requirements | FS                          | Rel.  | PE                                     | Operability  | Security  | Comp.  | Maintainability  | Transf.                                       |
|--------------|-----------------------------|---|--|--|---|--|--|---|
|              | Appropriateness<br>Accuracy | Availability<br>Fault-tolerance<br>Recoverability | Time-behaviour<br>Resource-utilisation | Ease of use<br>Learnability<br>Helpfulness<br>Attractiveness<br>Technical accessibility<br>Appropriateness recognisability | Confidentiality<br>Integrity<br>Non-repudiation<br>Accountability<br>Authenticity | Replaceability<br>Co-existence<br>Interoperability | Modularity<br>Reusability<br>Analysability<br>Changeability<br>Testability<br>Modification testability | Portability<br>Adaptability<br>Installability |
| AA1          | x -                         | - -   | - -                                    | - -  | - -   | - -  | - -  | x x x   |
| AA2          | x -                         | - -   | - -                                    | - -  | - -   | - -  | x -  | x x -   |
| AA3          | x -                         | - -   | - -                                    | - -  | - -   | - -  | - -  | - - -   |
| AA4          | x x                         | - -   | - -                                    | x x  | - -   | - -  | - -  | - - -   |
| AA5          | x -                         | - -   | - -                                    | x x  | - -   | - -  | - -  | - - x   |
| AA6          | x x                         | - -   | x -                                    | - -  | - -   | - -  | - -  | - - x   |
| PD1          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| PD2          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| PD3          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| PD4          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| PD5          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| PD6          | x -                         | x x   | x x                                    | x -  | x -   | - -  | x -  | - - -   |
| UA1          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| UA2          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| UA3          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| UA4          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| UA5          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| UA6          | x x                         | x x   | x x                                    | - -  | x x   | x x  | - -  | - - -   |
| AF1          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| AF2          | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF3          | x x                         | x x   | x x                                    | x -  | - -   | x x  | - -  | - - -   |
| AF4          | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF5          | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF6          | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF7          | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF8          | x -                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF9          | x -                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF10         | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF11         | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| AF12         | x x                         | x x   | x x                                    | x -  | x -   | x x  | - -  | - - -   |
| GE1          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE2          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE3          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE4          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE5          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE6          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| GE7          | x x                         | x x   | x x                                    | x -  | - -   | - -  | x -  | - - -   |
| Imp. SC (%)  | 100 68                      | 84 84 68  | 86 84                                  | 70 3 62 22 86 86   | 32 16 14 11 8   | 0 5 11   | 51 3 0 0 0 3   | 5 5 8   |
| Imp. C (%)   | 100                         | 84  | 86                                     | 92   | 35  | 16   | 54   | 11  |

maternal and infant mortalities are preventable and healthcare solutions to handle and avoid complications are well-known [221]. In this regard, it is particularly important that all births are attended by skilled health personnel and that all women have access to the appropriate level of care before, during and after pregnancy and childbirth. Timely, high quality PNC is crucial for maximizing maternal and newborn health. Although for most women and newborn infants, the postnatal period is uncomplicated and manageable, effective and adequate care during this period needs to address any deviation from expected recovery after birth and to appropriately intervene in a timely fashion [222]. Nevertheless, PNC services tend to be poorly covered when compared with other reproductive health care services. The inadequacy and the underutilization of PNC services likely emanate from several factors ranging from poor education and poverty to limited access to healthcare facilities [14]. The void in PNC can also be attributable to differing priorities and perceptions of maternal and infant needs among healthcare providers, new mothers and their families which is also likely influenced by regional and cultural practices [223].

On these grounds, mobile technology has the potential to bridge this gap and considerably advance all the aspects of reproductive health through designing user-centered mobile solutions that resonate with the international health regulations. In terms of PNC, there is, currently, an increasing proliferation of apps that bring up new opportunities to improve maternal and infant health care services [15,224].

### **3.4.1 Methodology**

The search for PNC apps was addressed through the use of SLR methodology [225] that ensures the accuracy and completeness of the search and retrieval process. Prior to performing the search for candidate PNC apps, a protocol which outlines the different steps constituting the SLR process developed, was designed in accordance with a set of guidelines delineated by the Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) [170] statement. The PRISMA guidance is said to improve the quality reporting in systematic reviews and provide substantial transparency in the selection process. The review of PNC apps was completed through the following steps: (1) framing the RQs, (2) defining search strategy, (3) identifying eligibility criteria for the selection process, (4) determining elements for analysis and (5) formulating assessment questions. Each of these steps was accomplished independently by the author of this thesis. Any disagreements and discrepancies were discussed between the rest of the co-authors of this study until consensus was reached.

#### **Framing the research questions (RQs)**

To rigorously yield the purpose of the review, a set of five RQs was identified by the authors as presented in Table 3.10. These RQs were informed by the scientific literature

related to the PNC for mother or/and newborns [222,226–228] and a preliminary analysis of available PNC apps.

### Defining search strategy

The leading app stores namely, Google Play store and Apple app store [229] were considered to perform the search for candidate PNC apps. The PICO criteria (Population, intervention, Comparison and Outcome) [105] were used to define a search string that ensures the maximum coverage. The Population considered was that of new mothers and their newborns. The Intervention consisted of free and paid apps which are intended to be used during the postnatal period. Given that the primary focus of the present study was not comparative and did not seek to find evidence about the existing PNC apps, the Comparison criterion was disregarded. With respect to the last criterion, all the aspects and outcomes of PNC apps were of interest in the present study, of which managing the postnatal period and promoting maternal and infant care were the mostly considered. The following terms: ‘Postnatal’ OR ‘Postpartum’ OR ‘After childbirth’ OR ‘newborn’ OR ‘(Postnatal OR Postpartum OR new- born) AND care’ were therefore identified and were primarily applied to the title and description of the apps using the search tools in both app stores. The search process took place in January 2019.

### Identifying eligibility criteria for the selection process

To identify the candidate PNC apps and discard the disqualifying ones, a set of eligibility criteria was defined. Apps fulfilling all the IC were included in the present study. These criteria are the following: **IC1.** Free or paid apps obtained using the predefined search terms and available in the reviewed app stores. The paid version of a given app was only considered if it presents additional features of functionalities when compared to the free version. **IC2.** Apps pertaining to categories related to health namely, Health & Fitness or Medical. Given that the newborn care is inherently encompassed in the PNC, parenting category was also considered for apps in the Google play store. **IC3.** Apps that are mainly focused on any aspect related to PNC for the mother and/or the newborn. Further exclusion

Table 3.10: Review of postnatal care apps: Research questions

| Research Question (RQ)   | Rationale   |
|--|---|
| <b>RQ1.</b> Which are the common types of the PNC apps selected?                 | Determine the classification of the apps selected in terms of their purpose.  |
| <b>RQ2.</b> Which are the predominant characteristics of PNC apps?               | Identify the common functionalities and features among the PNC apps.  |
| <b>RQ3.</b> To what extent do the PNC apps comply with the items analyzed?       | Examine the comprehensiveness of the apps selected in terms of functionalities and features.  |
| <b>RQ4.</b> Are user ratings proportionally linked to the apps’ characteristics? | Investigate the relationship between users’ perception of the quality of the apps selected and the relevance of the functional content of these apps. |

criteria (EC) were applied to the apps identified throughout the selection process to eliminate: **EC1.** Duplicates. This exclusion criterion aims to discard duplicates either within the same app store and apps available for both platforms under the same name and have identical content. **EC2.** Apps that are not designed with an English interface, **EC3.** Apps that were lastly updated before the 1st January 2018. This criterion is intended to keep solely the apps that release regular updates that include relevant bug fixes and features. **EC4.** Apps that cannot be installed or accessed to. This criterion excludes all apps presenting any kind of bug or error during or after installation that prevent authors from conducting an appropriate analysis of content.

### **Determining elements for analysis**

Scientific literature and PNC apps available in the app store were reviewed to identify the main components for the evaluation of features and functionalities of the PNC apps selected. Two components were determined: (1) app characteristics comprising the common features of any app; and (2) data items including the fundamental functionalities and features to be included in a PNC app at a functional and a technical level.

- **App characteristics**

The app characteristics that should be retrieved from the app store for each app selected include: the full name, the operating system (Android or iOS), cost (free, paid, in-app purchases), the app link in the app store or app website (if available), date of the latest update, user ratings, number of raters and country of origin of app developer.

- **Data items**

A thematic template was designed containing the data that should be extracted in regard to the functional content of the PNC apps selected. This template was piloted using a small sample of published papers, standards and guidelines related to PNC as shown in Table 3.11; agreement was reached about six blocks for a comprehensive PNC app among the first three authors.

*Postnatal care for mothers and newborn infants.* Services providing PNC are supposed to incorporate all the essential elements required for the health of the mother and of her newborn infant in an integrated fashion. This category of data includes information related to the postpartum care and the newborn care. The terms ‘postpartum’ and ‘postnatal’ are often used interchangeably [231,232] but sometimes the former refers to the issues pertaining to the mother while the latter refers to those pertaining to the baby. To aid clarity and avoid confusion, the term ‘postnatal’ was adopted to refer to the care after childbirth for both mothers and babies [230]. The core pillar of a healthy postnatal period is to tackle all aspects of mental and physical health and wellbeing of the mother and the newborn infant. A typical

postpartum care plan provided to new mothers includes tips and advice with regard to the recovery from childbirth as well as to inform of the danger signs and life-threatening conditions in the postnatal period such as hemorrhage, infections and pre-eclampsia [222]. The provision of useful information related to the physiological and metabolic changes that take place during the postnatal period is also of a great importance. New mothers should be aware of the way the body reverts to the non-pregnant state to ensure optimum health-management [233]. To cope with pain associated with these changes, mothers tend to use prescribed medications, adapt some comfort measures or do physical exercises. Physical activity during the postnatal period is proven to not only improve the health and wellbeing of the new mothers but also helps in strengthening the woman's body reducing the risk of developing lifestyle-related diseases such as obesity and cardiovascular diseases [234]. Besides physiological adjustments, the postnatal period brings about other social and emotional changes that render new mothers vulnerable to a range of mental and behavioral disorders such as baby blues, postpartum depression and puerperal psychosis [232]. Amid the postnatal period, many women experience feelings of sadness, anxiety and depressed mood, especially, in the few days following the childbirth. While many mothers suffer from brief to a mild bout of maternal blues, others suffer from long-lasting and severe depression. If not treated, these mental disorders may carry significant lifetime consequences for mother themselves and for their newborns [231]. Appropriate screening and treatment are subsequently paramount [235]. A myriad of coping strategies should be introduced to new mothers during the postnatal period to lessen the severity of depression. Yet, these strategies should not interfere with their cultural and religious preferences [236]. With regards to newborn infant care, the provision of a complete parenting guide to new mothers is necessary to avoid neonatal morbidities during the postnatal period. This has to include recommendations and advices on how to care for the baby in the first few days and throughout the postnatal

Table 3.11: Review of postnatal care apps: Relevant sources of information for each block of items.

| Data items                                     | Relevant sources of information  |
|--|--|
| Postnatal care for mothers and newborn infants | <ul style="list-style-type: none"> <li>✓ Recommendations and guidelines on postnatal care [222, 230]</li> <li>✓ Studies about maternal health during the postpartum period [231–237]</li> </ul>  |
| Postnatal counselling                          | <ul style="list-style-type: none"> <li>✓ Counselling guides for maternal and newborn health care [12, 238–240]</li> </ul>  |
| Reminders and push notifications               | <ul style="list-style-type: none"> <li>✓ Studies tackling the use of reminders in mobile apps for maternal health medication adherence [241, 242]</li> </ul>   |
| Notes and records                              | <ul style="list-style-type: none"> <li>✓ A study analyzing functionalities of personal health records for prenatal care [184]</li> </ul>   |
| Social support                                 | <ul style="list-style-type: none"> <li>✓ Studies endorsing the importance of social support in improving maternal well-being during the postpartum period [243, 244]</li> </ul>  |
| App technical features                         | <ul style="list-style-type: none"> <li>✓ Studies about security and privacy concerns in mobile health applications [215, 245, 246]</li> <li>✓ Internationalization requirements catalog for health applications [247]</li> <li>✓ Studies evaluating mobile health applications' compliance with usability guidelines and standards [183, 201, 248]</li> <li>✓ Reusable usability requirements repository for mobile health applications [249]</li> </ul> |

period. It is important to provide new mother with practical tips on umbilical cord care, hygiene, and routine practices such as changing diapers, baby holding, feeding, burping and swaddling [230]. Moreover, new mothers should be taught essential instructions to detect and handle suspected and manifest neonatal complications [237].

*Postnatal Counselling.* Throughout the postnatal period, new mothers should be counselled on various topics including nutrition, hygiene, family planning and infant feeding [12]. To provide positive and successful counselling which engender a considerable support for the new mothers, it is always important to put into practice the following skills: listening; learning; building confidence and giving support [238]. It is recommended to perform counselling session before and after childbirth during the postnatal visits. Cards are often used by counsellors and health specialists to cover all the essential postnatal topics [12,238]. Since PNC is usually considered as the weakest health program among all reproductive and infant health programs [223,230], postnatal counselling sessions are unlikely to take place. By taking advantage of mobile technologies, new mothers can be counselled on the postnatal health issues to maintain their health and that of their newborns. After delivery, new mothers should increase their food intake to cover the energy cost of breastfeeding and for her to recover her normal energy and health. Counselling on maternal nutrition includes advices and recommendations on adopting a balanced and varied healthy food and drink plenty of clean water [239]. Moreover, new mothers should be provided with recommendations about infant feeding and should be encouraged to exclusively breastfeed their newborns up to six months after birth [240]. Besides nutrition and breastfeeding, attention should be drawn to maternal hygiene. New mothers should be counselled on how to take care of their personal hygiene (e.g. Perineal and breast hygiene) to prevent infections [241]. Sexuality is perhaps one of the important elements to be addressed during the postnatal period. Therefore, counselling should cover the resumption of sexual intercourse along with the postpartum family planning. New mothers should be taught about the appropriate contraceptive methods to use to avoid unwanted pregnancies. Research suggests waiting at least 24 months before attempting the next pregnancy to reduce the risk of maternal and infant complications [239].

*Reminders and push notifications.* Most of new mothers become busy and frustrated during the postnatal period owing to the multiple needs underlying motherhood. Consequently, they become less attentive to their postnatal check-ups, their newborns' pediatric visits and vaccinations appointments. In this respect, reminders based on a pre-scheduled events can considerably improve medical appointment attendance [242]. Given that a number of drugs and medicines can be prescribed for both the mother and the newborn during the postnatal period, push notification reminders can play a great role in improving medical adherence and uptake [250].



*Notes and records.* Similarly to pregnant women [184], new mothers can record major milestones of their postpartum period and their newborns' development. As regards to newborns, it is important and practical to record routine activities (e.g. diapers changes, bottle feeding and sleeping patterns), the medical care received (vaccination shots, medications) and to keep track of the developmental milestones by entering measurements such as height and weight of the newborn. This can objectively indicate accelerated or delayed newborn growth. New mothers can make use of diary and recording features to take control of some of vital settings in their wellbeing, such as weight and sleep. Recording weight regularly can help the mother remain alerted and effectively manage their postnatal weight so as to avoid obesity [251]. Likewise, keeping a sleep diary on hand is important in evaluating sleeping patterns in order to detect and diagnosis some discomforts such as fatigue, insomnia and anxiety [252].

*Social support.* To buffer the fluctuations associated with the postnatal period, new mothers need a large social and emotional support. In addition to providing social support, social media offer another venue for social learning and behaviour acquisition through observation, interaction and encouragement [243]. Sharing experiences with others can be of great help in addressing certain issues about motherhood and raising kids. Social support proved to reduce levels of postnatal stress and panic [244] as well as improving the overall health and quality of life [243].

*App technical features.* Convenient, secure and easy-to-use mHealth apps have the potential to increase adherence and engagement with the health system as a whole [245]. Security and privacy are considered as the most challenging risks encountered when developing mHealth solutions [215]. Health-related apps, in particular, are dedicated for tracking, recording and managing personal health information (PHI) of users. PHI is extremely sensitive and needs to be highly protected through robust security and confidentiality mechanisms such as encryption and authentication methods. In fact, unauthorized access to health information is a serious threat to privacy and security. Moreover, for users of mHealth apps, the existence of a privacy policy is an important baseline standard to know why, where, and how personal details and PHI will be collected, used, shared and protected [246]. Another app feature worth mentioning is internationalization (i18n). The i18n is the process of designing a software product that is able to adapt to different languages, regions and cultures. Health-related programs and practical guides are often elaborated to respond to all people's needs regardless their cultural environment. Thus, i18n is a relevant aspect that renders mHealth solutions valuable for a wider number of users [247]. The usability, for its part, is identified as one of the decisive factors in building efficient and intuitive apps [201]. It relates to the ease with which users can complete their tasks in a specified context of use [183]. Task structure and interaction style should be optimal to minimize usability flaws [249]. Besides, usability

aspects have a great impact on improving users' interaction with the apps, and ultimately, enhancing the overall user experience [248].

### **Formulating assessment questions**

To extract relevant data for an optimal analysis of the functional content of the PNC apps selected, a set of Yes/No questions was developed as shown in Table 3.12. The developed questionnaire was drawn on the predefined data items and was validated by a gynecologist and pediatricist who are both highly acquainted with mobile technologies. The data obtained using the questionnaire were employed in answering the RQs. Each app was assessed separately for all the questions. The scoring was performed as follows: Yes (Y) = 1 point, the app offers the feature described in the question. No (N) = 0 points, the app does not offer the feature described in the question.

### **3.4.2 Results and discussion**

This section presents and discusses the principal findings of the assessment conducted in the present study. Characteristics, functionalities and technical features of PNC apps were retrieved and evaluated using a questionnaire of 37 items. The findings are sorted and grouped by RQ.

#### **Selection process**

The selection process of PNC apps and the resulting number of apps after applying the IC and EC is shown in Figure 3.6. The app repository search identified 1596 free and paid apps, of which 45% (n=719) were excluded for not pertaining to the categories defined in the present study. After reviewing the in-store description and screenshots of the 877 remaining apps, only 73 apps were retained for further eligibility assessment. Ten apps were excluded after installation and full review of their contents. Apps designed for Android were downloaded in an OPPO A37 fw while iOS dedicated apps were downloaded in an iPhone 6 Plus. Among the 63 apps reviewed, 15 apps were available in both repositories and duplicates were therefore excluded. These apps were counted as one since they provided similar functionalities. However, some differences with regard to the visual design and layout of cross-platform apps were observed. For instance, the menu of BabyTime app was displayed in the top and the bottom of the screen in the iOS version while it was fixed as a three-bar menu icon in the top left of the screen in the Android version. The multi-platform publishing is currently considered a norm in mHealth app market [253], which justifies the number of cross-platform apps selected in the present study. A total of 48 apps were selected for analysis of functional content, of which 25 apps were found in the Google Play Store, 8 apps originated from the Apple App Store and 15 apps were available for both platforms. The disparity across the Android and iOS platforms in terms of the number of PNC apps is

Table 3.12: Review of postnatal care apps: Assessment questionnaire.

| Data items   | Questions  |
|--|--|
| <b>Postnatal care for mothers and newborn infants (PN)</b> | <ol style="list-style-type: none"> <li>1. Does the application require specifying the newborn's birthdate?</li> <li>2. Does the application provide tips for the postpartum recovery process?</li> <li>3. Are postpartum life-threatening conditions identified in the application?</li> <li>4. Does the application inform about physiological and metabolic changes occurring during the postnatal period?</li> <li>5. Does the application include physical exercises and workouts for women in the postnatal period?</li> <li>6. Does the application offer information about postpartum mental disorders such as Postpartum depression and baby blues (e.g. symptoms, coping strategies)?</li> <li>7. Does the application provide practical tips on how to take care of the newborn (e.g. hygiene, diapers' changing, burping)?</li> <li>8. Does the application include information about manifest neonatal complications and warning signs?</li> <li>9. Does the application inform about the immunizations that newborns need?</li> </ol> |
| <b>Postnatal counselling (PC)</b>                          | <ol style="list-style-type: none"> <li>10. Does the application provide postnatal nutritional counselling for mothers?</li> <li>11. Does the application include infant feeding counselling?</li> <li>12. Does the application recommend breastfeeding?</li> <li>13. Does the application provide a breastfeeding guide and support?</li> <li>14. Does the application include personal hygiene practices for women in the post-natal period?</li> <li>15. Does the application encompass methods for postpartum family planning and birth spacing?</li> </ol>   |
| <b>Reminders and push notifications (R)</b>                | <ol style="list-style-type: none"> <li>16. Does the application allow to set reminders for medical appointments (e.g. post-natal check-ups, pediatric visits, vaccination)?</li> <li>17. Does the application include push notification reminders for scheduled medications/Vaccines?</li> <li>18. Does the application allow to schedule reminders for routine activities (e.g. diapering, feeding, pumping, sleep)?</li> <li>19. Does the application allow users to change reminders and notifications settings?</li> </ol>   |
| <b>Notes and records (N)</b>                               | <ol style="list-style-type: none"> <li>20. Does the application allow to record routine activities of the newborn (e.g. diapers changes, bottle feeding, sleeping patterns)?</li> <li>21. Does the application allow to take note of the medical care the newborn has received (e.g. medications and vaccination shots)?</li> <li>22. Does the application allow to track the newborn's developmental milestones?</li> <li>23. Does the application record anthropometric measurements of the newborn (e.g. height, weight and head circumference)?</li> <li>24. Does the application record measurements of the mother's postnatal weight?</li> <li>25. Does the application allow the mother to create a sleep diary?</li> </ol>   |
| <b>Social support (S)</b>                                  | <ol style="list-style-type: none"> <li>26. Is the application integrated with social networks (e.g. Facebook, Twitter)?</li> <li>27. Is there an FAQ page in the application?</li> <li>28. Does the application provide users with social mechanisms to interact with each other and share experiences (e.g. Community, forum, chat)?</li> </ol>   |
| <b>App technical features (A)</b>                          | <ol style="list-style-type: none"> <li>29. Does the application ask users for authentication?</li> <li>30. Does the application present a privacy policy?</li> <li>31. Is there a possibility to back-up/restore data within the application?</li> <li>32. Does the application have a multi-language support?</li> <li>33. Does the application allow users to update their unit preferences?</li> <li>34. Does the application use a tone that is simple, informal and friendly?</li> <li>35. Does the application adapt to screen orientation (portrait and landscape)?</li> <li>36. Does the application learn user's preferences over time?</li> <li>37. Does the application implement intuitive and predictable navigation patterns?</li> </ol>   |

mainly due to the advantages of the Android platform in terms of the global reach of the market and the simple guidelines and system reviews of the Google play store.

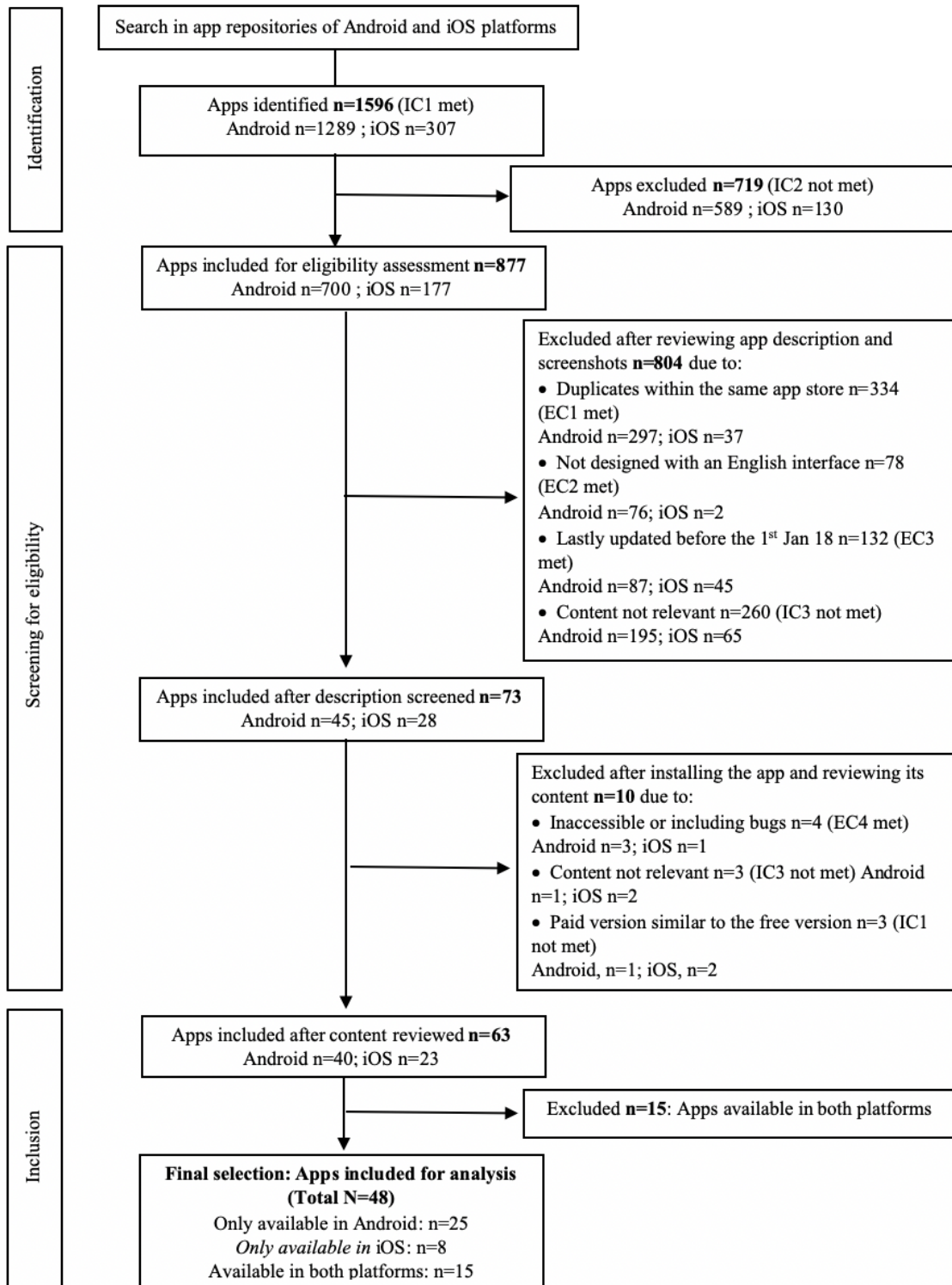


Figure 3.7: Review of postnatal care apps: Results of the selection process of postnatal care apps.

### General app characteristics

The overall characteristics of the apps selected are presented in tables A.1 and A.2 in Appendix A. Among these, 25 apps were focused on the Health & Fitness category, 9 apps

were considered medical and parenting apps accounted for 7. The 7 remaining apps were found in different categories across Android and iOS platforms: (1) Baby tracker-feeding, sleep and diaper app was found in parenting category in Android platform and in Health & Fitness in iOS platform; (2) Six apps (e.g. Baby+, Glow Baby Newborn Tracker App) were found in the parenting category for the Android platform and were considered medical in iOS platform. Among the apps selected, 26 apps were free, 7 apps were paid, and 15 apps offered additional features for purchase. With regard to the country of origin, 22 apps originated from the United States while the remaining apps were developed in various countries including Netherlands, United Kingdom, India, Canada, Egypt, Germany. This confirms the growing interest in developing mobile solutions for the management of the postnatal period across the globe.

### **Analysis of functional content**

The results obtained from the assessment questionnaire are presented in table A.3 in Appendix A. The total score percentage for each app evaluated which illustrates the assessment of its functional content in addition to the total percentage of each question referring to the number of apps fulfilling this question can also be depicted in table A.3 in Appendix A. For better analysis and interpretation, Figures 3.7 and 3.8 illustrate these results. Figure 3.7 presents the scores obtained by the 48 PNC apps for each of the six blocks of assessment questions while Figure 3.8 displays the number of apps fulfilling each of the 37 assessment questions. Based on these results, the maximum score (22 points) was obtained by three apps; Baby+, you+baby and baby & me, while Postnatal pilates by reform app obtained the lowest score (3 points).

With regards to the assessment questions, the highest score (83%) was reached by the informal writing style question (A34), followed by the intuitive navigation patterns question (A37) which attained a score of 79%. Moreover, the presence of a privacy policy question (A30) achieved a score of 63% and the specification of the newborn's birthday (PN1) was included in 58% of the PNC apps. The question related to the ability to create a sleep diary (N25) attained the lowest score (0%). Prior to answering the RQs, it is worth mentioning that given the complexity of the postnatal period and the various elements it gathers, the PNC apps selected in the present study are likely to yield relatively low scores with regard to the features they implement.

#### **1. Which are the common types of the postnatal care apps selected?**

Facilitated by the technological advances, the range of mHealth solutions being designed is constantly expanding. This fundamental shift in mHealth landscape resulted in informed decision-making, improved self-management and increased practice's efficiency and effectiveness. Moreover, mHealth apps have proven to enhance access to basic levels of healthcare and save time for both patients and healthcare providers [172]. There is a particularly broad

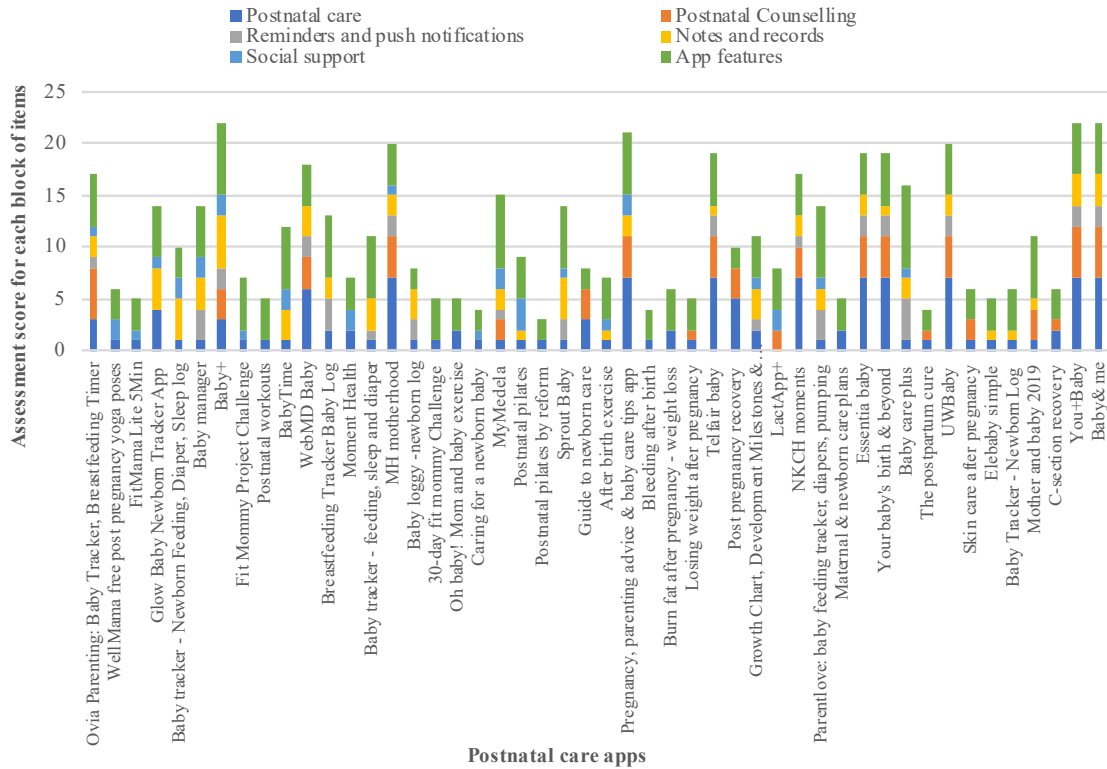


Figure 3.8: Review of postnatal care apps: Classification score of the 48 selected postnatal care apps.

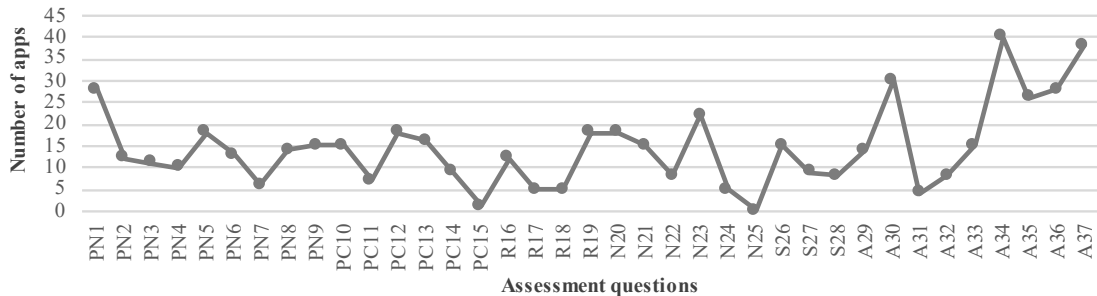


Figure 3.9: Review of postnatal care apps: Number of apps fulfilling each of the assessment questions.

array of mHealth apps that serve different purposes such as providing a clinical diagnosis, remote monitoring, self-management, in addition to promoting healthy living and raising healthcare education and awareness. Correspondingly, the PNC apps selected fall into three main categories (Figure. 3.10). Forty percent of apps exclusively included features to track, monitor and record different information of infant development such as routine activities (e.g. diapering, feeding and sleeping), medical history and anthropometric measurements, in addition to the postnatal weight of the mother as in Baby+ app. Along with WebMD Baby app, Baby+ provide valuable information related to the development milestones of the infant as a reference for growth tracking. Another prevalent category is the provision of

information and tips related to the postnatal period. Accounting for 35% of the apps selected, information is generally displayed into categories related to a single postnatal aspect as postpartum haemorrhage (e.g. Bleeding after birth app), or multiple aspects encompassing the health-management of the mother and the infant, postnatal counselling (e.g. Essentia baby app) and providing parenting tips (e.g. Pregnancy, parenting advice & baby care tips app). Of the 17 informative apps, eight offered features of tracking and recording the newborn measurements, doctoral appointments and feeding as in Telfair baby and MH Motherhood apps. Lastly, a total of 12 apps were designed to encourage weight loss during the postnatal period through physical exercises, nutritional and diet recipes and recommendations (e.g. Burn fat after pregnancy - weight loss app). With the aim to hasten postpartum recovery and assist with muscle strength and toning, these apps offer a selection of postnatal workouts through videos as in After birth exercise app or step-by-step visual and audio instructions as in FitMama Lite 5 Minute Workouts app.

2. Which are the predominant functional characteristics of postnatal care apps?

To answer this RQ, the results obtained through the assessment of the functional content of the apps selected were used. As shown in table A.3 in Appendix A, 58% of apps implemented the specification of the newborn's birthday feature (PN1) which stands upon specifying the birthdate of the newborn. This characteristic was found in all apps specially dedicated to the newborn care management. Besides allowing to constantly track the age of the infant, this characteristic helps in providing straightforward developmental milestones as a function of the infant age as in Baby+ and Sprout apps. In these same apps, additional details were required such as the name and the gender of the infant. Another recurrently covered functionality is recording of infant anthropometric measurements (N23) including height, weight and head circumference. At birth, the evaluation of these parameters is performed to mark out fetal growth restriction among newborns [254]. Throughout the postnatal period, recording accurately these measurements is important in monitoring and tracking infant health and growth.

Thus, it may be observed that most of the PNC apps analyzed in the present study are

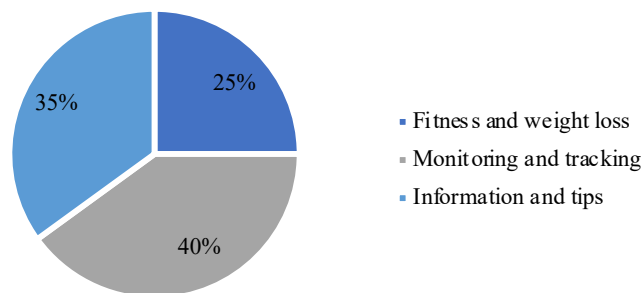


Figure 3.10: Review of postnatal care apps: Types of the selected postnatal care apps.

limited to the management of PNC of the newborn. Significant efforts are required to address the needs of mothers during the postnatal period. With regards to the technical features, two usability aspects were largely present in the PNC apps, namely informal writing style (A34) and intuitive navigation patterns (A37). Familiar writing style and intuitive layout accounted for 83% and 79% of the apps analyzed. Another prevalent feature (A30) which achieved a score of 63% was that of including a privacy policy that clearly and comprehensively discloses how the app collects, uses and shares information.

3. To what extent do the postnatal care apps comply with the items analyzed?

This RQ approaches the main objective of the present study, which consists on measuring the compliance of the PNC apps with the functional characteristics analyzed. Using the assessment results presented in table A.3 in Appendix A, each block of data items was separately investigated.

**Postnatal care for mothers and newborn infants.** The characteristics of PNC were addressed to a large extent (78%) in 9 apps that were predominantly informative. The provision of postnatal fitness recommendations and awareness on postpartum metabolic changes and complications were the features the most commonly disregarded among these apps as in *Telfair baby and Pregnancy, parenting advice & baby care tips apps*, respectively. The apps designed for postnatal fitness and weight loss (e.g. *postnatal workouts* app) yielded the lowest score in this category of characteristics (12%). Furthermore, only 6 out of 48 apps (e.g. *guide to newborn care* app) provide practical tips on the basic everyday care of the newborn such as bathing, feeding and soothing. Only 27% of apps addressed maternal mental health. Apps like *WebMD Baby* and *Post pregnancy recovery* help in acquiring knowledge about symptoms, signs and remedies of postpartum depression and associated anxieties. Besides, *Moment Health* was found to be the unique app to offer a clinically-approved screening tool for postnatal depression. By combining symptoms' checking and tracking of emotional changes, this app is said to likely allow a rapid mental recovery. Ultimately, 15 apps provide users with important information on immunizations recommended to newborn infants. Breastfeeding Tracker *Baby Log* app offers the possibility to display the immunizations' list according to the recommendations of 19 countries including United States, France and Brazil.

**Postnatal Counselling.** This block of data refers to the features designed to cater support on nutrition, hygiene and family planning. Twenty-seven apps did not include counselling features, while only three apps were found to be extensively supportive, yielding a score of 83% on postnatal counselling characteristics. It was observed that support for family planning and birth spacing was the least addressed among the apps analyzed. Accordingly, *Ovia Parenting: Baby Tracker, Breastfeeding Timer* was the unique app to tackle this topic through placing emphasis on the postnatal contraception and listing the major safe and efficient birth control options to choose during the postnatal period, namely, Lactational Amenorrhea



method, implant and Intrauterine Device. This lack of interest with respect to the postnatal contraception is perhaps owing to the existence of fully-fledged family planning apps. What is more, family planning is often closely associated to ethnic and cultural beliefs which hinder the usefulness of the counselling. Further, 38% of the apps analyzed recommend and encourage breastfeeding by highlighting its multiple short and long-term benefits in improving mother's health as well as health of the infant. Breastfeeding was therefore considered as the most recurrently approached topic in postnatal counselling.

**Reminders and push notifications.** Principally considered as a promising strategy for enhancing users' engagement, push notifications prompts with contextually tailored messages have proven to be extensively effective in sustaining repeat use of health-related apps [255]. Reminders is one of the most encountered form of notifications. Only one app (*Baby care plus*) implements all the characteristics comprised in this block. Moreover, merely 10% of the apps analyzed allow to schedule reminders for routine and basic needs of the newborn such as feeding (e.g. *WebMD Baby*), sleeping and tummy time (e.g. *ParentLove: Baby Tracker Feedings Diapers Pumping*). In addition to reduce forgetfulness, reminders have a considerable impact on maintaining medical adherence [256]. Therein, five apps include reminders for scheduled medications (e.g. *Baby loggy-newborn log*) and vaccines (e.g. *Baby care plus*). Moreover, it was noted that 38% of apps analyzed give greater control on in-app notifications and reminders. Most of these apps allow to enable or disable notifications by means of a toggle button while barely a few apps offer the possibility to customize the frequency between notifications as in *Baby manager* and *You+Baby* apps. With the possibility to change notification settings, users are able to prioritize their tasks according to their preferences and to cut down on useless notifications.

**Notes and records.** Thirty apps provide the users with recording features. With the exception of the N25 characteristic that stands for the ability to create a sleep diary, *Baby+* was the only app to fully implement postnatal records. Tracking vital parameters of newborn growth was present in 22 apps while only five apps (e.g. *After birth exercise*) offer the possibility to record the postnatal weight of the mother. Among the 22 apps, users are able to add growth details for weight, height and head circumference and visualize these measures plotted on a graph as in *Glow Baby New-born Tracker App*. Moreover, eight apps allow to track and check the developmental milestones of the newborn infants according to a range of age like 2 months, 4 months and so forth. Each development milestone is shown with reference photo or a video of kid with the reference age (e.g. *Growth chart*), or descriptive information (e.g. *Ovia Parenting: Baby Tracker, Breastfeeding Timer*). The feature of recording basic newborn needs such as feeding including breastfeeding and bottle feeding, diaper changes and sleep patterns was offered in 38% of the apps analyzed (e.g. *Baby tracker- feeding, sleep and diaper*). What is more, these apps allow users to log pumping and play time activities. The medical

history of the newborn infant was another recurrently encountered feature. For instance, *UW Baby* app allow users to log vaccinations already given to the newborn and monitor those still needed. Also, it is possible to log temperature and to take note of administered medications by entering the name of the medication, the dosage and date of the first dose, as in *Baby nursing* app. In contrast, none of the apps selected include a sleep diary for the mother. Consequently, these findings highlight the limitation of recording features to the newborn care management in the PNC apps.

**Social support.** In the light of the overwhelming changes mothers go through after giving birth, social support is perceived as a powerful mechanism in buffering the effects of postnatal anxieties [243]. Nonetheless, only 21 apps include at least one aspect of social support. Among these apps, fifteen apps are integrated with social networks such as Facebook and Twitter through social login as in *parentlove: baby feeding tracker, diapers, pumping* app. Other apps (e.g. *Baby+* and *Sprout Baby*) provide link to their proper pages on social networks, namely Facebook, Twitter and Instagram. Social sharing is also possible in *FitMama Lite 5 Min* app where users can share fitness achievements on Facebook. Included in nine apps, the FAQ section is generally accessible through app settings (e.g. *MyMedela*). Moreover, eight apps allow users to interact with others through in-app community as in *Moment Health* app, or integrated social media community as in *Postnatal pilates* app, while real-time chat is provided by a single app called *Fit Mommy Project challenge*. Another feature that was perceived to likely enhance social support is friends or family members' referral. *Ovia Parenting: Baby Tracker, Breastfeeding Timer* and *Baby tracker-Newborn Feeding, Diaper, Sleep log* apps allow users to invite their family members to access app content in order to gain further social, emotional and organizational assistance and help.

**App technical features.** In light of the massive attention drawn to mHealth industry, privacy and security issues still pose significant challenges for developers and researchers. Among the apps analyzed, only 14 apps offer an authentication mechanism. In addition to the standard authentication using email and password, *WebMD Baby* implements a pin login which allows users to access their data only by typing a 4-digit authentication pin. In contrast, privacy policy is included in a total of 30 apps. With the ongoing proliferation of mHealth apps, privacy policies become increasingly important [246]. This feature was particularly found in apps dealing with private and sensitive data of the mother and/or the newborn.

Table 3.13 summarizes all important information about the privacy policies available for the PNC apps assessed. While most of the privacy policies discovered (n=13) apply to multiple apps or all services offered by the developer, a total of 11 privacy policies is limited to the single app in question, such as *Baby care plus* and *Lactapp+*. Moreover, six privacy policies assessed were found to be inherently associated with the hospital's website to which certain apps are affiliated (e.g. *Baby & me* and *Telfair Baby*). It was observed that eight privacy

policies assessed comply with international and federal laws including "European Union's General Data Protection Regulation (GDPR) 2018" (e.g. Glow Baby Newborn Tracker App) and The Health Insurance Portability and Accountability Act of 1996 (HIPAA) (e.g. *Your baby's birth and beyond*). Accordingly, the extant guidance and regulation as regards privacy policies are scarce and only apply to a narrow scope. Endeavors are therefore required to harmonize data protection legislation and broaden the scope of the current policies [246].

Table 3.13 presents an overview of the content categories addressed by the privacy policies discovered. It was observed that 93% of the privacy policies assessed inform users about the information collected while only 60% disclose the ways information collected is being gathered, used and shared. A total of 22 privacy policies describe the security measures that are likely to protect and ensure the safety of the information collected as shown in table 3.13. In addition, 53% of the privacy policies assessed include a section that covers cookies and precisely half of the privacy policies focused on privacy of the child which one (*Breastfeeding Tracker Baby Log* app) complied with the US Children's Online Privacy Protection Act (COPPA). Correspondently, these privacy policies assume that individuals under the age 13 are not allowed to gain access to the app in question without a prior consent of a parent or a guardian (e.g. *Glow Baby Newborn Tracker* App).

Almost 27% of the privacy policies assessed offer information with regard to the control of personal information. Means for notifying users on changes to privacy policies or privacy practices are mentioned in 70% of the privacy policies assessed. In view of the importance of privacy policies in mHealth solutions, there remains a significant lack of standardization, transparency and harmonization of their contents. Furthermore, the security of data was addressed in only 4 apps which allow users to back-up and restore the app's content into a local storage (e.g. *Baby care plus*) or into a cloud platform (e.g. *Baby tracker-feeding, sleep and diaper*). Even though cloud platforms offer enormous advantages such as cost-effectiveness, speed, elasticity of resources and dynamic scaling [257], they inherently raise a host of concerns about security threats. Cloud storage, in particular, faces major challenges when it comes to data protection and security of which data segregation and data leakage are of great impact. Besides traditional attacks ranging from data breaches, data loss, account hijacking and Distributed denial-of-service attacks, the multi-tenancy nature of the cloud platforms create new attack surfaces for malicious actors. In view of these various security issues, IT leaders and security professionals are waging a constant battle to ensure proper data security. Along with the privacy policy statement, four apps (e.g. *Ovia Parenting: Baby Tracker, Breastfeeding Timer*) include a disclaimer of liability which attests that the content of the app in question is provided for educational and informational purposes only and should not be used for diagnosing or treating a health problem or disease.

While security measures help gain users' trust and confidence, the internationalization practices are considered a key element that make users feel prioritized and substantially considered. In this direction, only 8 apps were found to support multiple languages such as

Table 3.13: Review of postnatal care apps: Assessment of the privacy policies available in 30 postnatal care apps.

| Privacy policy content            |  | Total of privacy policies N (%) |
|-----------------------------------|--|---------------------------------|
| Categories                        | Sub-categories                           |                                 |
| Collection and disclosure of data | Type of information collected            | 28 (93%)                        |
|                                   | Rationale for collection                 | 16 (53%)                        |
|                                   | Use and sharing of information collected | 18 (60%)                        |
|                                   | Third party services                     | 16 (53%)                        |
|                                   | Data transfer                            | 5 (17%)                         |
| Security and privacy              | Security practices                       | 22 (73%)                        |
|                                   | Retention                                | 6 (20%)                         |
|                                   | Children's privacy                       | 15 (50%)                        |
|                                   | Use of cookies                           | 16 (53%)                        |
| Users' controls                   | Rights of users                          | 9 (30%)                         |
|                                   | Controlling personal data                | 8 (27%)                         |
| Changes to the privacy policy     |  | 21 (70%)                        |

French, German, Spanish (e.g. *MyMedela*) and Hindi (e.g. *Pregnancy, parenting advice & baby tips*). Another aspect of internationalization that is provided by 15 apps (e.g. *Baby Tracker - Newborn log*) consists of the possibility to change preferences with regard to the units of measurements related to the growth parameters of the newborn, feeding and temperature units. With respect to usability, four main features were considered (assessment questions A34-37) to evaluate the writing style, layout and learnability of the apps selected. These features were mainly extracted from previous empirical studies that apply iOS and Android usability guidelines to digital health applications. On the whole, only 12 apps complied with all these usability features. Although, 83% of the apps contained simple and friendly writing style. Keeping the terminology and writing style consistent will help users follow and comprehend the app easily and effectively [183]. Moreover, users feel more engaged with the app when this latter employs a conversational tone. This was approached through the use of contractions (e.g. *Ovia Parenting: Baby Tracker, Breastfeeding Timer app*), the second person (e.g. *Glow baby newborn tracker app*) and the baby's real name as in *Sprout baby app*. Familiar writing is proven to echo a friendly tone [249] and mimic a natural conversation, which by then contribute in seamlessly engaging users.

Ensuring that an app's content displays in the orientation (portrait or landscape) preferred by the user is fundamental to gain user's accessibility and satisfaction. Considering their mounted devices, users with dexterity impairments are likely to depreciate apps that restrict the screen to a particular display orientation.

Besides, supporting both screen orientations will allow users with low-vision to view content in the orientation that works best for them as to make the text easily readable. In this regard, only a total of 26 apps handled screen orientation (e.g. *Baby care plus, Essentia baby*). Another feature that affects usability consists of recalling users' preferences over time so that they do not input information each time they gain access to the app's content. A total of 20 apps do not include this feature either because they are purely informative, thus

do not implement any kind of settings as in *Skin care after pregnancy* app or require users to re-enter their preferences, for example, as regards measurement units (e.g. *Baby Tracker -Newborn log* app). Lastly, discoverable and accessible navigation patterns were encountered in 37 apps. Users value the layout of an app that is efficient, intuitive, and allows for easy content navigation. Accordingly, hamburger menus (e.g. *Lactapp+*) and tab bars (e.g. *Breastfeeding tracker baby log*) were the mostly present navigation patterns in the apps analyzed.

**Extra features.** In conjunction with the characteristics analyzed, auxiliary features were encountered in different apps. It was noted that most of the apps dealing with newborn care support multiple children and multiple caregivers. In fact, these apps (e.g. *BabyTime*) allow users to synchronize with family members or relatives in regard to the care given to the newborn infant. Another extra feature that was included in the apps selected consists of the ability to upload photos illustrating the development and the special moments of the newborn infant (e.g. *Baby+*). Further, the possibility to export app data (e.g. records) into a CSV, PDF or HTML formats was granted in 10 apps (e.g. *Breastfeeding Tracker Baby Log*).

#### 4. Are user ratings proportionally linked to the apps' characteristics?

The answer to this question will help determine whether there is a relationship between the users' ratings for the apps selected and their corresponding assessment scores. One of the most interesting aspects of the mobile marketplaces (e.g. Google Play Store and Apple App store) is the emphasis on user feedback. In fact, these platforms allow the users to review-comment and rate the published apps between one to five stars according to the level of satisfaction about the app and its features [258]. This process helps developers in obtaining an insight into the users' opinions about their app(s). A recent paper [259] found that star-ratings are a crucial factor in the overall ranking of an app and can drastically affect user downloads. Table 3.14 presents the ratings achieved by each of the apps selected along with the total number of raters as displayed in the app store at the time of the data extraction. As portrayed in Table 3.14, all apps that provided star-ratings were considered, including those available for both platforms. An independent-samples t-test was used to check the existing variances in the user ratings and the total number of raters for the PNC apps between the Android and iOS platforms. The t-test did not yield a statistically significant difference between the two platforms neither for the users' ratings  $t(45)=-1.581, p=.06 > .05$ , nor for the number of raters  $t(45) = -1.207, p = .055 > .05$ . Thus, it is likely assumed that the ratings of the apps being studied are similarly distributed to a normal distribution. In an attempt to examine the compliance between the app functional content and user satisfaction, we conducted a Pearson product-moment correlation coefficient. As shown in Table 3.15, the coefficient ( $r=-.072$ ) denotes that the linear association between the two variables studied is very weak. Nevertheless, there is insufficient evidence to assume that this correlation exists given the statistically non-significant p-value ( $p=.629$ ). The scatter plot in Figure 3.11 illustrates the distribution of the PNC apps analyzed around the line of best fit. It can be

observed that two apps (*NKCH moments* and *MH Motherhood*) yielded a great assessment score but obtained a low user-rating (1 star). Furthermore, some apps (e.g. *Skin care after pregnancy* and *Maternal and newborn care plans apps*) with five star-ratings only attained a score of 9%. This inconsistency between user feedback and the characteristics of the apps is perhaps due to the relatively low number of raters in such apps given their contingent

Table 3.14: Review of postnatal care apps: Users' ratings of the apps selected.

| ID  | Application name   | OS      | Ratings (Number of stars) | Total of raters |
|-----|--|---------|---------------------------|-----------------|
| A1  | Ovia Parenting: Baby Tracker, Breastfeeding Timer  | Android | 4.7                       | 7188            |
| A2  |  | iOS     | 4.7                       | 1109            |
| A3  | WellMama free post pregnancy yoga poses  | Android | 3.9                       | 5               |
|     |  | iOS     | -                         | -               |
| A4  | FitMama Lite 5Min  | Android | 4                         | 31              |
|     |  | iOS     | -                         | -               |
| A5  | Glow Baby Newborn Tracker App  | Android | 4.7                       | 6790            |
| A6  |  | iOS     | 5                         | 3975            |
| A7  | Baby tracker - Newborn Feeding, Diaper, Sleep log  | Android | 4.6                       | 15925           |
| A8  |  | iOS     | 4.5                       | 41773           |
| A9  | Baby manager   | Android | 4.8                       | 13680           |
| A10 |  | iOS     | 2.8                       | 29              |
| A11 | Baby+  | Android | 4.5                       | 8056            |
| A12 |  | iOS     | 5                         | 2979            |
| A13 | Fit Mommy Project Challenge  | Android | 4.9                       | 11              |
|     |  | iOS     | -                         | -               |
| A14 | Postnatal workouts   | Android | 3                         | 3               |
|     |  | iOS     | -                         | -               |
| A15 | BabyTime   | Android | 4.7                       | 11769           |
| A16 |  | iOS     | 4.7                       | 75              |
| A17 | WebMD Baby   | Android | 4.1                       | 5497            |
| A18 |  | iOS     | 4.3                       | 384             |
| A19 | Breastfeeding Tracker Baby Log   | iOS     | 4                         | 658             |
| A20 |  | Android | 4.1                       | 507             |
| A21 | Moment Health  | iOS     | -                         | -               |
|     |  | Android | 4.1                       | 9               |
| A22 | Baby tracker - feeding, sleep and diaper   | iOS     | -                         | -               |
|     |  | Android | 4.9                       | 22444           |
| A23 | MH motherhood  | iOS     | -                         | -               |
|     |  | Android | 1                         | 1               |
| A24 | Baby loggy -newborn log<br>30 day fit mommy Challenge<br>Oh baby! Mom and baby exercise<br>Caring for a newborn baby | iOS     | 4.5                       | 158             |
|     |  | iOS     | -                         | -               |
|     |  | iOS     | -                         | -               |
|     |  | iOS     | -                         | -               |
| A25 | MyMedela   | iOS     | 4.5                       | 844             |
|     |  | iOS     | -                         | -               |
|     |  | iOS     | -                         | -               |
| A26 | Sprout Baby  | iOS     | 5                         | 11943           |
| A27 | Guide to newborn care  | Android | 4.7                       | 31              |
| A28 | After birth exercise   | Android | 4.5                       | 109             |
| A29 | Pregnancy, parenting advice & baby care tips app   | Android | 4.1                       | 2795            |
| A30 | Bleeding after birth   | Android | 2.1                       | 3               |
| A31 | Burn fat after pregnancy - weight loss<br>Losing weight after pregnancy  | Android | 3                         | 2               |
|     |  | Android | -                         | -               |
|     | Telfair baby   | Android | -                         | -               |
| A32 | Post pregnancy recovery  | Android | 5                         | 5               |
| A33 | Growth Chart, Development Milestones & Vaccination   | Android | 4.9                       | 189             |
| A34 | LactApp+   | Android | 1                         | 1               |
| A35 | NKCH moments   | Android | 1                         | 1               |
| A36 | Parentlove: baby feeding tracker, diapers, pumping   | Android | 4.7                       | 277             |
| A37 | Maternal & newborn care plans  | Android | 5                         | 2               |
| A38 | Essentia baby  | Android | 4                         | 7               |
| A39 | Your baby's birth & beyond   | Android | 2.5                       | 9               |
| A40 | Baby care plus<br>The postpartum cure  | Android | 4.3                       | 644             |
|     |  | Android | -                         | -               |
| A41 | UWBaby   | Android | 3.5                       | 9               |
| A42 | Skin care after pregnancy  | Android | 5                         | 6               |
| A43 | Elebaby simple   | Android | 4                         | 16              |
|     | Baby Tracker - Newborn Log   | Android | -                         | -               |
| A44 | Mother and baby 2019   | Android | 4.3                       | 19              |
| A45 | C-section recovery   | Android | 4                         | 2               |
| A46 | You+Baby   | Android | 3                         | 1               |
| A47 | Baby & me  | Android | 3.1                       | 10              |

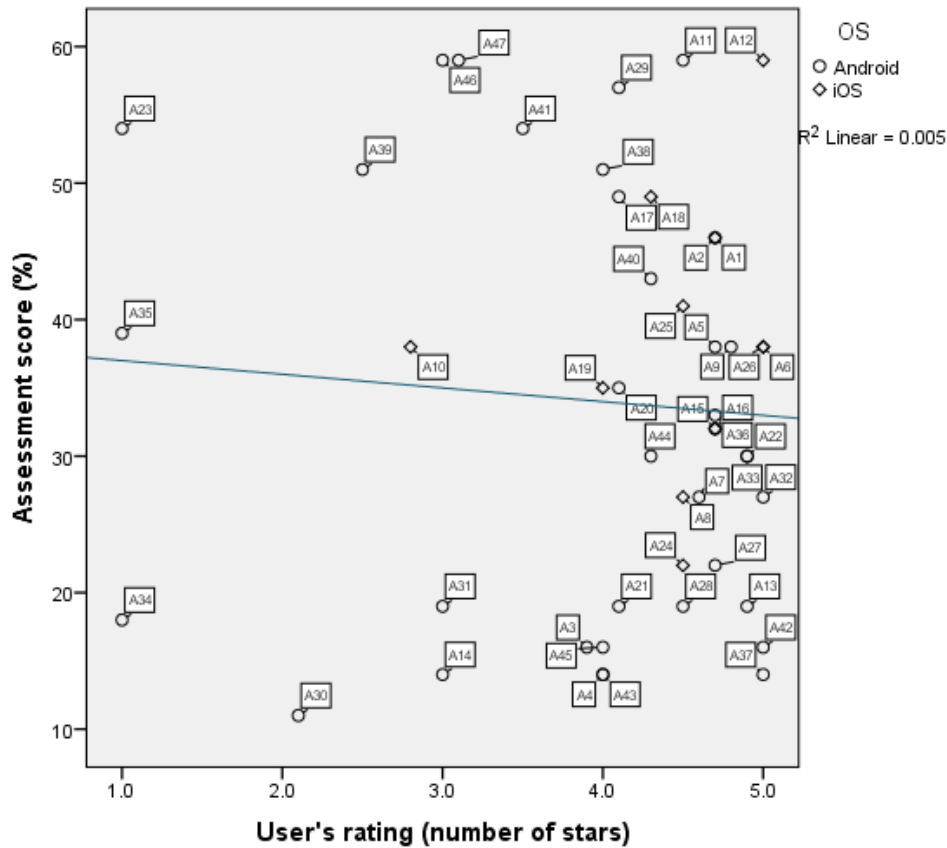


Figure 3.11: Review of postnatal care apps: Scatter plot for the apps' scores and ratings.

unpopularity. Device-specific problems determine another plausible factor that creates the discrepancy between the quality and users' reviews of apps, especially for Android platform. It was noted that device-specific problems could impact the ratings assigned to an app, given the varying capabilities of devices (e.g., hardware and software) [260]. Users are likely to complain about the incompatibility of a given app with their device or OS version which negatively influence their feedback as regards the overall quality of the app despite its actual functional richness and responsiveness.

Table 3.15: Review of postnatal care apps: Person correlation results.

|                      |                     | User's rating | Assessment score (%) |
|----------------------|---------------------|---------------|----------------------|
| Users' rating        | Pearson Correlation | 1             | -.072                |
|                      | Sig. (2-tailed)     |               | .629                 |
|                      | N                   | 47            | 47                   |
| Assessment score (%) | Pearson Correlation | -.072         | 1                    |
|                      | Sig. (2-tailed)     | .629          |                      |
|                      | N                   | 47            | 47                   |

### 3.4.3 Threats to validity

Although the present study was conducted with the aim to yield the most possible accurate and objective findings, there may have been some threats to the validity of the process. Given the limited filtering features in both app stores and the redundancy of the apps resulting from each search round, there were likely some relevant PNC apps that were unknowingly discarded. Moreover, the search string used to gather the PNC apps may have overlooked pertinent terms leading to an uncomplete set of apps. To alleviate this threat to construct validity, the PICO criteria were used to enrich the search string to the utmost extent. During the elicitation phase of the assessment questions, some important characteristics may have been omitted, therefore threatening the internal and conclusion validity. However, this bias was substantially reduced through performing a thorough review in scientific literature and app repositories to select the most significant characteristics in relation to the postnatal period. Moreover, both the development of the assessment questionnaire and the evaluation of the apps selected were performed independently by the first two authors and reviewed by the remaining authors. Another threat to conclusion validity concerned the accuracy of the results obtained. To mitigate this issue, the findings were presented textually and graphically. Lastly, the external validity may have been biased by the unavailability of users' ratings for certain apps. This was solved by only considering the apps that provided users' ratings.

## 3.5 Conclusion

This chapter has studied the functionalities and gamification aspects of ten gamified BD apps selected from a total of 801 apps available in four mobile app repositories. The results of this study showed that the majority of the apps were present in Android and iOS related app stores. Among the investigated functionalities, notifications, geolocation and social networking were the most commonly integrated in the analyzed BD apps. Despite its significance in user audience expansion, the support for multiple languages was provided in only one app. The results also showed that gamification was applied in different ways combining points with badges or badges with leaderboards, or even opting for financial rewards (e.g. coupons, gift cards) to enhance the retention rate of blood donors. Moreover, a software QA was performed using the ISO/IEC 25010 quality model to calculate the degree of influence of the most prevalent requirements in gamified BD apps on 30 quality characteristics. According to the outcomes of this research, some quality characteristics, through certain sub-characteristics, were more impacted by BD apps requirements than others, namely, Functional Suitability, Operability, Reliability, Performance Efficiency and Security.

Further, this chapter has evaluated the relevance of the functionalities and features offered by the PNC apps available in Google play store and Apple app store. A total of 48 apps was, therefore analyzed based on a set of 37 assessment questions covering postnatal-related characteristics together with security, usability and internationalization aspects. The find-



ings of this review revealed that in large part, PNC apps mostly focused on monitoring the newborn infant development and activities or providing valuable information and guidance with respect to newborn and postpartum care. It was also noted that the compliance of these apps with the assessment items was relatively very low in that the highest score (59%) was only yielded by three apps. This clearly points out the incompleteness of these apps in terms of features and functionalities, particularly as regards mothers' needs during the postnatal period. In this regard, this research can provide a baseline for developing qualified and effective apps that are suited to the needs of new mothers to effectively take care of themselves and their newborns. App developers, on the other hand, are required to utilize proper measures and safeguards to minimize the usability flaws and security issues in the PNC apps.

As future work, it is intended to comprehensively measure the compliance of the BD and PNC apps with usability guidelines and quality characteristics using eminent quality assessment tools (e.g. Mobile App Rating Scale MARS) and international standards. Being particularly important in facilitating user experience and promoting efficiency, effectiveness and user satisfaction, usability is still widely recognized as a key quality factor in the development of successful interactive software applications. In this regard, assessing the fulfillment of usability attributes in these apps can be particularly helpful for researchers and developers to improve the design and ergonomics of PNC apps which thereby enhances their overall quality.

# Gamification applied to blood donation and postnatal care

## 4.1 Introduction

In the last decades, an increasing emphasis has been placed on gamification in mHealth settings. Accordingly, many apps are utilizing gamification techniques to drive positive health behaviour change. Notwithstanding this increasing interest, mHealth app developers should ground their solutions on well-founded strategies that effectively cater to the users' needs in terms of improved health care, appealing and more engaging user experience. This chapter is organized as follows: Section 4.2 reports the results of a survey conducted among Spanish individuals to understand blood donors' behaviour change using TTM. Section 4.3 describes the design of a user-dependent mobile solution to promote BD through gamification and TTM principles. Section 4.4 presents the requirements specification, design and implementation of a mobile solution intended to improve access to practical guidance and valuable information related to PNC. A potential design of integrating gamification techniques in this solution is also proposed in this section. Section 4.5 presents the conclusions of this chapter.

## 4.2 Understanding blood donor's behaviour change using TTM: A survey

In recent decades, researchers have identified a range of sociodemographic, organizational, psychological and physiological factors that impact the individual's willingness to donate blood [261–263]. Although BD is considered as a purely prosocial behaviour, altruism and empathy were portrayed among the less significant motivations driving the BD decision [7]. Moreover, many studies have emphasized that social influence, personal norms, awareness of the need of blood and perceived psychological and health benefits, each play a

prominent role in motivating individuals to donate blood [92,264]. Yet, there is a disparity among the motivators that stand out across the four donors' profiles (first-time donor, repeat, lapsed and eligible non-donor) [265]. It stands to reason that understanding the factors that influence donors to donate blood can be of particular benefit to blood collection agencies [264]. Different theories and models of behaviour change have been applied to health contexts to assist in the design of behaviour change interventions. In this respect, six main theoretical perspectives to boost adherence to health behaviours have been identified (biomedical, behavioural, communication, cognitive, self-regulatory and stage perspectives) encompassing, each of them, different theories [74]. The most recurrently used theories are those within cognitive and stage perspectives. The cognitive perspective includes theories that consider attitudes and beliefs as the locus of the individual's behaviour. Of those theories, TPB is the most widely cited and applied theory in predicting BD behaviour and intentions [75]. On the other hand, stage-based theories contend that individuals go through distinct stages as they learn and develop. TTM is the most prominent and widely applied among stage models [76].

Specifically, this study aims at applying TTM to BD behaviour among a Spanish population. To this end, five research questions (RQ) were investigated:

- RQ1.** How are the recruited participants distributed over the five stages of change?
- RQ2.** How do the Processes of Change vary across stages of change?
- RQ3.** How do and Decisional balance (Cons/Pros) differ across stages of change?
- RQ4.** How does Self-efficacy vary/differ across stages of change?
- RQ5.** How is the correlation between the Processes of changes and Decisional balance, and Processes of changes and Self-efficacy?

#### **4.2.1 Materials and method**

##### **Study design and participants**

This study is cross-sectional in design and consisted of the dissemination of a paper-based survey among a population to gather their data with regards BD behaviour. All the procedures employed in this study were approved by the Ethics Committee of the University of Murcia. The recruitment phase led to the recruitment of 602 participants from the University of Murcia and Reina Sofia Hospital in Murcia. A total of 158 first and second-year students from the Faculty of Nursing were approached during lectures and were asked to fill in a survey designed to develop and validate processes of change, self-efficacy and decisional balance measures. The remainder of the sample (N=444) was recruited at Reina Sofia Hospital where hospital staff, patients and their companions were handed the same questionnaire to fill in after giving their written informed consent to take part in this study.

The questionnaires were completed under the supervision of the researcher who resolved any doubts. All participants were assured of anonymity and confidentiality.

**Data collection instruments and procedures**

The study was quantitative, with data gathered through self-administered questionnaires. These questionnaires were designed such that they help to measure the four constructs of the TTM. A review of the literature in TTM and BD was conducted and integrated into the development of the questionnaire’s items to derive salient beliefs about BD [74,262,263,266]. An adaptation to measures developed for BD and other content areas in previous studies [84,86,93,267,268] was conducted to refine the questionnaire’s items. The resulting questionnaire as presented in Appendix B was translated into Spanish and consisted of five categories:

a) Demographic characteristics

Various socio-demographic characteristics were assessed including age, gender, marital status and education level. Participants were also asked about their blood type.

b) Stages of Change

Participants were asked to answer a short series of questions (Q1-Q4) regarding their past BD behaviour and their future intention to donate. Accordingly, a staging algorithm was developed and followed to place the participants in one of the exclusive five clusters for stage of change as shown in Figure 4.1.

c) Processes of Change

A total of thirty items representing the ten Processes of Change (three items per process of change) were randomly comprised into the questionnaire. Participants were given a

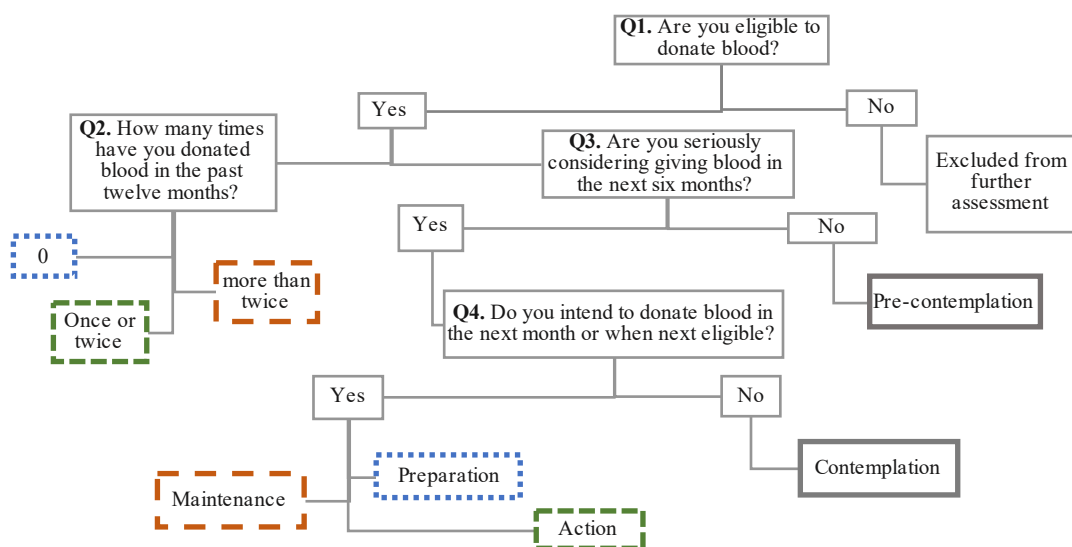


Figure 4.1: Algorithm of TTM Stages of Change for blood donation.

five-point scale ranging from “Never” to “Repeatedly” to rate the frequency in which they make use of a situation, thought and feeling to enhance their readiness to donate blood. Table 4.1 presents the description and the three proposed items for each process of change.

d) Self-efficacy

Self-efficacy is a measure of the extent to which an individual is confident in their

Table 4.1: Description of the processes of change and their corresponding items.

|                          | Processes of Change        | Items  |   |
|--------------------------|----------------------------|--|---|
| Experiential Processes   | Consciousness Raising      | I recall articles, posts and/or TV messages about donating blood.<br>I look for information related to blood donation process.<br>I seek out groups of people who can raise my awareness about how to become a blood donor.  |   |
|                          | Dramatic Relief            | Portrayals of people whose lives are saved by blood donation affect me emotionally.<br>I am moved by a person who helped save lives by donating blood.<br>I get upset when I hear stories about people whose lives depend on regular blood transfusions.             |   |
|                          | Environmental Reevaluation | I am considering the idea that I could save lives by donating blood.<br>I stop to think about how donating blood would be beneficial for people in my community.<br>I realize that people who donate blood are a great source of inspiration to others.              |   |
|                          | Self-Reevaluation          | I think that being a blood donor supports my view of myself as a caring and responsible person.<br>I feel very competent and proud when I (decide to) donate. blood.<br>Being a non-donor makes me feel disappointed and helpless.                                   |   |
|                          | Social Liberation          | I am aware that society is actively encouraging and supporting people to become blood donors.<br>I notice that there are more opportunities to donate blood in my community.<br>I see more companies and organizations hosting and sponsoring blood drives.          |   |
|                          | Behavioural Processes      | Self-Liberation  | I make commitments to myself to donate blood.<br>I recognize I have the energy needed to be a blood donor.<br>I tell myself that I can be a blood donor despite the fact that my relatives and friends don't support my decision. |
| Reinforcement Management |                            | I can expect to be praised and appreciated by others for donating blood.<br>I feel respected in society for being a blood donor.<br>I reward myself with a treat after donating blood.   |   |
| Helping Relationships    |                            | I share with someone my thoughts and feelings about blood donation.<br>There are special people around me that encourage me and improve my willpower to continue donating blood.<br>I have a friend on whom I can count to come with me when I want to donate blood. |   |
| Counter Conditioning     |                            | I keep in mind that blood donation is a simple and safe process to overcome the fear of donating.<br>When I am hesitant to donate blood, I remind myself that it helps save lives.   |   |
| Stimulus Control         |                            |  | Whenever I feel tempted to reassess being a blood donor, I begin to think about all the health benefits it offers.<br>I make sure I know when and where nearby blood drives are held.   |
|                          |                            |  | I schedule my blood appointments.<br>I keep around any source of information associated with blood donation to reconsider my reasons for donating blood.  |

ability to donate blood in the face of prospective hard situations (e.g. When I am feeling a physical discomfort). Eight items were designed to develop the self-efficacy scale. Responses were made on five-point scale, ranging from 1=" Not at all confident" to 5=" Extremely confident". Table 4.2 shows the eight statements used to measure self-efficacy.

e) Decisional Balance

Twelve items were designed to assess how an individual evaluates the pros and cons of BD. Six items were employed to reflect the Pros of BD (e.g. I will be helping to prevent blood shortages) and the remaining six items were evenly distributed among Physical Cons (e.g. I am likely to faint at the sight of blood) and Eligibility Cons (e.g. I might be told I am not eligible to donate blood). Participants responded on a five-level scale ranging from 1=" Not at all important" to 5=" Extremely important" to rate the importance of each item is in their decision to donate blood. Items used to measure the pros and cons of BD are depicted in Table 4.3.

### Statistical analysis

Frequency analysis was primarily performed to explore the distribution of the recruited individuals across Stages of Change with respect to BD behaviour. Multivariate and Univariate Analysis of Variance (MANOVA and ANOVA) tests along with post-hoc analyses were conducted to identify the differences in Process of Change subscales, Decisional Balance scales and Self-Efficacy scale with the five Stages of Change. For all TTM constructs, raw scores were converted to T-scores (Mean = 50, standard deviation [SD] = 10) in order to make comparisons easier in the magnitude of differences. In addition, Pearson correlations were examined between the different TTM variables. All statistical analyses applied in this study were performed using IBM SPSS 21.0.

## 4.2.2 Results

### Sample

Of the 602 participants, 98 individuals were excluded from further assessment as they failed to answer (either by refusal or answering 'I don't know') to the question concerning their eligibility to donate blood. The remainder sample (N=504) was predominantly constituted by female (62.9%), and ages ranged from 18-80 with a mean of 27.32 (SD=11.134). The reported education level showed that 46.8% of participants completed high school degree and 36.7% are currently enrolled or completed undergraduate degree program. Regarding blood types, A+ and O+ were the prevailing blood types among participants, accounting for 27.98% and 29.36% respectively. Table 4.4 depicts the frequency distribution of the recruited sample in relation to the demographic characteristics.

Table 4.2: Items developed for measuring self-efficacy.

| Self-efficacy items   |
|---|
| 1) When I am very anxious and stressed.   |
| 2) When I am feeling a physical discomfort.   |
| 3) When I witness a bad blood donation experience (e.g. Someone fainting).                            |
| 4) When I realize I have not donated for a long while.  |
| 5) During or after experiencing personal problems (e.g. family, financial).                           |
| 6) When I have other time commitments.  |
| 7) When I remember having a negative reaction to donating that caused me light-headedness and nausea. |
| 8) After recovering from an illness or an injury  |

### Stages of change

All 504 participants were placed into four exclusive categories based on their responses to the aforementioned algorithmic staging questionnaire. The distribution by stage of change for the entire sample was as follows: Pre-contemplation 36.9% (N=186), Contemplation 41.7% (N=210), Preparation 9.3% (N=47), Action 10.3% (N=52) and Maintenance 1.8% (N=9).

### Processes of Change by Stage of Change

A one-way Multivariate Analysis of Variance (MANOVA) was conducted to test the hypothesis that there would be one or more mean differences between the ten Processes of Change and the five Stages of Change. A statistically significant MANOVA effect was obtained, Wilk's  $\Lambda = .697$ ,  $F(40,1814) = 4.54$ ,  $p < .001$ , partial  $\eta^2 = .086$ . These results revealed that the ten Processes of Change subscales were not equally and similarly triggered by Stage of Change. A series of one-way Analysis Variance (ANOVA) on each of the ten dependent variables was conducted as a follow-up tests to the MANOVA. Except for the experiential process of change 'Dramatic Relief', all effects were found to be statistically significant where the largest portion of variance was derived from Helping Relationships ( $\eta^2 = .18$ ), followed by Counter Conditioning ( $\eta^2 = .17$ ). The ANOVA values obtained were as follow: Consciousness

Table 4.3: Items developed for measuring decisional balance.

| Decisional balance items |   |
|--------------------------|---|
| Pros                     | I may help save someone's life.   |
|                          | Donating blood will reduce the risk of getting serious health conditions.     |
|                          | I will get a free of cost health check-up.                                    |
|                          | Donating blood will help me burn calories                                     |
|                          | I will be helping to prevent blood shortages                                  |
|                          | I will set a good example and inspiration for people around me.               |
| Physical Cons            | I am likely to faint at the sight of blood.                                   |
|                          | Donating blood depletes the calcium levels in the body.                       |
|                          | Donating blood is an uncomfortable experience because I am afraid of needles. |
| Eligibility Cons         | The blood bank might reject my blood due to low level of my Haemoglobin.      |
|                          | I may find out I have a disease.  |
|                          | I might be told I am not eligible to donate blood.                            |

Raising  $F(4,487) = 13.4, p <.001, \eta^2=.099$ ; Dramatic Relief  $F(4,487) = 2.27, p = .061 \text{ ns}, \eta^2=.018$ ; Environmental Reevaluation  $F(4,487) = 11.62, p<.001, \eta^2 = .09$ ; Self-Reevaluation  $F(4,487) = 10.26, p<.001, \eta^2 = .08$ ; and Social Liberation  $F(4,487) = 20.52, p <.001, \eta^2 = .05$ , Self-Liberation  $F(4,487) = 20.52, p<.01, \eta^2 = .14$ ; Reinforcement Management  $F(4,487) = 3.74, p<.05, \eta^2 = .03$ ; Helping Relationships  $F(4,487) = 25.46, p<.001, \eta^2=.18$ ; Counter Conditioning  $F(4,487) = 24.46, p<.001, \eta^2 = .17$ ; and Stimulus Control  $F(4,487) = 16.08, p<.001, \eta^2 = .12$ . Figures 4.2 and 4.3 show the experiential and behavioural Processes of Change comparison by Stage of Change, respectively.

Table 4.4: TTM Survey: Demographic characteristics of participants by stage of change.

| Characteristic         | TTM Stages        |       |               |       |             |       |        |       |             |       |       |       |
|------------------------|-------------------|-------|---------------|-------|-------------|-------|--------|-------|-------------|-------|-------|-------|
|                        | Pre-contemplation |       | Contemplation |       | Preparation |       | Action |       | Maintenance |       | Total |       |
|                        | N=186             |       | N= 210        |       | N= 47       |       | N= 52  |       | N= 9        |       | N=504 |       |
|                        | n                 | %     | n             | %     | n           | %     | n      | %     | n           | %     | N     | %     |
| <b>Gender</b>          |                   |       |               |       |             |       |        |       |             |       |       |       |
| Female                 | 101               | 54.3  | 137           | 65.24 | 35          | 74.47 | 38     | 73.08 | 6           | 66.67 | 317   | 62.9  |
| Male                   | 85                | 45.7  | 73            | 34.76 | 12          | 25.53 | 14     | 26.92 | 3           | 33.33 | 187   | 37.1  |
| <b>Age range</b>       |                   |       |               |       |             |       |        |       |             |       |       |       |
| <21                    | 43                | 23.12 | 81            | 38.57 | 22          | 46.81 | 20     | 38.46 | 5           | 55.56 | 171   | 33.92 |
| 21-30                  | 76                | 40.86 | 82            | 39.05 | 11          | 23.4  | 23     | 44.23 | 3           | 33.33 | 195   | 38.7  |
| 31-40                  | 18                | 9.68  | 20            | 9.52  | 4           | 8.51  | 4      | 7.69  | 0           | 0     | 46    | 9.12  |
| 41-50                  | 26                | 13.98 | 13            | 6.19  | 8           | 17.02 | 1      | 1.92  | 0           | 0     | 48    | 9.52  |
| 51-60                  | 15                | 8.06  | 1             | 0.48  | 0           | 0     | 1      | 1.92  | 0           | 0     | 28    | 5.56  |
| >60                    | 2                 | 1.08  | 0             | 0     | 0           | 0     | 0      | 0     | 0           | 0     | 2     | 0.4   |
| Don't know/ No answer  | 6                 | 3.23  | 5             | 2.38  | 2           | 4.25  | 1      | 1.92  | 0           | 0     | 14    | 2.77  |
| <b>Education level</b> |                   |       |               |       |             |       |        |       |             |       |       |       |
| Primary                | 8                 | 4.3   | 7             | 3.33  | 2           | 4.25  | 0      | 0     | 0           | 0     | 17    | 3.37  |
| Secondary              | 84                | 45.16 | 96            | 45.71 | 27          | 57.45 | 26     | 50    | 3           | 33.33 | 236   | 46.83 |
| Undergraduate          | 57                | 30.64 | 91            | 43.33 | 14          | 29.79 | 18     | 34.61 | 5           | 55.56 | 185   | 36.71 |
| Postgraduate           | 36                | 19.35 | 14            | 6.67  | 2           | 4.25  | 8      | 15.38 | 1           | 11.11 | 61    | 12.1  |
| Don't know/ No answer  | 1                 | 0.54  | 2             | 0.95  | 2           | 4.25  | 0      | 0     | 0           | 0     | 5     | 0.99  |
| <b>Marital Status</b>  |                   |       |               |       |             |       |        |       |             |       |       |       |
| Single                 | 129               | 69.35 | 175           | 83.33 | 36          | 76.6  | 46     | 88.46 | 7           | 77.78 | 393   | 77.98 |
| Married                | 45                | 24.19 | 31            | 14.76 | 9           | 19.15 | 5      | 9.61  | 1           | 11.11 | 91    | 18.05 |
| Divorced               | 8                 | 4.3   | 2             | 0.95  | 1           | 2.13  | 1      | 1.92  | 0           | 0     | 12    | 2.38  |
| Separated              | 3                 | 1.61  | 1             | 0.48  | 1           | 2.13  | 0      | 0     | 1           | 11.11 | 6     | 1.19  |
| Widowed                | 1                 | 0.54  | 1             | 0.48  | 0           | 0     | 0      | 0     | 0           | 0     | 2     | 0.4   |
| <b>Blood type</b>      |                   |       |               |       |             |       |        |       |             |       |       |       |
| A-                     | 8                 | 4.3   | 9             | 4.28  | 0           | 0     | 1      | 1.92  | 0           | 0     | 18    | 3.57  |
| A+                     | 45                | 24.19 | 59            | 28.09 | 12          | 25.53 | 20     | 38.46 | 5           | 55.56 | 141   | 27.98 |
| O+                     | 50                | 26.88 | 66            | 31.43 | 14          | 29.79 | 17     | 32.69 | 1           | 11.11 | 148   | 29.36 |
| O-                     | 15                | 8.06  | 29            | 13.81 | 6           | 12.76 | 5      | 9.61  | 0           | 0     | 55    | 10.91 |
| B-                     | 4                 | 2.15  | 2             | 0.95  | 0           | 0     | 1      | 1.92  | 0           | 0     | 7     | 1.38  |
| B+                     | 12                | 6.45  | 11            | 5.24  | 3           | 6.38  | 5      | 9.61  | 3           | 33.33 | 34    | 6.75  |
| AB+                    | 12                | 6.45  | 14            | 6.67  | 1           | 2.13  | 1      | 1.92  | 0           | 0     | 28    | 5.56  |
| AB-                    | 0                 | 0     | 1             | 0.48  | 1           | 2.13  | 0      | 0     | 0           | 0     | 2     | 0.4   |
| Don't know/ No answer  | 40                | 21.5  | 19            | 9.05  | 10          | 21.28 | 2      | 3.85  | 0           | 0     | 71    | 14.09 |



### Decisional Balance by Stage of Change

MANOVA revealed that individuals in different stages of change varied significantly on the Decisional Balance scales (Pros, Eligibility and Physical Cons) of BD  $F(12,1272) = 5.819$ ;  $p < .001$ ; Wilks  $\Lambda = 0.868$ , partial  $\eta^2 = .046$ . Follow-up ANOVA was conducted to compare the main effects of Decisional Balance scales across Stages of Change. All effects were found to be statistically non-significant at the .05 significance level except for Physical Cons. The main effect for Physical Cons yielded an F ratio of  $F(4,483) = 11.01$ ;  $p < .001$ , the strength of the relationship, as indexed by  $\eta^2$  was equal to .084. For Eligibility Cons, the main effect yielded an F ratio of  $F(4,483) = .808$ ;  $p = .52$  ns;  $\eta^2 = .007$  while the Pros of BD obtained an F ratio of  $F(4,483) = 1.966$ ,  $p = .099$  ns;  $\eta^2 = .016$ . A Tukey HSD post-hoc tests further indicated that mean scores for the Pros and Eligibility Cons did not differ significantly across the five stages of change. The mean scores for Physical Cons were statistically significantly different between Pre-contemplation and Contemplation ( $p < .001$ ), Pre-contemplation and Action ( $p < .001$ ) and Pre-contemplation and Maintenance ( $p < .05$ ) but not between Pre-contemplation

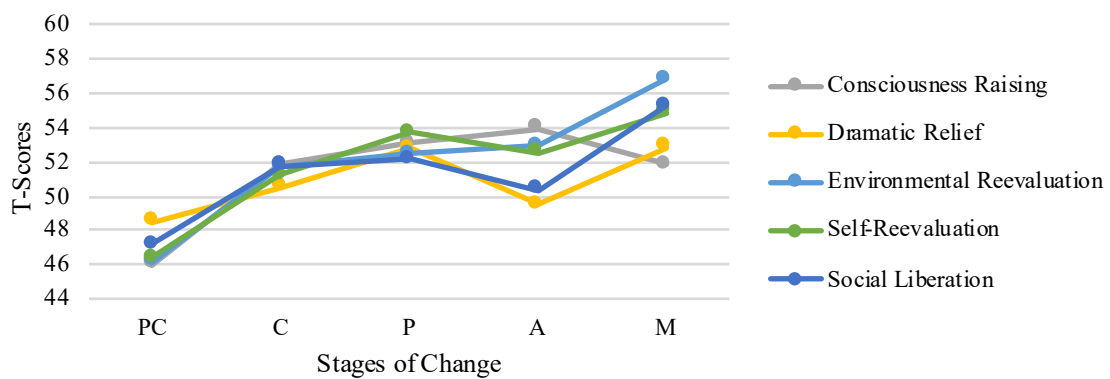


Figure 4.2: Experiential Processes of Change across Stages of Change.

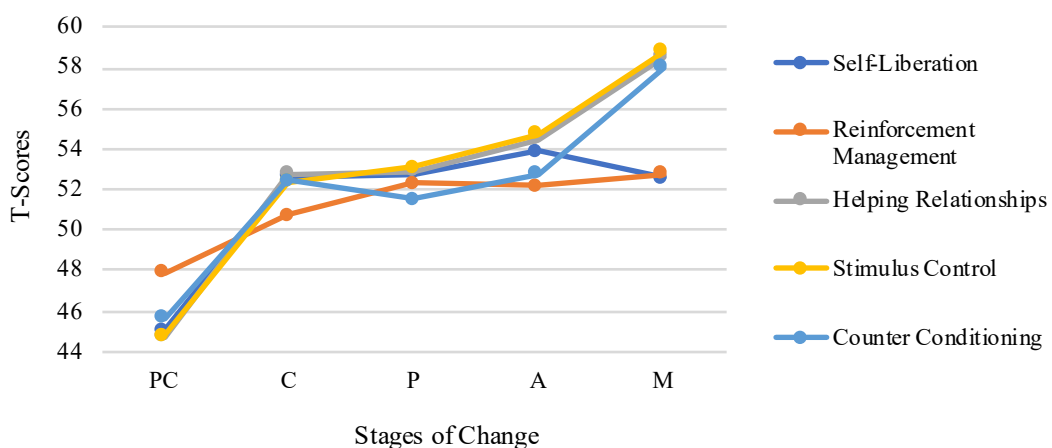


Figure 4.3: Behavioral Processes of Change across Stages of Change.

and Preparation ( $p = .069$ ). A graphical representation of T-scores on the decisional balance scales across the stages for BD is shown in Figure 4.4.

### Self-Efficacy by Stage of Change

Self-efficacy scores yielded statistically significant differences across the five Stages of Change  $F(4.489) = 38.091$   $p < .001$  with an effect size as indexed by  $\eta^2$  equal to .238. Post-hoc Tukey tests were performed to examine Self-efficacy mean comparisons across the five Stages of Change. The results revealed that Self-efficacy score were significantly higher in Action and Maintenance stages than in Pre-contemplation Stage. The variation of Self-Efficacy T-scores across stages is graphically shown in Figure 4.5.

### Processes of Change, Decisional Balance and Self-Efficacy

Table 4.5 illustrates the results of the correlation analysis to assess the relationships among the TTM constructs. Whilst all the correlation results were statistically significant, scores on both subscales of Processes of Change were not related to those on the Physical Cons. In addition, both behavioural and experiential Processes of Change for BD were positively correlated with Pros, Self-efficacy and Eligibility Cons. Physical Cons were positively related to Pros and Eligibility Cons. Overall, the strongest correlation yielded was that of Experiential Processes with Behavioural Processes ( $r = .793$ ) followed by that of Eligibility and the benefits of BD ( $r = .525$ ).

### 4.2.3 Discussion

The Stages of Change construct is one of the pillars of TTM theory. It reflects the individual's motivational readiness to make a specific behaviour change. Accurate staging is perhaps

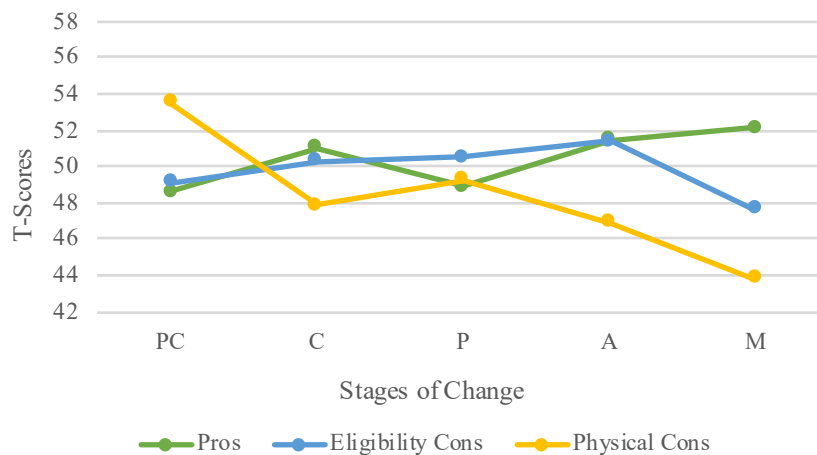


Figure 4.4: Decisional Balance scales across Stages of Change.

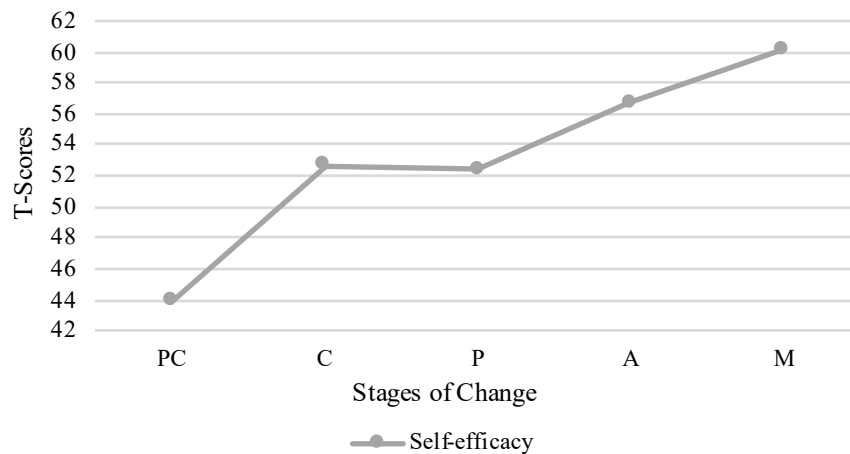


Figure 4.5: Self-Efficacy scale across Stages of Change.

the most crucial aspect of using TTM for developing health-related interventions [269]. To date, two major methods have been used for assigning stage classifications: staging algorithm and multidimensional questionnaire [270]. The staging algorithm approach uses a small number of questionnaire items to determine the participant’s stage. In the second approach, each Stage of Change is measured through a set of questionnaire items. With few exceptions (e.g. 17), a number of applications of TTM to various health behaviours employed staging algorithms [88,92,271]. The staging algorithm used in this study to classify participants into one of the five stages of change depends on the assessment of recent past behaviour and the willingness to change behaviour. In fact, in order to be allocated to one of the earlier stages (Pre-contemplation, Contemplation, Preparation), participants are required to state their intent to donate blood in the near future. Nevertheless, Action and Maintenance stages require the demonstration of both intention and regular past experience of BD. Research suggests that past behaviour is a significant predictor of future behaviour for regular and experienced donors (5 or more previous donations), and intentions were predictive of occasional donors (4 or fewer previous donations) [83,272]. For this reason, intentions outweigh past behaviour in the earlier stages of TTM. Consistent with previous research (e.g. [88,92]), participants in this study were predominantly categorized into the pre-preparation stages accounting

Table 4.5: Correlations between TTM constructs

| TTM constructs                     | EP | BP     | Pros   | EC     | PC     | SE      |
|------------------------------------|----|--------|--------|--------|--------|---------|
| <b>Experiential Processes (EP)</b> | –  | .793** | .389** | .324** | .010   | .379**  |
| <b>Behavioural Processes (BP)</b>  |    | –      | .320** | .278** | -.036  | .494**  |
| <b>Pros</b>                        |    |        | –      | .525** | .254** | .240**  |
| <b>Eligibility Cons (EC)</b>       |    |        |        | –      | .272** | .261**  |
| <b>Physical Cons (PC)</b>          |    |        |        |        | –      | -.193** |
| <b>Self-Efficacy (SE)</b>          |    |        |        |        |        | –       |

Note. \*\* . Correlation is significant at the 0.01 level (2-tailed)

for 78.6% which mirrors the deterrence of participants in donating blood and the need to trigger a range of motives to induce progression across stages of change. This shall therefore contribute in the development and promotion of stage-matched interventions that harness the relevant and modifiable stage transitions determinants.

With regards to domination of the processes of change across the five stages of change, previous studies based on TTM demonstrated that experiential processes benefit progression through the earlier stages of behaviour change while behavioural processes have greater importance during later stages. In the current study, both sets of Processes of Change were significantly lower for individuals in Pre-contemplation than those in further stages. This result supports the hypothesis of the TTM, which is that the more advanced an individual is in Stage of Change, the more frequently they will use the Processes of Change. Indeed, pre-contemplators are unmotivated and unaware of the need to change, thus harnessing fewer strategies towards behaviour change [93,273]. Moreover, individuals in Preparation stage were active on almost every process of change owing to the fact that prepared individuals are acutely motivated to experiment with changing behaviour employing therefore various methods that combine intention and behaviour criteria to improve their determination in favour of change. Aside from Consciousness raising and Self-liberation, all the processes of change peaked in the Maintenance stage. It is presumed that people in Maintenance stage do not apply Processes of Change as frequently as do people in earlier stages, yet, they need to stabilize their behaviour and work to avoid temptation and prevent relapses. In fact, most of the Processes of Change (e.g. counter conditioning, stimulus control) play a crucial role in helping individuals cope with high-risk situations that are associated to relapse. Based on ANOVA's findings, Dramatic relief has no effect on the staging progress. Excepting Reinforcement Management, all the behavioural processes obtained very large effect sizes. Additionally, individuals in Action stage reported using Self-liberation strategy more often than those in other stages. This is not surprising, as people in Action stage need to learn how to consolidate their commitments, hence seeking interventions that strengthen their belief and increase their autonomy to change [274]. In accordance with previous studies, results demonstrated that people in Action and Maintenance stages emphasize the usage of both counter-conditioning and stimulus control for coping with temptations [270,271]. Processes of Change offer theoretical valid strategies to help individuals progressively acquire new healthy behaviours. Given that specific Processes of Change are optimally effective at each stage of change, delivering tailored interventions that integrate the appropriate processes with the stages will promote behavioural change. However, failing to match processes of change to an individual's stage of change can hamper the expected usefulness of interventions [275].

Alike processes of change, decisional balance also varies significantly across stages

of change. The construct of decisional balance refers to the individual's weighing the potential benefits and costs involved with changing behaviour. While most TTM studies put emphasis on two-dimensional scale to measure decisional balance [90], some TTM applications yielded a different scale of more than two factors [276,277]. In the current study, the patterns of change in the pros and cons across the stages of change were found to be revealing. It was speculated that pros increase, and cons decrease from earlier to later Stages of Change defining a crossover pattern between Contemplation and Action stages. This result was achieved in Physical Cons and Pros and the crossover pattern occurs in the Preparation stage. However, the magnitude of change was not as large as expected. Physical cons of BD behaviour change significantly outweighed the pros in the Precontemplation stage and were lower than pros in the advanced stages. Indeed, individuals in earlier stages recall physical cons more often than those in further stages. In contrast, eligibility cons and pros did not yield a significant statistical difference across stages. Nonetheless, the pros increase slightly as individuals move toward the later stages with a small decrease in the Preparation stage. This result confirms that the progression across stages requires additional motivation by outbalancing the advantages of BD behaviour change over possible barriers. Moreover, eligibility cons did not decrease significantly across stages as did physical cons. This finding may have resulted from the possibility that regardless of their Stages of Change, blood donors may face rejection and deferral due to low haemoglobin level, high blood pressure and medication intake, to cite but a few [278]. Overall, Decisional Balance has demonstrated to be a good predictor through the stages of change.

Another major construct of TTM is Self-efficacy which refers to the perception and situational confidence that individuals have in their abilities to adopt and maintain the desired behaviour change even in difficult circumstances that often trigger relapse [81]. Research on TTM suggests that Self-efficacy increases in an almost linear fashion as the Stages of Change advances. Consistent with this, the Self-efficacy scores in the present study varied and rose significantly across stages. Contemplators had higher baseline of Self-efficacy scores than pre-contemplators and lower level than participants in advanced Stages of Change. In addition, participants in Preparation stage reported similar level of confidence to those in Contemplation stage. Perhaps individuals in preparation stage demonstrate ambivalence about their readiness to engage in the behavioural change. Moreover, participants identified in action and maintenance stages expressed the highest levels of self-efficacy with regard to BD in high-risk situations. This indicates that Self-efficacy is strongly influenced by performing the behaviour and that individuals in later stages are, by default, acting towards the behaviour change. The results obtained in this study provide evidence supportive of the applicability of the self-efficacy construct to actively change BD behaviour. This construct is genuinely considered a crucial resource to maintaining behaviour changes and preventing stage regression.

With respect to the associations among the TTM constructs, significant positive correlations were observed between the two dimensions of Processes of Change and Pros and Self-efficacy. Hence, TTM-based interventions that promote the usage of behavioural and cognitive Processes of Change should increase Pros and Self-efficacy accordingly. Eligibility concerns were positively related to all TTM constructs and particularly to the pros of donating. A possible explanation is that even though individuals have eligibility concerns to donate blood, they outbalance their perception of the benefits of donating over these concerns. Moreover, scores on both cognitive and behavioural processes were not correlated with physical concerns of BD. Consistent with this outcome, many studies have reported that physical concerns are less prominent in behaviour change [90,279]. Additionally, a significant negative correlation was found between self-efficacy and physical concerns. Therefore, it may be the case that as individuals gain confidence in their ability to donate blood, they start to attach little importance to the associated physical barriers. The highest correlation was found between the two dimensions of Processes of Change further supporting prior studies in which a tight association was perceived among processes [280].

### **Study limitations**

Despite the interest of this research, several limitations that had likely impacted the application or interpretation of the results of the present study are worth mentioning. First, due to the lack of a standardized measurement instrument for stage classification, the validity and reliability of staging algorithms have not yet been established [281]. To mitigate this constraint, the staging algorithm used in this study was elaborated on the basis of validated measures [88,268]. Moreover, the items developed to measure Processes of Change, Decisional Balance and Self-efficacy were derived from a selection of validated TTM measures in various health behaviours including BD. Despite the attempt to refine and adapt these measures to our study population, they may not have appropriately captured TTM constructs from the participants' perception. Second, the questionnaire used in this study to gather data relied on a self-report format, leading to possible response bias due to a lack of validity and reliability [282]. Nevertheless, self-report measures are largely considered as a pertinent tool in health behavioural research [283,284]. Finally, the size of the final sample was convenient, however, it comprises somewhat a restricted range of donors in advanced stages which was not representative of the rest of the blood donors' population. This may jeopardize the generalizability of the findings of this study. It is, therefore, necessary to conduct further assessment that includes greater percentages of regular donors to benefit the yielded measures.

### 4.3 Requirements specification of a gamified mobile application for blood donation

To reach self-sufficiency in blood products, efforts must focus on recruiting and retaining more regular, volunteer blood donors. BD apps are considered a promising approach for promoting donors' behavior and enhancing their motivation to donate [182,204]. Moreover, the features of mHealth apps are now strengthened by means of gamification techniques [285] that nurture users' loyalty and commitment to the foreseen health behavior change while ensuring an entertaining experience through game mechanics.

Nonetheless, there is a paucity of mobile solutions that incorporate gamification techniques in that only ten gamified BD apps were found in the four app repositories as reported in a recent review [209]. In contrast, several researchers have proposed BD solutions that implement gamification principles. For instance, Domingos et al. [205] designed an application that combines gamification techniques and social networking elements in order to make possible the interaction and information exchange between donors and blood centers. Another BD system proposed by Fotopoulos et al. [9], combines cloud-computing and mobile technology to empower blood agencies to effectively recruit and retain a healthy donors pool. This system is also expected to take advantages of gamification to bolster donors' motivation and minimize volunteer relapses. Despite the growing attention given to gamification in BD apps, many researchers reported that the positive effect of gamification is appeared to fade over time [140,286]. In fact, most of gamified systems do not adopt a user-centered approach as they fail to cater different users' needs. Thus, it is important to understand the users and grasp the determinants of their behavior change for better implementation of gamification techniques. In this section, we propose the design of a gamified mobile solution for BD that can be tailored to any donor profile through the integration of TTM constructs.

#### 4.3.1 Requirements specification and gamification principles

A Software Requirements Specification (SRS) covering functional and non-functional requirements for *Blood4Life* solution, has been elaborated according to the IEEE 29148 standard [287]. Initially, the following functional requirements were implemented:

- **User registration:** The user should be able to register using Google or Facebook credentials or by filling in the registration form including email, password, full name, phone number, age, gender and blood type.
- **Login:** A registered user should be able to log in to the app using login credentials (email and password). The login information will be stored on the phone and in the future, the user should be logged in automatically.
- **Retrieve password:** A user should be able to retrieve his/her password by email.

- **Visualize and edit profile:** A user should be able to edit his/her profile information including email, password and phone number.
- **Take TTM Quiz:** Once a user gets registered, he/she should take TTM quiz to obtain his/her stage of change upon which the app will be adapted.
- **Find nearby blood centers:** Given that a user is logged in to the mobile app, he/she should be able to search for nearby blood centers. The search results should be viewed on a map. The closest blood centers according to the users' location are displayed using specific pins.
- **Schedule appointments for BD:** The user should be able to schedule an appointment for donating blood (when eligible) at the selected blood center.
- **View donation history:** The user should be able to visualize the list of his/her past donations including date, center and type of BD.
- **Share donations on social media:** The user should be able to share his/her BDs on Facebook and Twitter.
- **Receive eligibility notifications:** The user should be notified about their eligibility to donate blood based on his/her history of donations.
- **Receive appointment reminders:** Given that a user has scheduled an appointment, he/she should receive a push notification to remind him/her of the upcoming BD appointment. The user shall set the frequency by which he/she wants to receive reminders.
- **Receive alerts during blood shortages:** The user should be able to receive notifications when his/her own blood type is needed.
- **Change notifications settings:** The user should be able to choose how and when he/she would like to receive notifications.
- **Create/Join teams:** The user should be able to create and/or join teams of blood donors and to visualize the prevalence of different donors' teams across the city.

In line with previous research studies on the application of ISO/IEC 25010 standard [98] to health-related software products including BD apps and m-health records [211, 288, 289], a set of non-functional properties has been determined to improve the product quality of *Blood4Life* solution. The core quality requirements that were considered are the following:

- **Functional suitability:** *Blood4Life* solution should meet users' needs through well integrated functions and appropriate content.



- **Performance efficiency:** *Blood4Life* solution should have a short response time to enhance user experience (UX).
- **Reliability:** *Blood4Life* solution should remain operational and accessible in a specific manner under the possible circumstances (background/foreground, with/without internet connection).
- **Operability:** *Blood4Life* solution should be scalable, it should be able to handle a large number of users or quantities of data.
- **Security:** *Blood4Life* solution should ensure encrypted communication, protection and security of users' accounts and sensitive information.
- **Compatibility:** *Blood4Life* solution should work well on different mobile devices with various features and appliances.
- **Maintainability:** *Blood4Life* solution should have a readable and extendible code to easily implement new functions and to avoid increasing maintenance cost.
- **Transferability:** *Blood4Life* should support the common mobile platforms.

### 4.3.2 Integration of TTM principles and gamification techniques

To effectively help individuals progress throughout TTM stages, a broad range of gamification elements has been implemented to trigger the TTM processes of change specific to each transition. These gamification elements comprise the following:

- **Status.** Status determines the relative position of the user in relation to others and is considered one of the most desired and sticky potential prize to win as it incorporates pride and motivation dynamics. Four statuses are to be obtained according to the stage of change of the user. The status should be systematically attributed to the user after obtaining TTM Quiz result as shown below:
  - No status is attributed to the user if her/his quiz result is 'Precontemplation'.
  - The user should be attributed 'Blood Noob' status if his/her quiz result is 'Contemplation'.
  - The user should be attributed 'Good Samaritan' status if his/her quiz result is 'Preparation'.
  - The user should be attributed 'Red Ninja' status if his/her quiz result is 'Action'.
  - The user should be attributed 'Red Blooded Hero' status if his/her quiz result is 'Maintenance'. Status should also be applicable during inter-stages progression which means that whenever the user progress towards the next stage, he/she receives the corresponding status.

- **In-app point system.** Being one of the most used gamification elements, point system is a powerful and important gamification element since it gives the users the extra nudge they need to get actively involved. Nonetheless, rewarding points may be wrongly utilized if they don't align with the desired behavior. *Blood4Life* solution primarily aims to increase BD, three point-based rewards are therefore implemented:
  - The user should earn 100 Donation Points (DPs) if he/she make a BD appointment.
  - The user should earn 150 DPs if he/she make a BD appointment particularly when blood stocks are running low.
  - The user should lose 50 DPs if he/she cancels the donation appointment. The user's score should be incremented or decremented accordingly.
- **Badges.** Badges are a visual and a collectible reward that marks tasks completion. Six badges are implemented in *Blood4Life* solution:
  - The user should win 'Welcome' badge upon their registration.
  - The user should win 'Let them know' badge for sharing BD appointments on social networks.
  - The user should win 'Be a member of' badge for joining a team of donors.
  - The user should win 'Spread the good will' badge for referring three friends within a week.
  - The user should win 'Red hat-trick' badge for taking the third BD appointment within one year.
  - The user should win 'Be there when needed' badge for donating when blood stocks are running low.
- **Trophies.** Trophies are recognition items that are commonly used in games owing to their versatility. Three types of trophies can be obtained in *Blood4Life* solution as described hereafter:
  - The user should win 'bronze trophy' upon unlocking three badges within a month.
  - The user should win 'silver trophy' upon collecting 500 DPs.
  - The user should win 'gold trophy' upon collecting 1000 DPs.
- **Progress bar.** People are inherently driven to have goals and then accomplish them. Progress bar is therefore an effective visual element that allows users track their progress towards goal attainment. In *Blood4Life* solution, the progress bar was conceived in a way that displays the milestones (stages of change) reached by the user.
- **Leaderboard.** The purpose of leaderboards is to show the ranking of users. In order to render it more social yet competitive, the leaderboard in the *Blood4Life* solution will display the ranking of users in each team based on their total earned DPs.

Given the characteristics of each stage of change, the inter-stage progression will be possible upon the fulfilment of a condition specific to each transition as depicted in Figure 4.6. The specified gamification aspects align well with the definition of the processes of change that are appropriate to each stage-transition. On the whole, the progression from Pre-contemplation to Contemplation primarily requires enhancing knowledge and awareness about BD process and its importance, in addition to emotionally levelling up the urge to donate blood through real videos and testimonies of people in need of blood transfusions or/and those whose lives were saved thanks to blood transfusions. Both transitions Contemplation-Preparation and Preparation-Action entail regular rewarding and increasing social influence whilst the progression towards maintenance stage implies substantial recognition through obtaining real-world items.

### 4.3.3 Implementation

*Blood4Life* solution consists of a cross-platform app being currently developed through Angular and Ionic framework and deployed using Apache Cordova. Hybrid development allows to develop apps that are consistent across different mobile platforms where only a single codebase is used. Several advantages come along hybrid app development such as cost-effectiveness, easy scalability and maintenance.

In the actual development phase, this application is solely dedicated to blood donors. Figures 4.7 to 4.11 show a few snapshots of user interfaces of the app. The user will be firstly asked to register and answer a short Quiz to determine her/his stage of change as detailed in Figures 4.7 and 4.8. At this point, the user might be ineligible to donate blood, hence, he/she can access the application in Guest Mode where only very limited functionalities are available such as consulting nearby blood centers and referring new friends to use the application. Once registered, the user will be able to schedule a BD appointment in the blood center he/she prefers from the list of the available blood centers (see Figure 4.9). Besides accessing his/her BD history, the user will be able to create or join a team to build a pervasive and competitive ambiance to further promote BD (see Figure 4.10).

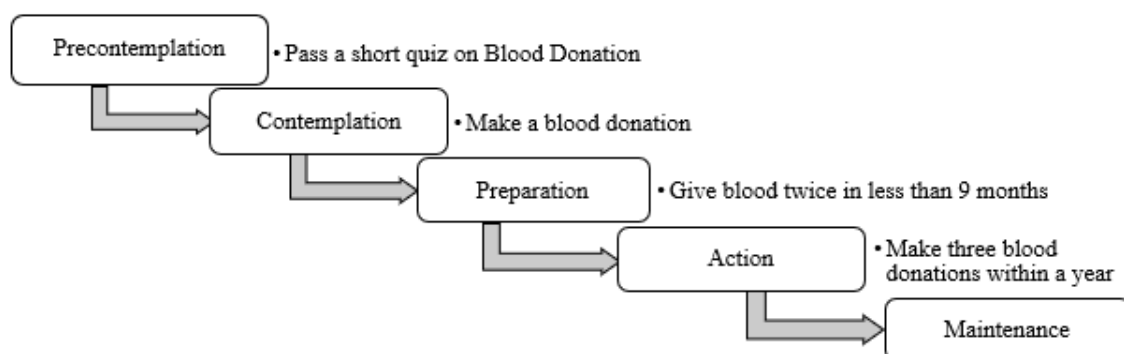


Figure 4.6: Conditions to transition between the five stages of change.

As shown in Figure 4.11 all the obtained virtual rewards will be systematically updated and displayed to the user. Moreover, the user will be able to switch on/off blood shortage alerts and eligibility notifications along with precisizing the frequency of which he/she would prefer to receive appointment reminders.

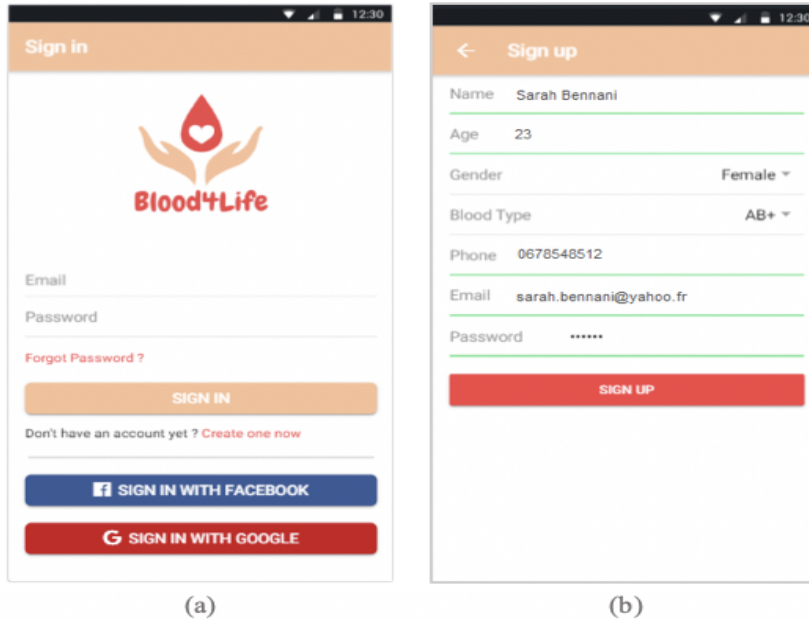


Figure 4.7: Screenshots of the *Blood4Life* app's interfaces: Sign in/up.

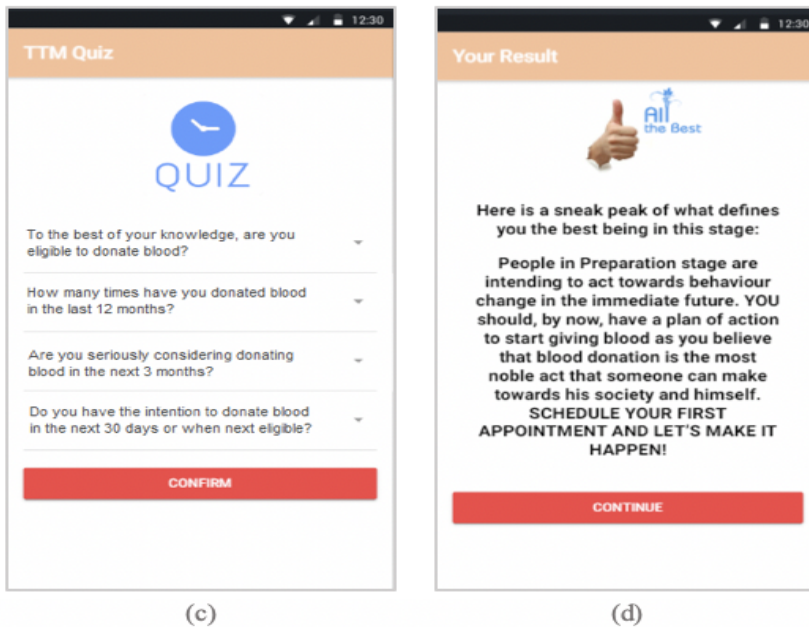


Figure 4.8: Screenshots of the *Blood4Life* app's interfaces: TTM Quiz.

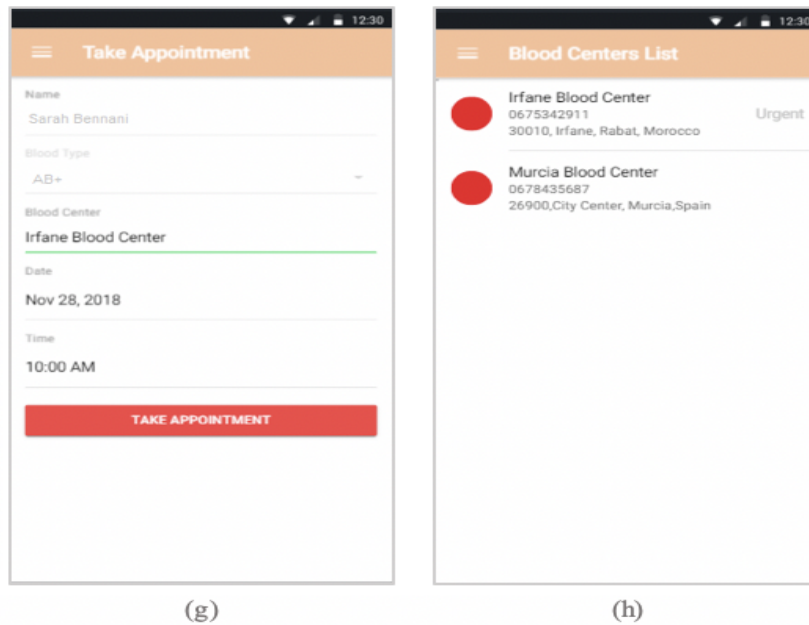


Figure 4.9: Screenshots of the *Blood4Life* app's interfaces: BD Appointment.

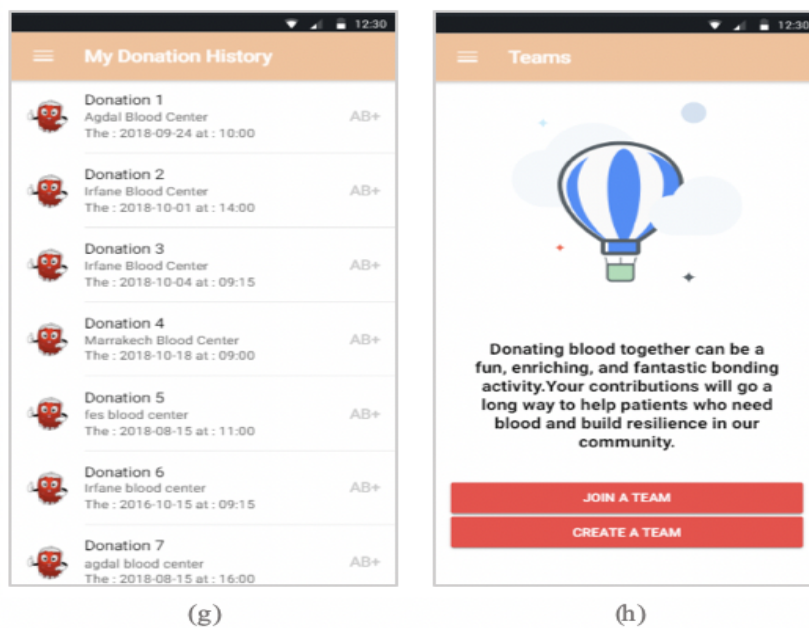


Figure 4.10: Screenshots of the *Blood4Life* app's interfaces: User's donation history and teams' creation.

#### 4.4 Requirements specification of a gamified mobile application for postnatal care

Albeit the critical importance of PNC in the lives of mothers and newborns, it consistently has the lowest coverage of interventions on the continuum of maternal and infant care. Poor communication, lack of awareness and information, financial difficulties are among the most

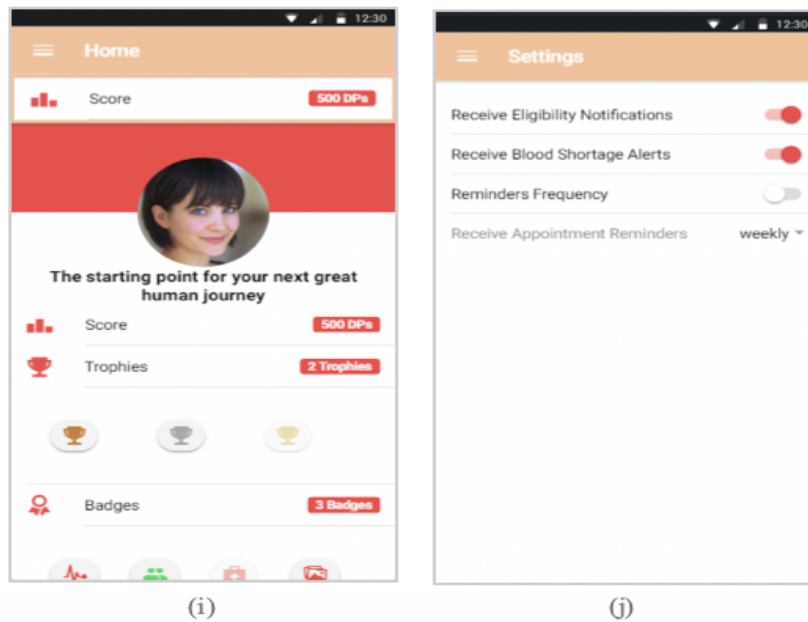


Figure 4.11: Screenshots of the *Blood4Life* app's interfaces: User's rewards and settings.

prevalent factors hampering the utilization of PNC services [290]. A potential intervention that could reduce some of these modifiable factors is the incorporation of mobile technology. A significant attention is being drawn to leveraging mobile technology in the promotion of reproductive health care services including contraception and family planning, pregnancy monitoring and PNC [184, 291]. As stated in a recent review [292], most of PNC apps available in app repositories overlook addressing mothers needs during the postnatal period, specifically as regards to postpartum weight monitoring, mental wellbeing support and family planning.

In this section, we propose a mobile solution that provides a functional content that combines newborn and maternal care along with the counselling sections on all aspects underpinning the postnatal period. A persuasive strategy based on gamification and game-like principles is also portrayed to foster engagement with the solution and induce pleasant user-experience.

#### 4.4.1 Requirements specification

##### Purpose of the solution

*Mamma&Baby* is the name given to the m-Health solution for PNC proposed in the present study. Being fully-fledged for women during the postnatal period, *Mamma&Baby* is a comprehensive user-centered app that is intended to accompany new mothers throughout their postnatal journey. The central objective of this app is to promote PNC through the provision of helpful tips for postpartum recovery and recommendations and advices on baby

care. The postnatal period is often considered as an emotional roller coaster for new mothers who require attentiveness and social support. Therefore, *Mamma&Baby* app promises to alleviate the emotional burden that is correlated with the postnatal period by means of social integration and counselling on mental wellbeing.

### Requirements development process

The development of requirements is a software engineering process that consists of four main activities:

1. *Requirements elicitation*: In order to build an m-Health solution that caters the needs of women in Morocco, a few visits to the Maternity Les Orangers that belongs to the University Hospital Avicenne of Rabat has been organized to closely observe the clinical intervention in terms of PNC. With the consent of the director of the maternity, several interviews have been conducted with the clinical staff (i.e. Doctors, interns and nurses) at the maternity to gather the maximum of information with regards PNC in Morocco.
2. *Requirements analysis*: The requirements identified in the first activity have been analyzed to ensure coherence and resolve conflicts between them. A scrupulous analytic review has been performed on existing apps for PNC to expand the set of requirements of the solution and assure its functional completeness [292].
3. *Requirements specification*: A Software Requirements Specification (SRS) covering functional and non-functional requirements for the m-Health solution for PNC has been elaborated according to the IEEE 29148 standard [287].
4. *Requirements validation*: The SRS developed has been finally presented to the clinical staff of the maternity for further validation.

### The SRS

Initially, the following functional requirements have been specified:

- **Baby management:**
  - The user shall be able to add multiple babies to her profile.
  - The user shall be able to select one of her babies to track her or his activities.
- **Newborn's daily habits recording:**
  - The user shall be able to record the daily habits of her newborn including diaper changes, feeding and sleep patterns.
  - The user shall receive alerting messages if her newborn's feeding and sleep patterns are alarming or the number of diapers changes that her newborn needs significantly exceeds the average number.

- **Growth measurements:**

- The user shall record the anthropometric characteristics of her newborn including weight, height and head circumference.
- The user shall be able to track her baby growth and compare it to standard child growth percentiles.

- **Health checkups and medication:**

- The user shall be able to schedule appointments for postnatal and pediatric check-ups. Three postnatal checkups are considered by default at the 6th day, 6th week, 6th month after delivery.
- Given that a user has scheduled an appointment, she shall receive a push notification to remind her of the upcoming medical visits (pediatric or postnatal visits).
- The user shall be able to manage and record medications.
- The user shall receive reminders of medication intake.

- **Immunization:**

- The user shall be able to track her newborn's vaccines.
- The user shall be able to consult the immunization schedule as recommended by the ministry of health in Morocco.
- The user shall schedule appointment for her newborn's vaccines and receive reminders accordingly.

- **Postpartum recovery:**

- The user shall be able to record and track her postpartum weight at any time.
- The user shall be able to access information about postpartum recovery tips including nutrition, physical exercises and hygiene.

- **Mental health:**

- The user shall be able to learn more about the symptoms and signs of Postpartum Depression (PPD) and baby blues.
- The user shall be able to acquire effective manners and strategies to cope with postpartum mental disorders.
- The user shall be able to screen for postpartum depression by filling in a 10-item self-report measure based on the Edinburgh Postnatal Depression Scale (EDPS) [293]. Note that users can fill in this self-report only once a week.



- **Community:**
  - The user shall be able to access the FAQ section to get answers about common doubts and concerns that new mothers have during their postnatal period.
  - The user shall be able to share her experiences and feelings with other new mothers through a forum.
  - The user shall be able to view and comment other users' posts.
- **Guides:**
  - The user shall be able to get basic baby care tips including burping, bathing, soothing, swaddling, etc.
  - The user shall be able to access useful information on how to improve her breast-feeding experience.
  - The user shall be able to learn more about baby development milestones as regards the age of her baby.
  - The user shall be able to acquire information about signs and symptoms of potentially life-threatening postpartum conditions.
- **Settings**
  - The user shall be able to update her preferences with regards the unit of measurement.
  - The user shall be able to change language preferences.

Along with these functional requirements, a number of non-functional requirements have been identified to enhance the quality and design of the m-Health solution *Mamma&Baby* based on the international standard ISO/IEC 25010 [98] and mobile design guidelines [294]. The core aspects of quality that have been considered are as follows:

- **Functional suitability:** *Mamma&Baby* solution should cater users' needs through well integrated functions, useful and appropriate content.
- **Performance efficiency:** *Mamma&Baby* solution should take a short time to load and provide onscreen feedback to the user.
- **Availability:** *Mamma&Baby* solution should remain operational and accessible in a certain manner under possible circumstances (e.g. unavailable network, limited bandwidth).
- **Scalability:** *Mamma&Baby* solution should be able to deal with increasing use and handle more data as time progress.

- **Usability and user interaction:**
  - *Mamma&Baby* solution should support both landscape and portrait orientations.
  - The user should be able to understand the flow of the solution easily without further training or help.
  - *Mamma&Baby* solution should use intuitive and predictable navigation patterns.
  - *Mamma&Baby* solution should use common icons' system.
- **Visual quality:**
  - *Mamma&Baby* should use familiar and simple tone along with an intelligible writing style.
  - *Mamma&Baby* should display graphics, text and images without noticeable distortion.
  - *Mamma&Baby* should use a coherent color theme that recalls its purpose.
- **Security and privacy:**
  - *Mamma&Baby* should use a strong authentication mechanism.
  - All private data should be stored in the solution's internal storage.
  - *Mamma&Baby* must protect any stored sensitive personal data from unauthorized access.
  - *Mamma&Baby* should ensure encrypted communications.
  - *Mamma&Baby* should include a privacy policy that is detailed, comprehensive and understandable.
- **Modifiability and maintainability:** *Mamma&Baby* should have a readable and extendible code to easily modify functions and implement new ones to avoid increasing maintenance cost.

With the aim to make the tedious and repetitive tasks included in the solution more fun, interactive and engaging, a gamification strategy is proposed to be implemented in the solution, and typically works in the following ways:

- **Point-based scoring:** Being one of the core gamification mechanics, allocating scores to users can motivate their willingness to continue to use the solution. Three point-based incentives are therefore proposed:
  - A user shall earn 15 points for filling in the self-report measure for postpartum depression screening.
  - A user shall earn 20 points for each medical appointment attended (gynecologic, pediatric or immunization visit).

- A user shall earn 10 points for taking medication properly by marking the medication intake as complete.
  - A user shall earn 5 points for each measurement recorded; including baby growth parameters and mother's weight.
- **Badges:** These are simple virtual elements that symbolize rewards given to users for their achievements. Badges act as a target setting and as a recognition tool that motivate users to get actively involved in the solution and work hard towards gamification objectives. Four various achievements need to be completed to unlock badges and trophies as described below:
  - Once registered, the user shall receive a 'Welcome' badge.
  - A user shall be able to unlock the 'Best nursing Mamma' badge for breastfeeding her baby at least during his or her six first months.
  - A user shall be able to unlock the 'Super Mamma' badge when she attends five medical appointments.
  - A user shall be able to unlock the 'Fit Mamma' badge for losing at least 6 Kgs (13 pounds) during the first six months of her postnatal period.
- **Progress bar:** It is perhaps one of the most straightforward gamification elements that displays operations' wholeness. It gives information about the progress users are making towards attaining a specific goal. In *Mamma&Baby* solution, the progress bar has been thought with regards baby growth measurements. In this respect, *Mamma&Baby* solution shall display the percentage users have completed as they enter values of their babies' vital parameters (height and weight) at a monthly basis during a twelve-month period.
- **Leaderboards:** The very presence of a leaderboard can elicit the desire to play. The simple goal of raising up the rankings serves as a powerful motivator to continue. Based on the amount of the points collected, users shall be able to see how they stack up against other users in the solution. The leaderboard is supposed to be displayed in the Community section where social interaction is endorsed.
- **Virtual goods:** Earned points can be exchanged for instant virtual rewards. Users shall be able to choose whether to redeem their points in the form of rewards and subsequently reset their score to the remaining points or keep on accumulating points without spending them. Three virtual rewards are proposed in *Mamma&Baby*:
  - A user shall be able to redeem '50 points' for a new display theme.
  - A user shall be able to redeem '100 points' for an electronic personalized photo frame for a specific photo of her baby that she will uploads.

- A user shall be able to redeem '200 points' for a customized electronic photo album of ten uploaded photos.

#### 4.4.2 Implementation

##### Tools and technologies used

From this initial system requirements specification, the structural and behavioral aspects of the system have been modeled using an open source UML (Unified Modeling Language) called StarUML. The main purpose is to fill the gap between documents written in natural language and use cases by modeling requirements in a graphical and tabular way, which can significantly improve the requirements representation and enrich the relationship between them. In this vein, high-level requirements have been captured using Use cases and the domain model has been represented using a class diagram. The control flow drawn from an operation to another has been represented using activity diagrams. In conjunction with these UML diagrams, user interfaces have been sketched to explore the design space of the solution more fully and to openly investigate multiple design directions at low cost. In parallel, the SRS document has been transformed into logical structure, which contains detailed and complete set of specifications that can be implemented in a programming language. Afterwards, the design has been implemented into source code in Android studio being the official integration environment for Android app development. To build a powerful solution, Firebase; considered a Backend as a Service (BaaS) has been used to leverage its numerous features including real-time database, hosting, cloud storage and social authentication, among others.

##### User interfaces

At the current stage of the development cycle, only the functional and non-functional requirements are fully implemented. The gamification aspects are now being analyzed in order to be incorporated in an updated version of the solution. Figures 4.12 and 4.13 depict a few screenshots of user interfaces of *Mamma&Baby*. Once launched, the user will be primarily asked to complete the registration form to create a new account. When logged in, the user gets access to the home page where she can choose the section she is interested of. Six menu cards are available, assembling each of them two to four functionalities or features such as tracking baby's daily activities, setting appointments' reminders, learning tips on baby care, screening for postpartum depression and sharing experiences and concerns with other mothers, to cite but a few. It is possible to keep health records and tracking measurements of multiple babies, at any moment the user can switch between her tracked babies. Also, the user can change her preferences with regards language and measurement units from the drawer menu.

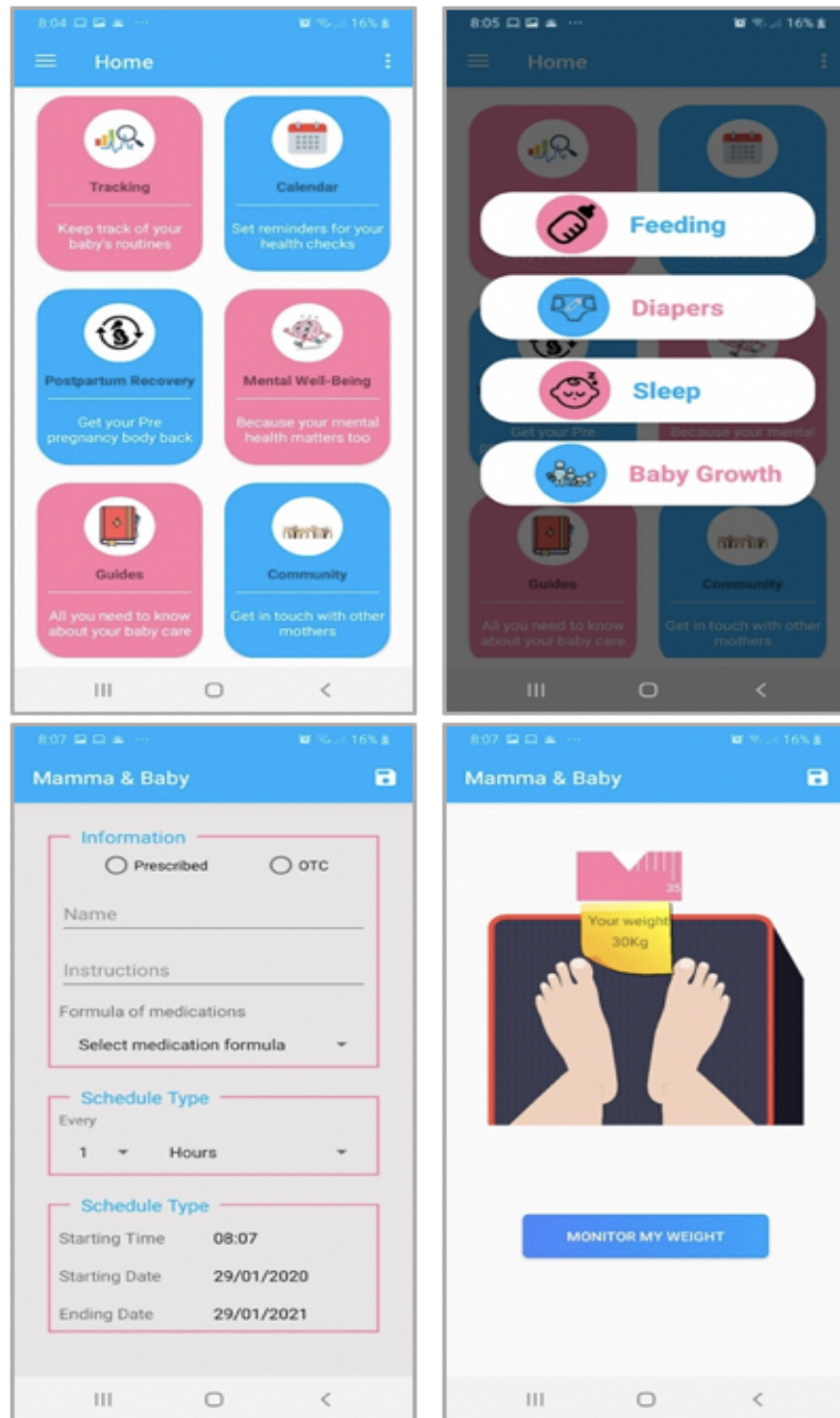


Figure 4.12: Screenshots of user interfaces of *Mamma&Baby* app (Dashboard, category's menu, medication details, postpartum weight monitoring).

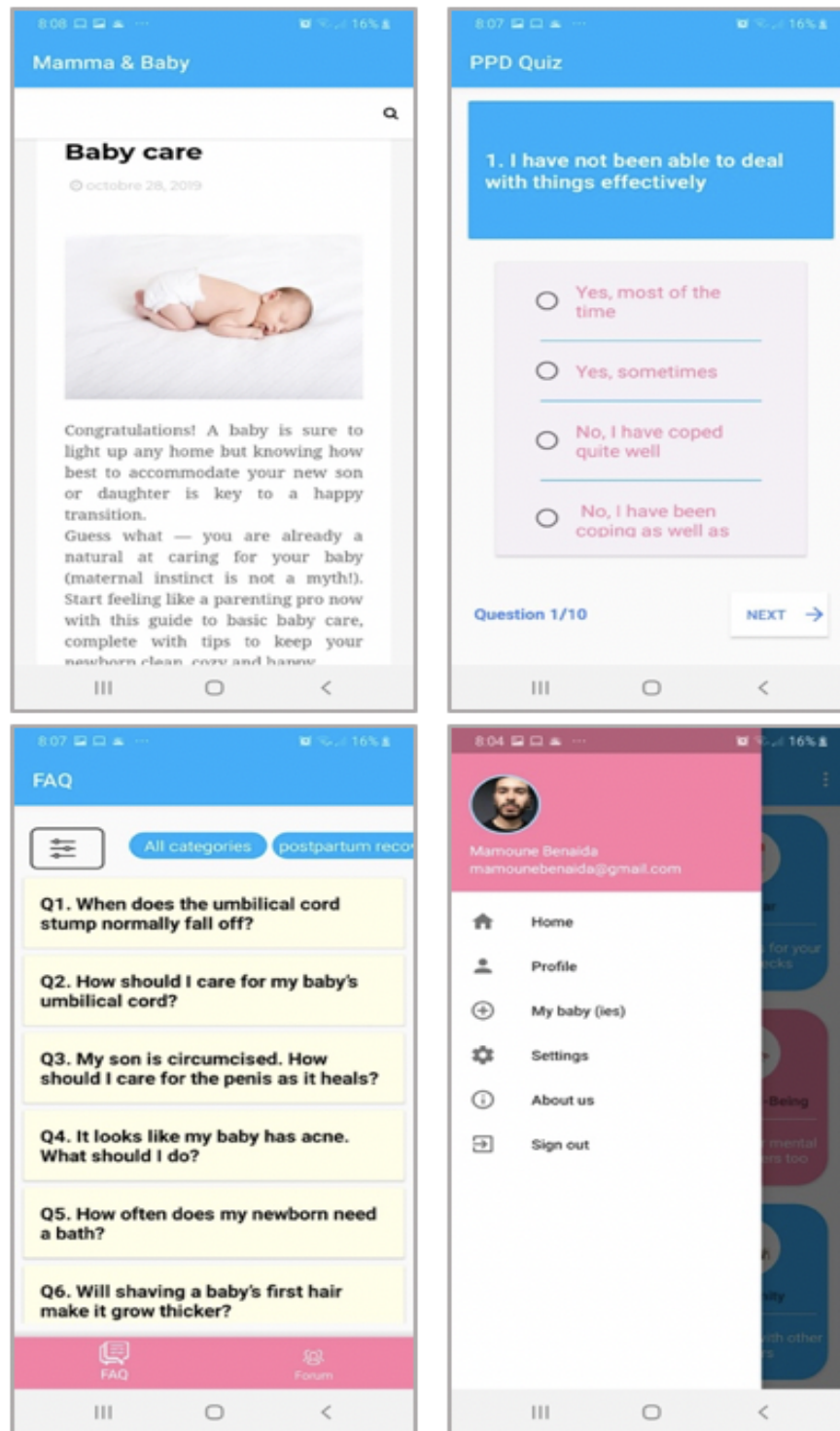


Figure 4.13: Screenshots of user interfaces of *Mamma&Baby* app (Guide, TTM Quiz, FAQ, settings).

#### 4.4.3 Quality assessment of the gamified app: An experiment design

Following the development of *Mamma&Baby* solution and testing its different functionalities using specification-based testing, the clinical staff at the Maternity Les oranges have

examined the different features and functionalities of the solution and have studied the overall content coherence in order to validate the solution from a clinical perspective. With the aim to assess the quality, effectiveness and usefulness of the solution, an experiment with real participants will be conducted at Maternity Les orangers under the close supervision of the same clinical staff already involved.

### **Participants and study procedures**

**Participants.** A total of sixty-five puerperal women are expected to be enrolled in this experiment. These women have to fulfill the following inclusion criteria to guarantee their participation: IC1) Being aged between 20 and 45 years old, IC2) being resident in the region of Rabat, IC3) having an Android smartphone, IC4) having a moderate level of experience with apps, IC5) willing to comply with the evaluation study procedures. A written informed consent form shall be administered to the prospective participants to be signed prior their effective enrollment in the evaluation. This informed consent will answer the common concerns and questions that cross participants' mind about the purpose of the evaluation, participation conditions, study procedures, confidentiality and withdrawal, before taking part of the study.

**Evaluation study procedures.** Before starting the experiment, all the participants enrolled will be initiated to the solution. The purpose and the main functionalities included in the solution will be explained in details and a quick video demonstration will be displayed to the participants to have a concrete idea on how to use the solution. Afterwards, the participants will be requested to have the *Mamma&Baby* solution running on their Android smartphone for up to six months of their postnatal period. They will have to complete all the tasks' instructions presented in Table 4.6 at a regular basis so that they will be able to provide a credible and well-founded feedback about the overall quality of the solution. After six months of use, the participants will be asked to complete two self-report questionnaires of quality assessment of the mobile solution.

### **Assessment criteria**

In order to assess the quality of the resulting gamified solution, two self-report questionnaires will be at disposal of the participants at the end of the experiment. The effectiveness and potential of the solution in promoting PNC and improving access to PNC services in Morocco will also be evaluated through a short questionnaire in which they will be asked to give their remarks and suggestions to improve the quality of the solution.

**Product quality.** It refers to the degree to which a product or a service fits patterns of users or customers' expectations and preferences. The international standard IEC/ISO

Table 4.6: *Mamma&Baby* Empirical evaluation: Participants' tasks.

| Tasks   | Participants will be instructed to:  | Participants will be informed that:  |
|---|--|--|
| <b>Task 1:</b> Sign up/Create an account then log in.                               | <ul style="list-style-type: none"> <li>- Enter their personal information (Full name, phone number, weight, type of delivery, email, password)</li> <li>- Enter baby's details: Name, gender, birthday.</li> <li>- Use their login credentials (email and password) to sign in.</li> </ul>   | <ul style="list-style-type: none"> <li>- The details entered should be accurate.</li> <li>- Their personal details will be kept secured in our database.</li> </ul>            |
| <b>Task 2:</b> Record regularly their baby's routine activities                     | <ul style="list-style-type: none"> <li>- Have their smartphones at hand to record their baby's habits (feeding/sleep) with an accurate timing.</li> <li>- Switch breasts multiple times when nursing and record the time spent on each breast until the breastfeeding session is over.</li> <li>- Track daily diaper output.</li> <li>- Get their baby's growth (height, weight and head circumference) measured at a monthly basis at each checkup or at any pharmacy,</li> </ul> | <ul style="list-style-type: none"> <li>- All the records made can be visualized on plots.</li> <li>- Month-over-month measures can be compared with the OMS charts.</li> </ul> |
| <b>Task 3:</b> Set reminders for health checks appointments and medication intakes. | <ul style="list-style-type: none"> <li>- Enter information about their postnatal checkups' appointments or those of their baby's pediatric visits.</li> <li>- Set a reminder for their appointments.</li> <li>- Mark complete when the appointment is attended and add note if needed/preferred.</li> <li>- Set a reminder to take their meds.</li> </ul>  | <ul style="list-style-type: none"> <li>- All the information related to the doctor visits or the medications should be correct.</li> </ul>                                     |
| <b>Task 4:</b> Track the vaccine schedule and set reminders for upcoming shots.     | <ul style="list-style-type: none"> <li>- Set reminders of upcoming vaccines in advance.</li> <li>- Record/mark as complete the vaccines that babies received.</li> </ul>   | <ul style="list-style-type: none"> <li>- All the vaccines presented in the vaccine schedule are mandatory and should not be delayed or skipped.</li> </ul>                     |
| <b>Task 5:</b> Monitor postpartum weight  | <ul style="list-style-type: none"> <li>- Track their postpartum weight regularly.</li> </ul>   | <ul style="list-style-type: none"> <li>- All the postpartum weight measurements are graphically displayed.</li> </ul>  |
| <b>Task 6:</b> Screen for postpartum depression                                     | <ul style="list-style-type: none"> <li>- Screen for PPD at least two times during the first 6 months after delivery.</li> <li>- Seek medical attention immediately is the quiz's result shows a possible presence of PPD symptoms.</li> </ul>  | <ul style="list-style-type: none"> <li>- Their answers to the quiz's questions should be honest and correct to receive the most accurate feedback.</li> </ul>                  |
| <b>Task 7:</b> Become a member of new mothers' community                            | <ul style="list-style-type: none"> <li>- Share their problems/concerns with other new mothers.</li> </ul>  | <ul style="list-style-type: none"> <li>- Their posts will be visible to all users.</li> </ul>  |
| <b>Task 8:</b> Learn more about postnatal period.                                   | <ul style="list-style-type: none"> <li>- Use our guides to acquire more information about numerous aspects of postnatal period such as: baby care, postpartum recovery, danger signs, postpartum mental health, etc.</li> <li>- Quickly get the answer to the most commonly asked questions by puerperal women.</li> </ul>   |  |

25010 defines a model for software product quality that is composed of eight characteristics which are further subdivided into sub-characteristics that are related to static and dynamic properties of the software product [98]. Several studies have used this model to evaluate health solutions as for cardiology [295,296], BD [289] and pregnancy monitoring [288]. Four characteristics pertaining to this model have been considered to develop the product



quality questionnaire which are: Functional suitability, Operability, Reliability and Security. These characteristics have been found to significantly affect the quality of mHealth solutions [288,289,296]. The number of items per each characteristic depended on both the number of its sub-characteristics and the degree of its impact's relevance on the quality of the software product. However, despite having only three sub-characteristics, eleven items have been developed for functional suitability characteristic. In fact, functional suitability is one of the most important quality characteristics as it entails the ability of a software product to match the needs and requirements of its users [297].

On the other hand, operability has also included eleven items given its numerous sub-characteristics that are mainly focused on the degree to which the software product is attractive, easy to learn and appropriate to use [98]. Five additional items have been determined to cover reliability which bears on the capability of a software product to perform failure-free operation for a specified period of time. Security, for its part, has comprised three items primarily relying on data integrity, confidentiality and privacy. Considering the personal and sensitive information used and shared in healthcare solutions, several security and privacy concerns have arisen and have significantly disturbed the course of the software development cycle. This has obliged the developers to take into consideration a number of security requirements from the early stages of the software development [298]. Table 4.7 summarizes the items of the product quality questionnaire. The possible answers to these items are either Yes/No or a 5-point Likert scale. The corresponding score to each of these answers are provided in Table 4.8. The resulting participants' scores will be obtained for each characteristic by summing all the scores obtained for their underpinning sub-characteristics. Further, they will be classified into five categories:

- i). Very high if the score is between 4.5 and 5
- ii). High if the score is between 3.5 and 4.5
- iii). Moderate if the score is between 2.5 and 3.5
- iv). Low if the score is between 1.5 and 2.5
- v). Very low if the score if between 1 and 1.5

**Quality-in-Use.** The concept of quality in-use corresponds to the user's perception of the quality of the software product in its context of use. It can therefore be used to validate the degree to which the software product meets the users' needs [299]. According to the ISO/IEC 25010 standard, the quality in-use model is decomposed into the following five characteristics: Effectiveness, Efficiency, Satisfaction, Freedom from risk and Context coverage [98]. Given the gamification aspects that are expected to be implemented in the solution before the evaluation, an adapted model of the quality-in-use model presented in the ISO/IEC 25010 standard has been used to define the questions of the quality-in-use assessment questionnaire.

Table 4.7: *Mamma&baby* empirical evaluation: Product quality assessment questionnaire.

| ID   | Question   | Answer      |
|------|--|-------------|
| FS1  | Did you find the various functions on this solution were well integrated?                            | 5-pt Likert |
| FS2  | Did you think there was not much inconsistency in this solution?                                     | 5-pt Likert |
| FS3  | Did you find this solution feature-rich?   | 5-pt Likert |
| FS4  | How useful did you find the 'Tracking' section?  | 5-pt Likert |
| FS5  | How useful did you find the 'Reminder' feature?  | 5-pt Likert |
| FS6  | Did you find the 'Guides' section very informative?  | 5-pt Likert |
| FS7  | Did you find the 'community' very supportive?  | 5-pt Likert |
| FS8  | Did the solution accurately report your data?  | Yes/No      |
| FS9  | Did you find the solution unnecessarily complex?   | 5-pt Likert |
| FS10 | Were there any restrictions on inputs?   | Yes/No      |
| FS11 | Would you recommend this solution to a friend?   | Yes/No      |
| OP1  | Did you think the font styles used in this solution were easily legible?                             | 5-pt Likert |
| OP2  | Did you find the content of the solution presented in a logical order?                               | 5-pt Likert |
| OP3  | How appropriate and consistent did you find the color theme of the solution?                         | 5-pt Likert |
| OP4  | How professional did you feel the solution was look at?  | 5-pt Likert |
| OP5  | Was this solution available in other languages?  | Yes/No      |
| OP6  | Did you think this solution had an ergonomic design?   | Yes/No      |
| OP7  | Did you find your measurements well presented?   | 5-pt Likert |
| OP8  | Did you think the solution was easy to use?  | 5-pt Likert |
| OP9  | Did you find the solution was interactive and responsive?  | Yes/No      |
| OP10 | Did you find the solution used a tone that is simple, informal and friendly?                         | Yes/No      |
| OP11 | Did the solution adapt to screen orientation (portrait and landscape)?                               | Yes/No      |
| R1   | Did the solution allow to edit your profile?   | Yes/No      |
| R2   | Did the solution allow you to update your preferences with regards to unit measurements or language? | Yes/No      |
| R3   | Did the solution remember your preferences and settings?   | Yes/No      |
| R4   | Were all the measurements entered stored in the solution?  | Yes/No      |
| R5   | Did you find the solution was bug-free?  | Yes/No      |
| S1   | Did you think the solution protects your data?   | 5-pt Likert |
| S2   | Did the solution include a privacy policy?   | Yes/No      |
| S3   | Did the solution support a back-up/restore feature?  | Yes/No      |

\*FS: functional suitability, OP: operability, R: Reliability, S: Security

Table 4.8: *Mamma&Baby* empirical evaluation: Score of the possible answers to the product quality assessment questionnaire.

| Question's ID                           | Possible answers/scores  |
|---|--|
| FS1-3, FS6-7, FS9, OP1-2, OP8, S1       | From 'Strongly disagree' (scored 1) to 'Strongly agree' (scored 5) |
| FS8, FS10-11, OP5-6, OP9-11, R1-5, S2-3 | 'Yes' (scored 5) or 'No' (scored 1)                                |
| OP3-4, OP7                              | From 'Poor' (scored 1) to 'Excellent' (scored 5)                   |
| FS4-5                                   | From 'Not useful' (scored 1) to 'very useful' (scored 5)           |

The QU-GamSoft model has been constructed taking into consideration the specific elements in gamified software [300]. A total of thirteen items has been developed to cover three characteristics, namely: Effectiveness, efficiency and satisfaction as shown in Table 4.9.

These characteristics have been found to be significantly influenced in gamified software [300]. Effectiveness refers to the accuracy and completeness with which users achieve specified goals owing to the engagement caused by the gamification elements whereas ef-

efficiency designates the resources exploited as regards the completeness with which users achieve those goals [98]. Besides, satisfaction implies the extent to which user needs are satisfied and fulfilled when gamified software is used in specific context of use. Unlike the efficiency and effectiveness characteristics, satisfaction is further divided into sub-characteristics including: enjoyment, usefulness and user trust [300]. The scoring system for this questionnaire is exactly similar to that of the product quality evaluation questionnaire. Accordingly, Table 4.10 displays the possible answers to this questionnaire’s items along with their corresponding scores.

**Potential.** The potential of the solution in promoting and improving PNC in Morocco will be assessed through the participants’ evaluation of a few aspects of the solution as presented below:

- The solution provides valuable information on parenting and baby care.
- The solution offers useful advices and recommendations about postpartum recovery.
- The solution helps to track the vaccine schedule of your newborn.
- The solution leverages socialization in a way that it allows you to share your experiences with others.

Participants are invited to freely choose a value between 0 and 100% that better accommodate their perception with respect to these aspects. An additional open question is included

Table 4.9: *Mamma&Baby* empirical evaluation: Quality in-use assessment questionnaire.

| ID  | Question   | Answer      |
|-----|--|-------------|
| E1  | Did you find that game elements made the solution more complex?  | Yes/No      |
| E2  | Did you find the game design elements of the solution were fun and pleasant?                             | Yes/No      |
| E3  | Do you think you would use this solution frequently because it is gamified?                              | Yes/No      |
| E4  | Did you find gamification increased your engagement with the app?  | Yes/No      |
| EF1 | How did you find the time taken to be assigned a game element?   | 5-pt Likert |
| EF2 | How did you find the number of game elements you were assigned while performing a task?                  | 5-pt Likert |
| SA1 | Overall, did you find the gamification aspects were well integrated into the activities performed?       | Yes/No      |
| SA2 | How useful did you find the proposed game design elements in motivating you to use the solution?         | 5-pt Likert |
| SA3 | Did you find the solution was fun to use?  | Yes/No      |
| SA4 | To which degree did earning game achievement make you happy?   | 5-pt Likert |
| SA5 | How did you find being able to earn game design elements increased your enjoyment of using the solution? | 5-pt Likert |
| SA6 | Did you think trying to earn game elements had a positive effect on your behavior?                       | Yes/No      |
| SA7 | Would you prefer to use this app with game design elements than without them?                            | Yes/No      |

\*E: Effectiveness, EF: Efficiency, SA: Satisfaction

Table 4.10: *Mamma&Baby* empirical evaluation: Score of the possible answers to the quality in-use assessment questionnaire.

| Question's ID         | Possible answers/scores   |
|-----------------------|---|
| EF1                   | From 'Extremely long' (scored 1) to 'Immediate' (scored 5)            |
| E1-4, SA1, SA3, SA6-7 | 'Yes' (scored 5) or 'No' (scored 1)                                   |
| EF2, SA4-5            | From 'Poor' (scored 1) to 'Excellent' (scored 5)                      |
| SA2                   | From 'Not useful' (scored 1) to 'very useful and complete' (scored 5) |

in the questionnaire to give to the participants the opportunity to make critics, remarks and suggestions to enhance the overall quality of the solution.

### Research questions

The results of this empirical evaluation will be used to answer the following research questions:

#### **RQ1. To what extent the solution adheres to quality characteristics?**

The aim of this question is to determine the degree of fulfillment of product quality characteristics (e.g. Functional suitability, Reliability and Security) by the solution. The overall average score for each product quality characteristic will be analyzed to answer this research question.

#### **RQ2. To which degree does gamification elements enhances the quality-in-use of the solution?**

This research question aims to investigate the importance of gamification aspects in improving user experience and user satisfaction with the solution. In order to answer this question, the overall score obtained in the quality-in-use assessment will be analyzed.

#### **RQ3. Is there a compliance between the solution's product quality, its quality-in-use and its potential as perceived and reported by the participants?**

The goal of this research question is to compare between the perceived product quality and quality-in-use of the solution and its potential as reported by the participants. First, the correlation between the overall scores obtained in the product quality and quality-in-use assessments will be studied. Then, these overall scores will be contrasted, one by one, with the results of the solution's potential assessment. This will likely indicate whether the potential of the solution in improving PNC is tightly linked with its overall quality and vice versa.

## 4.5 Conclusion

This chapter has reported the results of a cross-sectional study performed among a Spanish sample of 602 individuals on the application of TTM model to BD behaviour. A number of measures were developed to explore the relationships among TTM constructs. Overall, the results obtained showed a general accordance with the findings reported in previous studies which, therefore, supports the applicability of TTM to BD behaviour. On the basis of these measures, a stage-matched gamified mobile solution; *Blood4Life* was developed to aid in the recruitment and retention of motivated young blood donors. The purpose, design, and requirements specification of the solution have been described in this chapter. Taking advantage of gamification techniques and TTM principles, *Blood4Life* represents a novel approach in the development of tailored BD mobile solutions. It offers a unique experience to users based on their initial stage of change by triggering the processes of changes that are assumed to help them transition to the next stages by means of gamification elements and social influence. This research could be a starting point to investigate better ways of implementing tailored solutions for the promotion of BD on a global scale.

In addition, this chapter has presented the SRS and implementation of a comprehensive solution *Mamma&Baby* intended to promote PNC in Morocco in collaboration with Maternity les oranges in Rabat. The requirements identified in this chapter are fully aligned with actual women' needs drawn from the multiple visits to the maternity. Given the paramount role of persuasive strategies in enhancing engagement and inducing pleasant experiences, a gamification strategy has been proposed for further implementation in the PNC solution. In addition, this chapter has described the experiment design of a 6-months quality evaluation of *Mamma&Baby* with real participants to analyze the overall quality of the solution and assess the potential of gamification in yielding better outcomes. In this respect, the set of tasks to be performed by the participants and the three questionnaires they shall complete have been provided.

For future research, greater attention should be devoted to the implementation of the principles of behaviour change theories in the solutions intended to promote healthy lifestyle or/and induce permanent behavioural changes. By the same token, gamification techniques should be considerably adopted in these solutions to enhance users' experience. Nonetheless, it is advised that future proposed solutions should construct a well-grounded and appropriate gamification strategy that suits both the purpose of the solutions and the user.

# Reusable requirements catalog for gamified mobile health applications

## 5.1 Introduction

The success of a software product is often defined as one that is delivered on time, on budget and with all the features as originally specified. In this context, requirements reuse has been proposed as an advanced requirements elicitation technique that has a great deal of potential in terms of achieving maximum productivity, quality and consistency throughout the product development lifecycle [301,302]. The remainder of this chapter is structured as follows: Section 5.2 sheds the light on the concept of requirements reuse and summarizes the major findings of studies dealing with the construction of reusable requirements catalogs in the realm of healthcare. Section 5.3 presents the process of development of the reusable catalog for gamified mHealth apps and provides a description of the characteristics of interest included in this catalog. Section 5.4 identifies the main artifacts, activities and roles involved in an effective audit process as regards gamification and quality characteristics in the catalog. Section 5.5 shows two mHealth application examples that serve as a validation strategy of the applicability of the catalog GHA-CAT and the audit method. Section 5.6 discusses the results of the audit process on both apps. Finally, Section 5.7 draws some concluding remarks.

## 5.2 Requirements reuse

A variety of different approaches have been developed and used for enabling reuse of requirements such as structuring, matching, ontology, domain analysis and parameterization [303]. Pacheco et al. has proposed a structuring approach using software requirements catalogs (SRC) to support software reuse [304]. This approach structures requirements belonging to the same domain in sorted lists (i.e. catalogs), in which each one of the software

requirements has to be described in terms of its functionality and classified conforming to its importance. Moreover, these requirements must be identified in a unique way in order to facilitate the search within the catalog. A requirements catalog is versatile as it can be adapted into different projects. The SRC approach is oriented to small-sized software enterprises that develop custom-built software products. Health apps are a good instance of this specific type of software products.

The ubiquity of mHealth apps and their tremendous utility have driven many researchers to propose reusable requirements catalogs that are likely to improve the quality of the mHealth app being built. For instance, Ouhbi et al. [247] have defined an internationalization requirements catalog for audit purposes. A reusable requirements catalog that gathers sustainability requirements from relevant software engineering standards for connected health apps was presented by Ouhbi et al. [305]. Based on these two catalogs, Ouhbi et al. [306] have proposed a requirements catalog for internationalized and sustainable BD apps. Belén et al. [249] have presented an audit method to assess usability in mHealth apps based on a reusable requirements catalog. More specifically, Bachiri et al. [307] have defined a standard-based sustainability and internationalization requirements catalog limited to prenatal care apps. This catalog also included requirements related to additional quality characteristics, namely operability, performance efficiency, reliability and functional suitability. A reusable requirements catalog to improve security in healthcare applications has been presented by Jensen et al. [308]. With respect to gamification, a reusable catalog of gamification specifications for educational software has been recently proposed [309]. Table 5.1 summarizes the main findings of some of these related works.

### 5.3 Development of a reusable requirements catalog

The elaboration of the requirements catalog for gamified mHealth apps ‘GHA-CAT’ builds on a requirements engineering approach called SIREN (Simple REuse of software requiremeNts). Proposed and developed by a research group from the University of Murcia [310], this practical approach aims at reducing the total effort and cost of software development along with increasing the overall software productivity and quality [304], through the creation, selection and elicitation of reusable requirements. Several studies in the health area have used SIREN methodology for the development of reusable requirements catalogs [247, 249, 306]. The GHA-CAT was developed following the process depicted in Figure 5.1. First, the main information sources were identified. Literature and formal documents such as standards and guidelines were considered. Next, relevant requirements for the development of gamified mHealth apps were extracted from the sources previously selected. Then, the catalog GHA-CAT was generated from these requirements following the IEEE standards’ structure. Finally, the generated catalog is maintained and updated regularly upon changes and/or modifications in standards, policies and legislations. This last phase is

Table 5.1: Main findings of related reusable requirements catalogs

| Ref.   | Context               | Quality characteristics  | key findings  |
|--------|-----------------------|--|---|
| Ref 26 | Connected Health apps | Internationalization   | <ul style="list-style-type: none"> <li>To bridge cultural and linguistic diversity, connected health apps should take into account internationalization aspects.</li> <li>A standard-based reusable i18n requirements catalog for eHealth apps ‘eHI-C’ has been proposed.</li> <li>An internationalization audit method ‘eHIA-M’ has been designed to enable a systematic assessment of e-health applications with regard to i18n, including a qualitative and quantitative evaluation.</li> <li>A renowned ehealth app named SHealth has been used to assess the applicability of both the catalog eHI-C and the audit method eHIA-M.</li> <li>A 25-items questionnaire has been generated from the eHI-C as part of the audit method to help analyse to what extent the i18n aspects are covered by the application administered.</li> </ul>  |
| Ref 27 | Connected Health apps | Sustainability   | <ul style="list-style-type: none"> <li>Addressing sustainability in connected health apps engenders their large-scale adoption.</li> <li>A reusable catalog ‘SCH-CAT’ presents inherent properties of connected health regarding sustainability.</li> <li>The catalog contains requirements that cover the individual, social, environmental and technical dimensions of sustainability.</li> <li>Requirements related to operability, i18n should be considered in the development or /and evaluation of sustainability since they substantially influence the acceptability and adoption of connected health apps.</li> <li>To illustrate the evaluation process, the SCH-CAT has been applied to the Android version of a free blood donation app called Blood Donor+.</li> <li>Based on the evaluation scores obtained, a list of recommendations has been provided to improve the overall sustainability of the app.</li> </ul>  |
| Ref 29 | Health care apps      | Usability  | <ul style="list-style-type: none"> <li>Usability enhances user experience and improves interaction with the app.</li> <li>A software requirements catalog USB-CAT for usable mobile health applications has been proposed.</li> <li>All the requirements of the catalog have been drawn from software engineering recommended standards, popular guidelines and related papers.</li> <li>Usability requirements are focused on the next 4 characteristics: Ease of use, Personalization and internationalization, Learnability, Understandability and politeness, and Accessibility.</li> <li>An audit method has been provided to check the applicability of the catalog.</li> <li>A 133-item checklist has been generated from the catalog.</li> <li>A health application created by Samsung Electronics Co, denominated S Health has been used to validate the catalog along with the audit method.</li> <li>The audit report has provided a number of usability-related deficiencies and a set of recommendations to improve the application S Health.</li> </ul> |
| Ref 30 | Postnatal care apps   | Sustainability, Internationalization, Operability, Performance efficiency, Reliability, Functional suitability | <ul style="list-style-type: none"> <li>Mobile Personal Health Records for prenatal care are mobile applications that allow women to track, manage, access data related to their pregnancy through a mobile device.</li> <li>A standard-based requirements catalog for the inherent properties of mPHRs for prenatal care has been developed.</li> <li>Requirements concerning functionalities, sustainability, internationalization in mPHRs for prenatal care have been included in the catalog.</li> <li>Operability, Performance efficiency, Reliability and Functional suitability belonging to the ISO/IEC 25010 product quality model have been found as the characteristics mostly influenced by the requirements of mPHRs for prenatal care.</li> <li>A 30-item questionnaire has been generated from the catalog to evaluate the Android version of a highly downloaded mPHR for prenatal care, denominated Pregnancy+.</li> </ul>   |



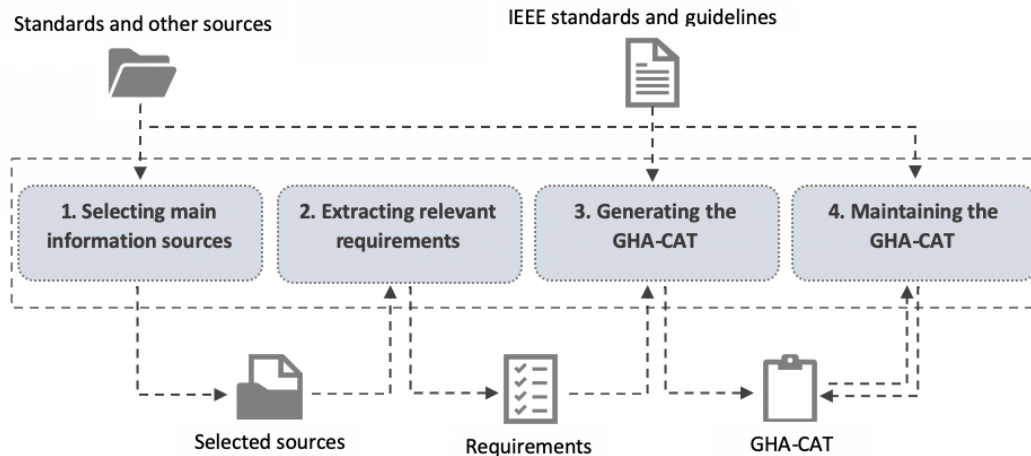


Figure 5.1: Catalog generation process.

paramount as it facilitates requirements' adaptation into new projects. Further, it addresses catalogs' incompleteness and performs a change control strategy for establishing a baseline for each developed catalog before potential modifications [304].

### 5.3.1 Information sources

Requirements for the GHA-CAT have been derived from literature on gamified solutions (e.g. [35, 58, 65, 285, 309, 311–315]) and from a number of studies dealing with software quality particularly with regards Usability, Operability and Security, including requirements catalogs [249, 308, 310, 316], evaluation studies [183, 201, 248, 297] and reviews [215, 298]. In addition, the following international standards and technical reports have been used to specify these requirements.

- ISO/IEC 25010 standard for software product evaluation which defines a quality in-use model and a product quality model that are relevant for all software products and computer systems [98].
- ISO/IEC 25023 standard providing quality measures for quantitatively evaluating system and software product quality in terms of characteristics and sub-characteristics defined in ISO/IEC 25010 [101].
- ISO/IEC 25040 standard providing a process description for evaluating software product quality and clarifies the general concepts [317].
- ISO/IEC 27799 standard for information security management in health [318].
- CEN/TR 15640 standard providing measures with which to ensure the safety of patients using health software [319].
- ISO 9241-210 standard for ergonomics of human-system interaction [320].

- The W3C standards for web and mobile devices [321].

### 5.3.2 Catalog Requirements specification

Following the identification of relevant standards and information sources, requirements related to the focal areas of the present study were analysed and specified. The requirements specification process was conducted based on recommendations and guidelines provided by the IEEE 29148 standard [287] which not only describes in a comprehensive manner the processes related to requirements engineering activities but also defines a complete and normative guide for the proper preparation of Software Requirements Specification (SRS). A thoughtful and well-organized SRS document reduces significantly the development cost and is a prerequisite to high-quality software product [322]. Drawing on this guidance, the general structure of the catalog was organized in a way that complies with the contents of an SRS recommended by IEEE 29148 as shown in Table 5.2.

Based on the structure presented in Table 5.3, all requirements of the GHA-CAT are encompassed in Specific requirements section and are organized under their corresponding subsection. On the recommendation of the IEEE 29148 standard with regards additional requirements, gamification requirements are organized under a separate section labelled 'other requirements'. What follows is the presentation of each category of these requirements.

#### Gamification requirements

Perhaps the core pillar delineating the success and effectiveness of gamified mHealth apps is the efficient use of appropriate game-design elements. Gamification requirements therefore constitute an important section in GHA-CAT. Due to the absence of a standardized guidance on building gamified mHealth apps, some developed gamified apps may negatively impact the overall user experience resulting in unintended or unethical behaviour. An effective gamified health solution should include a combination of game-design elements that promote

Table 5.2: Table of contents (IEEE 29148-2011)

|                                   |
|-----------------------------------|
| 1. Introduction                   |
| 1.1. Purpose                      |
| 1.2. Product scope                |
| 1.3. Product overview             |
| 1.3.1. Product perspectives       |
| 1.3.2. Product functions          |
| 1.3.3. User characteristics       |
| 1.3.4. Limitations                |
| 1.4. Definitions                  |
| 2. References                     |
| 3. Specific requirements          |
| 4. Appendices                     |
| 4.1. Assumptions and dependencies |
| 4.2. Acronyms and abbreviations   |

most of the following persuasive strategies [58]:

- **Relatedness and social influence:** Relatedness is one of the three basic intrinsic needs postulated within the Self-Determination Theory (SDT) [323]. The need for social connectivity represents the innate desire of individuals for integration with the social environment.
- **Purpose and goal setting:** Gamification is inherently a goal-oriented discipline; aimed at inducing motivation. Conjointly with the SDT, the goal-setting theory, which posits that setting and monitoring goals affect performance [324], may be considered as a theoretical and conceptual platform for gamification.
- **Mastery:** is the process of becoming skilled and competent. It is assumed that every human strives for mastery and superiority due to an inherent tendency towards feeling competent and achieving perfect completion. Mastery is another human psychological need of the SDT [64].
- **Reinforcement and progress-tracking:** According to Skinner’s Reinforcement Theory [325], the individual’s behaviour is a function of its consequences. Based on the principles of causality, this theory implies that an individual’s behaviour is regulated by the type of reward or reinforcement. Given that gamification is reward-oriented, the reinforcement theory may be regarded as another important theoretical background for gamification.

Table 5.3: Specific requirements section structure.

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|   |
|---|
| 3. Specific requirements                |
| 3.1. External interfaces                |
| 3.2. Functions                          |
| 3.3. Usability requirements             |
| 3.3.1. Learnability                     |
| 3.3.2. Operability                      |
| 3.3.3. User interface aesthetics        |
| 3.4. Performance requirements           |
| 3.5. Logical database requirements      |
| 3.6. Design constraints                 |
| 3.7. Software System quality attributes |
| 3.7.1. Functional Suitability           |
| 3.7.1.1. Functional appropriateness     |
| 3.7.2. Reliability                      |
| 3.7.3. Availability                     |
| 3.7.4. Security                         |
| 3.7.4.1. Confidentiality and privacy    |
| 3.7.4.2. Integrity                      |
| 3.7.4.3. Authenticity                   |
| 3.7.5. Maintainability                  |
| 3.7.6. Portability                      |
| 3.8. Supporting information             |
| 3.9. Other requirements                 |
| 3.9.1. Gamification requirements        |

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- **Autonomy:** Considered as a salient psychological need that everyone strives to achieve, autonomy refers to one's perception of having freedom to make meaningful choices [326]. Its inclusion in the gamification process should foster engagement, sustainable motivation, enjoyment, and better performance [327].
- **Fun and playfulness:** Fun is the key to create motivation, addiction and virality. Conceptually, this is the fundamental process of gamification that induces pleasant feelings and enjoyable experiences. Because of this goal, it is very important that using the system is ultimately fun and the user has a positive experience, otherwise it does not matter how well it should theoretically work.

### **Functional suitability requirements**

Functional suitability is one of the most important quality characteristics, since it entails that a software product meets the needs and requirements of its users. Besides functional appropriateness, it covers functional correctness which alludes to the degree of the system to generate correct results with the needed level of precision, and functional completeness that stands for the system's capacity to provide all the functions specified by the user [98].

- **Functional appropriateness requirements**

Functional appropriateness is understood as the capacity of the system to facilitate the accomplishment of the different tasks and usage objectives that have been specified through carrying out the necessary requirements [98,297]. It is one of the three sub-characteristics of functional suitability as defined in the ISO/IEC 25010 Product Quality Model. The functional appropriateness of a given software system is measured through assessing the outcomes' appropriateness of all the identified usage objectives that can be pursued in the system, individually and collectively [100]. With respect to gamified apps, functional appropriateness is a crucial quality attribute that should be covered to strengthen the intended persuasive benefits of the gamified software.

### **Usability requirements**

Usability has long been recognized as an influential factor affecting the productivity and the success of interactive systems and products [320,328]. As a product quality characteristic, usability is defined in the ISO standard [98] as "the extent to which a product, system, or service can be used by specified users to attain specified goals with effectiveness, efficiency, freedom of risk and satisfaction in a specified context of use". Six attributes are encountered under the usability characteristic which are: appropriateness recognizability, learnability, operability, user interface aesthetics, user error protection and accessibility.

- **Learnability requirements**

Learnability is, in some respect, the most fundamental usability attributes that not only leads to better productivity but also plays a central role in adopting or rejecting a software application upon the first use. It implies the ease with which a software product can be grasped and understood by users. Learnability encompasses three major measure dimensions: simplicity, description and user guidance completeness and error messages understandability [100]. Simplicity entails a genuine and self-explanatory user interface that enables user perform common tasks without prior training or seeking external assistance. The second dimension denotes the integrity of the details present in user documentations that are supposed to facilitate the use of the software product. Error messages understandability, for its part, points to the clarity, language appropriateness and placement of error messages. Error messages should acutely define the problem, the cause of it and presents possible solutions.

- **Operability requirements**

Operability is another essential sub-characteristic of usability. It delineates the capability of the software product to enable the user to operate and control it [98]. A highly operable software system is one that minimizes the time and effort needed for unplanned actions in order to keep the system running; similarly, a software system with good operability will make diagnosis and anticipation of errors straightforward. Assessing operability revolves around several metrics including system consistency and suitability, self-explanatory messages, undoability, customisability and familiarity [100]. System consistency implies the coherence between appearance and operational behaviour while performing interactive tasks. Self-explanatory messages depict the self-descriptiveness of the software product through all the available messages that could eventually help the user in making good use of the software and/or resolving a potential error. While undoability marks the capability of the software product to allow users cancel or undo actions without harmful effects to the normal operation, customisability points out the ability of the software system to enable users to customize interface elements and system functionalities to match their specific preferences and conveniences. Familiarity, for its part, refers to whether the interface of the software product has elements that are familiar to the users and convenient for their tasks that can likely improve the user experience.

- **User interface aesthetics requirements**

Whereas most of usability sub-characteristics fall into inherent usability assessment, user interface aesthetics is considered an apparent usability attribute and one of the determinants of user satisfaction. It is defined as “the extent to which the user interface enables pleasing and satisfying interaction for the user” [98]. The aesthetic-usability effect which refers to the tendency to perceive attractive software products as more usable has been first studied in the field of human–computer interaction in 1995 [329] and it was concluded that aesthetic appeal is strongly correlated to perceived ease of use rather than to the actual one. Thus, it is

necessary to state that users are positively influenced by an aesthetically appealing interface which is likely to make them more tolerant of minor usability issues, yet, not of more serious ones. Measuring user interface aesthetics of a given software product requires a scrupulous evaluation of factors such as the visual appeal of the user interface, the clarity and size adequacy of objects, the font suitability and the colour combinations employed [330].

### **Security requirements**

Security and data privacy issues are one of the major hurdles threatening the effectiveness of mHealth apps. Being one of the central quality characteristics, security is defined as the degree of information and data protection provided by a software product so that users have a level of data access appropriate to their types and levels of authorization [98,319]. It covers five sub-characteristics which are confidentiality, authenticity, integrity, non-repudiation, accountability.

- **Privacy and confidentiality requirements**

Although the terms privacy and confidentiality are commonly used interchangeably, they are related but not identical concepts. While both are rooted in law, confidentiality is particularly rooted in ethics. In digital healthcare, confidentiality serves to protect users from inappropriate disclosure of personal health information hence limiting access to only authorized parties [98]. Privacy, on the other hand, refers to the legal protection of data through granting users the right to have some control over the acquisition, uses, or disclosure of their personal (and personal health) information [215]. Two essential elements are used to measure the confidentiality and data privacy of a given software product: access controllability which restricts the accessing grants of any illegal users to data, and data protection which is tightly associated with the level of correctness and strength of encryption algorithms and mechanisms [100].

- **Integrity requirements**

Integrity is another crucial sub-characteristic of security. When it comes to data, integrity demands maintaining and assuring their overall completeness, accuracy and completeness. This implies that the data should not be illegally tampered, improperly modified, deliberately deleted, or maliciously counterfeited. Therefore, integrity can be assessed through measuring the extent to which the software system prevents violations through user errors and malicious intrusions by unauthorized entities [100]. Additionally, the robustness of protection mechanisms that eradicate data corruption and ensure data longevity highly affects the level of data integrity [100,308].

- **Authenticity requirements**

Authenticity is an integral component of information security. It involves proof of identity [100], thus helps to reduce instances of illegal intrusions by way of misrepresentation. It can be verified through identification acuteness and the strength of the authentication mechanisms implemented [308].

### **Generation of the catalog**

With the purpose of simplifying the search and reuse of the requirements identified in the GHA-CAT and in conjunction with their integration with the existing requirements documents, each category of requirements investigated in the present study is incorporated in the corresponding subsection of the SRS. Requirements for each subsection are shown in Table 5.4 to 5.7. The identification of requirements has been performed in a way that adheres to ‘loose coupling and high cohesion’ guideline, in order to ensure a high degree of flexibility of the whole system. Each requirement has a unique identifier and a clear description. Additional attributes may be completed to capture further information about the requirement such as source, date, priority, status, rationale and risk [331]. These attributes can subsequently be used to manage both the requirements and the project along with helping to track the status of the project and its underlying engineering activities throughout the system lifecycle. Requirements traceability is an overarching requirements management practice that not only defines requirements dependencies but also allows for analysis of how potential changes in requirements impact other requirements and the project as a whole. Tracing requirements can take different forms such as dependency, derivation, inclusion, exclusion, satisfaction, validation, among others [332]. Table 5.7 presents some examples of requirements extracted from the aforementioned information sources. For each example, the source, original texts and final requirement description are indicated.

## **5.4 Audit method**

Using the GHA catalog as a starting point, an audit method has been defined on the basis of previous audit approaches for requirements engineering [247,249,333] to systematically and comprehensively evaluate gamified mHealth apps. Artifacts, activities and actors involved in the audit method are depicted in Figure 5.2.

### **Artifacts and roles of the audit method**

During the audit process, an adapted version of the catalog CHA-CAT\* is generated to suit the specific gamified health app and its working context in which the audit is to be applied. The CHA-CAT\* artifact may include only a subset of requirements presented in the catalog but should keep all their properties intact. Afterwards, a customized and user-friendly checklist is obtained from the GHA-CAT\* to ensure the fulfillment of each item

Table 5.4: Gamification requirements.

| ID     | Requirement description  |
|--------|--|
| G-G1   | The app shall be user-centered in that it reflects user perceptions.   |
| G-G2   | The app shall integrate a combination of game mechanics.   |
| G-G3   | Gamification elements shall be well and seamlessly integrated.   |
| G-G4   | The app shall stand upon a clear set of guiding rules to avoid reward-driven behavior and cheating.  |
| G-G5   | Gamification elements shall not crowd out intrinsic motivation for performing interesting tasks.   |
| G-RS11 | The app shall enable social discovery between users.   |
| G-RS12 | Basic information in user profiles shall be public within the app community to promote social interactions.  |
| G-RS13 | The app shall provide at least one social interaction mechanism (commenting, tagging, instant messaging, etc).   |
| G-RS14 | The app shall enable users to build and/or join communities of users that truly match their areas of interest and goals.   |
| G-PG1  | The app shall scale the difficulty and help users acquire new skills.  |
| G-PG2  | The app shall scale the challenges according to the user's current abilities.  |
| G-PG3  | The app shall provide constant and actionable feedback which not only inform users about their performance but also hints at the potential next actions towards the goals. |
| G-PG4  | The app shall help users identify the importance of their goals in order to facilitate goal commitment.  |
| G-PG5  | The app shall encourage users to fail and try again to foster persistence.   |
| G-PG6  | The app shall include small attainable goals to help users begin new behaviors and keep commitments.   |
| G-M1   | The gamification strategy employed in the app shall lead to a sense of mastery.  |
| G-M2   | The app shall show users a path to mastery.  |
| G-M3   | The gamification elements shall remain tangibly motivating users toward total mastery.   |
| G-M4   | The app shall offer a challenging environment and guidance for users to achieve their mastery interests.   |
| G-M5   | The app shall implement levels in that they strengthen competence and mastery.   |
| G-RP1  | The app shall provide users with an immediate feedback on their performance.   |
| G-RP2  | The app shall enable users to constantly track their progress.   |
| G-RP3  | The app shall reward each user's progress through extrinsic incentives (e.g. points, badges, trophies).  |
| G-RP4  | The app shall display rewards in real time.  |
| G-RP5  | Rewards shall not be overwhelming.   |
| G-A1   | Users shall have the ability and freedom of choice, decision and/or customization  |
| G-A2   | The app shall allow users create their own visual character (avatar).  |
| G-A3   | The app shall enable users to choose from a set of predefined challenges.  |
| G-A4   | The app shall grant users with the possibility to redeem virtual rewards.  |
| G-A5   | Tasks implemented in the app shall be meaningful for the user.   |
| G-FP1  | The app shall induce a sense of game-like playfulness while serving a serious purpose.   |
| G-FP2  | The app shall include a roster of quests that update on a daily basis  |
| G-FP3  | The app shall be fun to use.   |

\*G: General, RS1: Relatedness and Social influence, PG: Purpose and Goal-setting, M: Mastery, RP: Reinforcement and progress tracking, A: Autonomy, FP: Fun and Playfulness.

Table 5.5: Functional suitability requirements.

| ID     | Requirement description   |
|--------|---|
| FS-FA1 | The functional content of the app shall be useful for users in a way that matches their needs and expectations. |
| FS-FA2 | The features and functionalities of the app shall be clear and simple to access and use.                        |
| FS-FA3 | The features and functionalities of the app shall be consistent and well-integrated.                            |
| FS-FA4 | Through its different sections, the app shall provide utile and adequate content to the users.                  |

\*FA: Functional appropriateness



in the app under study. The last artifact is the audit report which is created to synthesize the results of the evaluation made. The actors or roles implied in the audit process are the following:

- Audit client: Person or organization that requests the audit for a given gamified mHealth app.

Table 5.6: Usability requirements.

| ID     | Requirement description  |
|--------|--|
| U-L1   | The user shall be able to easily learn to use the app and its features.  |
| U-L2   | The design of the app shall be comprehensible by the user.   |
| U-L3   | The interaction design of the app shall be intuitive, easy to learn and equally easy to remember.                      |
| U-L4   | The design elements and controls shall be placed in familiar locations and similar functions shall behave similarly.   |
| U-L5   | The app user interface should be simple with succinct elements and clear features.                                     |
| U-L6   | The app shall include a help section.  |
|        | [U-L6-1] The help section shall be well complete, easy to scan and effortlessly searchable.                            |
|        | [U-L6-2] The help section shall have all resources and contact information accessible at any given point.              |
|        | [U-L6-3] The help section shall be context sensitive and shall explain how to achieve common tasks.                    |
| U-L7   | The app shall handle errors in a right way.  |
| U-L8   | The error messages shall be polite, friendly and jargon-free.  |
| U-L9   | The error messages shall be placed next to the user interface elements they are related to.                            |
| U-L10  | The app shall use a visual design that make error messages easily noticeable.  |
| U-OP1  | The interface actions and elements of the app shall be consistent.   |
| U-OP2  | The app informational content shall be categorized adequately.   |
| U-OP3  | All in-app messages available in the application shall be clear, concise and understandable.                           |
| U-OP4  | The error messages shall be helpful to fix system's issues and recover from the error.                                 |
|        | [U-OP4-1] The error messages shall be specific to the situation  |
|        | [U-OP4-2] The error messages shall be constructive and precise.  |
| U-OP5  | The app shall provide users with the ability to back track and with means to undo or reverse actions.                  |
|        | [U-OP5-1] Undo function shall be available for most operations.  |
|        | [U-OP5-2] Actions which cannot be undone shall ask for confirmation.   |
| U-OP6  | The app shall be customizable to meet specific user needs.   |
|        | [U-OP6-1] The app shall enable users to configure language settings to suit their preferences.                         |
|        | [U-OP6-2] The app shall enable users to change the units of measurement when convenient.                               |
|        | [U-OP6-3] The app shall be built to handle both screen orientations (vertical and horizontal).                         |
| U-OP7  | The user interface design of the app shall contain recognition patterns which give slight hints on how the apps works. |
| U-OP8  | The app shall use a simple and natural dialogue that speaks the language of the user.                                  |
| U-UIA1 | The app content shall be well-presented and well-ordered.  |
| U-UIA2 | The overall app user interface shall have an appropriate outlook.  |
| U-UIA3 | The design of the app user interface shall suit the purpose of the app.  |
| U-UIA4 | The objects of the app user interface shall be appealing to the user.  |
|        | [U-UIA4-1] The objects shall be visually identifiable.   |
|        | [U-UIA4-2] The objects shall occupy an appropriate area.   |
| U-UIA5 | The fonts used for text in the app shall be appropriate.   |
|        | [U-UIA5-1] The font styles shall be easily legible.  |
|        | [U-UIA5-2] The font styles shall be attractive.  |
| U-UIA6 | The color scheme used on the app's user interface shall be adequate.   |
|        | [U-UIA6-1] The colours used shall be logically related.  |
|        | [U-UIA6-2] The colours theme shall be consistent.  |
|        | [U-UIA6-3] The colours shall be attractive.  |

\*L: Learnability, OP: Operability, UIA: User interface Aesthetics

Table 5.7: Security requirements.

| ID     | Requirement description  |
|--------|--|
| S-PC1  | The app shall provide a privacy policy.<br>[S-PC2-1] The privacy policy shall be understandable and conspicuously posted.<br>[S-PC2-2] The privacy policy shall clearly inform users of the information accessed, collected or transmitted by the app and how that information is used, secured and disclosed.   |
| S-PC2  | Functionality that may infringe the privacy and security of users shall not be activated before the user voluntarily and in the knowledge of the related risks gives his/her consent.  |
| S-PC3  | The app data stored in the user device shall be encrypted to prevent leakage.  |
| S-PC4  | The personal data shall be adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed.<br>[S-PC4-1] Only personal data necessary for the purpose(s) shall be processed.  |
| S-PC5  | Personal data shall be processed in a manner that ensures appropriate security, including protection against un-authorized or unlawful access and processing.  |
| S-I1   | Personal data shall be processed in a manner that ensures appropriate protection against accidental loss, destruction or damage.<br>[S-I1-1] Data transit (Sending and receiving) inside the app shall be via secure mediums.  |
| S-I2   | The app shall consider data portability to leverage the security level of bigger companies and save the hassle to collect and protect user's data.   |
| S-I3   | The app shall allow input validation to check the data supplied by the user in order to prevent malformed data.  |
| S-AUT1 | The app shall verify the identity of users before allowing them access to its functionalities.<br>The app shall provide a strong authentication mechanism (at least a two-factor authentication such as Username/password identification).<br>[S-AUT4-1]. The password should contain at least eight characters and should expect at least one uppercase, one digit and one special character. |
| S-AUT2 | [S-AUT4-2]. The app shall not allow users to use the exact same previous password when resetting a new password.<br>[S-AUT4-3]. The app shall provide an additional layer of security (e.g. biometric identification) when it comes to authentication on devices that support it (e.g. iris/facial recognition, fingerprint).  |

\*PC: Privacy and confidentiality, I: Integrity, AUT: Authenticity.

- System administrators: People assigned to install and manage the gamified mHealth app.
- RE team: People responsible for the creation of the CHA-CAT and supposedly the generation of the GHA-CAT\* and the checklist. These two artifacts can be managed by the RE team and audit team conjointly or by one of them.
- Audit team: Person or group of people in charge of performing the audit process.

### Phases and activities of the audit method

The four different artifacts are either created or used by the actors throughout the audit process. The main activities and phases that constitute the audit method are described as follows:

#### Phase 1. Initial analysis of the situation

In this first phase, the environment of the system to be audited is thoroughly inspected to grasp the settings that are triggered when the system is running. The audit client, audit

Table 5.8: Examples of requirements for gamified eHealth apps as extracted from some information sources.

| Sources   | Original text   | Extracted requirements  |
|---|---|---|
| <b>Example 1. Gamification requirements -Relatedness and Social influence</b> |   |   |
| [285]   | "From a social perspective, gamification has a huge potential as regards improving communication and bilateral encouragement among users by means of social sharing (e.g. posts) and instant messaging."  | [G-RSI3]. The app shall provide at least one social interaction mechanism (commenting, tagging, instant messaging, etc).  |
| [49]  | "Social influence, through the identification and internalisation processes relevant for group-formation, affects attitude to using the service."   | [G-RSI4]. The app shall enable users to build and/or join communities of users that truly reflect their connections of interest and goals.  |
| [334]   | "Receiving recognition from others positively affects the user's attitude to using the service."  |   |
| [335]   | "Relatedness can be supported by various social interactions, such as tagging, rating, commenting and sharing with communities."  |   |
| <b>Example 2. Functional suitability -Functional appropriateness</b>          |   |   |
| [336]   | "A releasable product should cover a coherent set of tasks and objectives and meet clear needs."  | [FS-FA1]. The functional content of the app shall be useful for users in a way that matches their needs and expectations.   |
| [296,307]   | "Each section in the app shall be complete and useful for users."   |   |
| <b>Example 3. Usability – Learnability</b>                                    |   |   |
| [337,338]   | "Keep the interface simple. The best interfaces are almost invisible to the user. They avoid unnecessary elements and are clear."   | [U-L5]. The user interface of the app should be simple with succinct elements and clear features.   |
| [339]   | "Keeping the user interface lightweight, so it does not delay work."  |   |
| [340]   | "Over-crowded features or over-precisely arrangement of objects may lose spontaneity and dilute focus."   |   |
| <b>Example 4. Security – Authenticity</b>                                     |   |   |
| [308]   | "Services should identify and verify the identity and of all of its human users before allowing them access to their resources."  | [S-AUT2]. The app shall provide a strong authentication mechanism (at least a two-factor authentication such as Username/password identification).  |
| [215]   | "The authentication must be done with a unique ID and a password only known by the user. The password used must be complex, with at least seven characters and a combination of letters and numbers, including one capitalized letter and a special character." | [S-AUT2-1]. The password should contain at least eight characters and should expect at least one uppercase, one digit and one special character.  |
| [337]   | "Give people a simple and secure way to sign in."   | [S-AUT2-2]. The app shall not allow users to use the exact same previous password when resetting a new password.<br>[S-AUT2-3]. The app shall provide an additional layer of security (e.g. biometric identification) when it comes to authentication on devices that support it (e.g. iris/facial recognition, fingerprint). |

team and system administrators are all involved in the activities of this phase. The audit client is interviewed to determine and reach an agreement on the budget and schedule of the audit process. A questionnaire is, then, administered to the system administrators in order to demarcate the scope of the system, its functional and non-functional specification, its documentation and its users' profiles. The last activity of the first phase deals with the analysis of the questionnaire submitted by the system administrators to assist the RE team in specifying the particular needs of the client in terms of characteristics to be audited.

## Phase 2. Expert audit of the system

This is the core phase of the whole audit process and is divided into three major activities. First, the RE team creates an adapted and a more concise version of the catalog GHA-CAT\* using reusable requirements approach and the audit team proceeds to orderly map all the requirements onto items of a checklist to conduct the audit. Subsequently, the audit team checks the system to verify the fulfilment or non-fulfilment of the requirements contained in the GHA-CAT\* and to assess the items included in the checklist. Although it is not necessary, the user audit validation is the last activity of this phase which consists of completing the checklist by real results and compare their results with those obtained in the second activity.

### Phase 3. Final audit report and conclusions

To wrap up the audit process, the audit team collects the assessment results and write the final audit report in which weaknesses of the system, threats for the users and recommendations are identified. Once the report has been completed and delivered to the audit client, an interview is held between the audit team and the system administrators. This interview has a dual purpose. On the one hand, the audit team should explain to the system administrators the information contained in the report and describe the deviations detected in the e-health system. On the other hand, the system administrators are supposed to understand the threats pointed out in the audited system and adopt the corrective measures proposed by the audit team.

## 5.5 Audit illustration

This section illustrates the applicability of the catalog GHA-CAT and the audit method described previously using two mHealth apps illustrations. The selected apps; *Blood Donor*

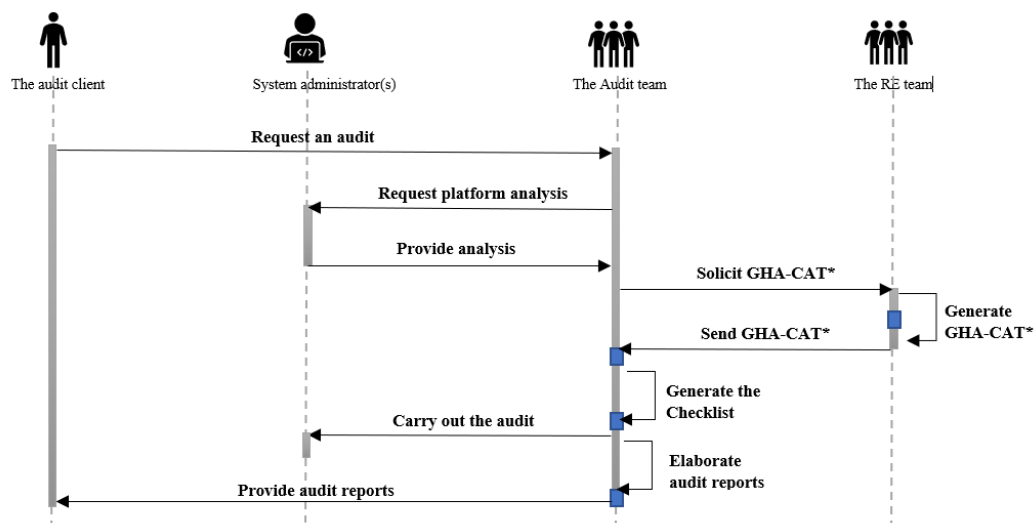


Figure 5.2: Audit process.

and *Move it Mama* are dedicated for BD and PNC, respectively. The *Blood Donor* app is perhaps the most gamified app in BD field. The *Move it Mama* app, in contrast, does not employ gamification in a comprehensive manner, however it is the only app for PNC that include at least one gamification element. Note that the design, development and evaluation of BD and PNC apps represent one of the main investigation areas of the authors. Moreover, evaluating two applications pertaining, each, to different health aspect rather than a large discipline, will likely emphasize the pertinence of the evaluation and refine the resulting conclusions.

**Illustration 1: Blood donation App**

*Blood Donor* is a free app developed by the American Red Cross to motivate people to donate blood through gamification principles. The app is available in both Google play and Apple app stores. For the sake of this evaluation, the iOS version of the Blood Donor app has been used. Some characteristics of the app can be found in Table 5.9. The Blood Donor app offers plenty of features that help users geolocate nearby blood drives and donation centers, schedule and manage their donation appointments, track their donation history and earn virtual rewards, to cite but a few.

**Illustration 2: Postnatal care App**

*Move it Mama* is a paid app developed for both platforms; Android and iOS which offers a 7-day trial. In this study, only the iOS version has been considered. This application provides guided and personalized training for puerperal women towards an easy and fast postnatal recovery. Besides, it gives information on all pregnancy and postnatal phases. Table 5.10 displays some of the characteristics of this app. Both apps have been installed on an iPhone X, iOS 13.3.1. Given that both apps are gamified, they have been analysed, separately, using the audit method previously described to check whether they properly integrate gamification principles and adequately cover the aspects included in the GHA-CAT. The results of these analyses may be helpful in the identification of potential gaps in the features offered by the apps and the improvement of their capabilities with regards the characteristics embodied in

Table 5.9: Characteristics of the *Blood Donor* app

|                         |   |
|-------------------------|---|
| <b>Name</b>             | Blood Donor   |
| <b>Developer</b>        | American Red Cross  |
| <b>Website</b>          | <a href="https://www.redcrossblood.org/blood-donor-app.html">https://www.redcrossblood.org/blood-donor-app.html</a> |
| <b>Category</b>         | Medical   |
| <b>iOS</b>              | Requires iOS 12.0 or later  |
| <b>Version</b>          | 1.10.0  |
| <b>Last update</b>      | January 23, 2020  |
| <b>Rating</b>           | 3.7 out of 5  |
| <b>Number of raters</b> | 931   |
| <b>Downloads</b>        | 500 000+  |
| <b>Languages</b>        | English   |
| <b>Login</b>            | Mandatory (Password)  |

Table 5.10: Characteristics of the *Move it Mama* app

|                         |   |
|-------------------------|---|
| <b>Name</b>             | Move it Mama  |
| <b>Developer</b>        | MO BIG GmbH   |
| <b>Website</b>          | <a href="https://www.moveitmama.de/">https://www.moveitmama.de/</a> |
| <b>Category</b>         | Health & Fitness  |
| <b>iOS</b>              | Requires iOS 11.0 or later  |
| <b>Version</b>          | 1.4.0   |
| <b>Last update</b>      | February 25, 2020   |
| <b>Rating</b>           | Not enough  |
| <b>Number of raters</b> | -   |
| <b>Downloads</b>        | -   |
| <b>Languages</b>        | English   |
| <b>Login</b>            | No  |

the GHA-CAT. Each phase of the audit process is detailed in the following paragraphs. All the individuals involved in this audit are IT professionals and highly acquainted with quality evaluation of mobile software.

**Initial analysis of the situation.** As a first step of the audit process, a preliminary analysis of the app work environments has been performed. The user documentation and information available in the official website of the app [341, 342] and in the app’s website at Apple app store [343, 344] have been studied to gain insight into the purpose of the app, its functionalities and features.

**Expert audit of the e-Health system.** The RE team has then carried out an expert audit of the two apps. In this respect, a checklist has been generated from the adapted catalog GHA-CAT\* which included major aspects in terms of gamification, functional suitability, usability and security. To facilitate the audit process, the checklist took the form of a questionnaire regrouping 29 items. The possible answer to these questions is either ‘Yes’, ‘No’, ‘Partially’ or ‘N/A’ which means not applicable. Table 5.11 displays the results of the audit performed on both apps. The results obtained are supposed to draw conclusions on the inclusion of gamification elements and the degree to which the two apps fulfil most of the quality aspects previously described. Accordingly, there was a variance in the answers obtained for the two apps. For *Blood Donor* app, twenty-six questions (89.7%) received positive answers and three questions received negative answers. It became clear that this app has gone through iterative tests and evaluation to yield this large coverage in terms of gamification and quality aspects. With regards *Move it Mama* app, a total of eighteen questions received positive answers and five questions got negative answers. Four other questions were rated as ‘partially’ fulfilled such as for Q1 and Q11. Indeed, *Move it Mama* app relies solely on badges as the gamification element which substantially impacts the perceived playfulness of the application. The two remaining questions were judged not applicable for this application. The *Move it Mama* app does not provide an informational content, nor it handles utilization errors.

**Final audit report and conclusions.** As a final step in system audit, the RE team gathered

all the assessment results obtained to write a final audit report for each app. A simple instance of this output is presented in Table C.1 in Appendix C. In this table, the audit report for both apps are displayed separately for a better space optimization.

## 5.6 Discussion

Despite the growing popularity of gamification in mHealth apps, no specific standard has been found to clearly define reusable requirements in terms of the integration of gamification elements. Thus, the GHA-CAT is very useful for developers and designers of gamified mHealth apps. Conjointly with gamification core pillars, the GHA-CAT also includes reusable relevant quality requirements of which developers can elicit and specify their needs with regards functional suitability, usability and security as being considered highly effective within gamified systems [300].

The primary common use of reusable requirements catalogs is to serve as a leadoff for the efficient development of recurring software products in order to achieve better quality, reduce time-to-market and lower development cost [302]. Yet, they may also be exploited to perform an audit on a specific software feature. Accordingly, the GHA-CAT was used to conduct an audit on two gamified mHealth apps dedicated for distinct health disciplines. Auditing software product is a unambiguous process that is easy to learn and apply. The expertise of the auditors in the domain is important but not imperative thanks to the use of checklists. The use of checklists in auditing is progressively gaining attention given its multiple advantages in terms of time efficiency, easiness and effectiveness. In fact, the checklist approach is considered as a basic tool for auditors and it is remarkably convenient to use in that it helps to assure the full coverage of software requirements along the systematization of the whole audit process and the uniformity between the auditors [345]. On this wise, the checklist generated from the GHA-CAT includes the most relevant requirements among the categories addressed in the present study. In what follows, the results of the audit conducted

Considering the fulfilled items among those in the checklist, the *Blood Donor* app yielded a coverage score of 89.7% whereas the *Move it Mama* app has obtained a score of 74.1%. Perhaps the main reason behind the difference between these scores is the infancy of gamification use in PNC apps. However, after completing a search of apps for PNC, the *Move it Mama* app was found to be the unique app that employs at least one gamification aspect. It has been noted that *Move it Mama* app integrates a poor combination of gamification elements consisting of badges and challenges which certainly bolster the sense of mastery and autonomy. Correspondingly, several other game mechanics shall be implemented to yield user motivation and engagement with this app, such as in-app points system, leaderboards and a social community. Earning points in real time for accomplished missions and losing them for unaccomplished or missed goals are considered a great practice to efficiently encourage users to loyally use the app [285]. Moreover, enhancing social influence by means of social

CHAPTER 5. REUSABLE REQUIREMENTS CATALOG FOR GAMIFIED HEALTH APPS

Table 5.11: Generated audit checklist applied to *Blood donor* and *Move it Mama* apps.

| ID  | Question   | Results         |                  | Corresponding requirement ID |
|-----|--|-----------------|------------------|------------------------------|
|     |  | Blood Donor App | Move it Mama App |                              |
| Q1  | Does the app integrate a combination of game mechanics?  | Yes             | Partially        | G-G2                         |
| Q2  | Are the gamification elements well and seamlessly integrated into the application?   | Yes             | Yes              | G-G3                         |
| Q3  | Does the app provide at least one social interaction mechanism (commenting, tagging, instant messaging, etc.)?             | Yes             | No               | G-RSI3                       |
| Q4  | Does the app enable the user to build and/or join communities of users that truly match their areas of interest and goals? | Yes             | No               | G-RSI4                       |
| Q5  | Does the app scale the challenges according to the user's current abilities?   | Yes             | Yes              | G-PG2                        |
| Q6  | Does the app include small attainable goals to help users begin new behaviors and keep commitments?                        | Yes             | Yes              | G-PG6                        |
| Q7  | Does the app provide the user with an immediate feedback on their performance?   | Yes             | Yes              | G-RP1                        |
| Q8  | Does the app enable the user to constantly track their progress?   | Yes             | Yes              | G-RP2                        |
| Q9  | Does the app reward user progress through extrinsic incentives (e.g. points, badges, trophies)?                            | Yes             | Yes              | G-RP3                        |
| Q10 | Does the app grant users with the possibility to redeem their virtual rewards?   | Yes             | No               | G-A4                         |
| Q11 | Does the app include a sense of game-like playfulness while serving a serious purpose?                                     | Yes             | Partially        | G-FP1                        |
| Q12 | Are the features and functionalities of the app clear and simple to access and use?  | Yes             | Partially        | FS-FA2                       |
| Q13 | Are the features and functionalities of the app consistent and well-integrated?  | Yes             | Partially        | FS-FA3                       |
| Q14 | Is the design of the app easily comprehensible by the users?   | Yes             | Yes              | U-L2                         |
| Q15 | Is the interaction design of the app intuitive, easy to learn and equally easy to remember?                                | Yes             | Yes              | U-L3                         |
| Q16 | Does the app include a help section?   | Yes             | No               | U-L6                         |
| Q17 | Does the app handle errors in a right way?   | Yes             | N/A              | U-L7                         |
| Q18 | Are the error messages polite, friendly and jargon-free?   | Yes             | N/A              | U-L8                         |
| Q19 | Is the informational content of the app categorized adequately?  | Yes             | Yes              | U-OP2                        |
| Q20 | Is the undo function available for most operations?  | Yes             | Yes              | U-OP5-1                      |
| Q21 | Does the app enable users to configure language settings to suit their preferences?  | No              | No               | U-OP6-1                      |
| Q22 | Does the app enable users to handle both screen orientations?  | No              | Yes              | U-OP6-3                      |
| Q23 | Is the content of the app well-presented and well-ordered?   | Yes             | Yes              | U-UIA1                       |
| Q24 | Are the fonts used for text in the app appropriate?  | Yes             | Yes              | U-UIA5                       |
| Q25 | Is the color scheme used on the user interface of the app adequate?  | Yes             | Yes              | U-UIA6                       |
| Q26 | Does the app provide a privacy policy?   | No              | Yes              | S-PC1                        |
| Q27 | Does the app process only relevant personal data?  | Yes             | Yes              | S-PC4-1                      |
| Q28 | Does the app allow input validation to check the data supplied?  | Yes             | Yes              | S-I3                         |
| Q29 | Does the app provide a strong authentication mechanism?  | Yes             | Yes              | S-AUT2                       |



interaction and sharing is essential to create engaging gamified services [49]. In that, getting recognized for completing challenges is likely to strengthen commitment towards them and induce friendly competition and social connectivity. While gamification is still in its infancy in PNC arena, the BD arena, has already taken advantage of the benefits of the various persuasive strategies of gamification through several apps [209]. Moreover, gamifying BD has gained attention from many researchers who have clearly reported their usefulness and effectiveness in promoting BD [205,206,292].

Accounting with twenty-six positive answers, the *Blood Donor* app has only a few minor flaws with regards usability and security. Therein, this app lacks the ability of screen orientation which it is not only helpful for users with low vision but also provides opportunities to create better user experience as it offers an additional layout with a simple turn of the device. Further, the Blood Donor app does not implement a multi-language support, undoubtedly, because it is intended for American residents, however, the United States has always been a country noted for its linguistic diversity. It goes without saying that English language apps tend to fare well in many parts of the world but adopting the native language of users is paramount as it avoids miscommunication, widens reachability and builds loyalty and user trust. Furthermore, the absence of the privacy policy in this app may lead in violation of user privacy. Although being included in the website of the app, it is highly recommended to present an in-app privacy policy that accessible for the user at any moment [215].

The *Move it Mama* app however, obtained eighteen positive answers due to the poor gamification implementation and numerous usability issues. The overall design of the app rendered it confusing and difficult to comprehend. With redundancy of content among sections, inconsistent features and ambiguous navigation, the user experience is likely to be negatively affected. Thus, in order to enhance the user experience, it is advisable to follow certain design practical guidelines such as simple navigation, concise and clear content, easily readable text and appropriate colour scheme. Another flaw noticed in the *Move it Mama* app is the absence of an in-app help section that shall clearly displays help and useful instructions for the users. This section shall be easily reachable, and its content shall be straightforward and concise. Analogous to the Blood Donor app, the Move it Mama app also lacks the multilingual support which may significantly hamper its ability to reach wider audience.

On the average, both apps have been found to suffer from a few usability and security issues that are likely to impact their user experience regardless of their popularity and the health purpose they aspire to. In contrast, it has been elucidated that gamification has gained more popularity in BD area and still in its early emergence when it comes to PNC. App developers shall therefore endorse the persuasive strategies of gamification in order to render PNC apps more playful and enjoyable while still assisting the mothers in their postnatal journey.

### Study limitations

This study may have several limitations. First, it may have overlooked a number of requirements relevant for gamified mHealth apps. However, to mitigate this issue, many recommended standards, guidelines and pertinent scientific researches have been considered in the elicitation of the most common requirements for gamified mHealth apps. Second, this study has only investigated two mHealth apps as examples to evaluate the catalog and assess the applicability of the audit process. As an attempt to alleviate this issue, the two apps belong to different health disciplines and have been used essentially to illustrate the application of the GHA-CAT in the evaluation of gamified systems. Third, the efficiency of the audit method may appear too straightforward and draws biased conclusions. In an attempt to mitigate this issue, the auditors have a significant level of practical knowledge in terms of requirements engineering and auditing and have conducted the process in the utmost objectivity and credibility. Finally, the checklist generated may have omitted certain valuable requirements for one or both application examples. Notwithstanding, this checklist has covered all the main categories of requirements. Importantly, the checklist remains adaptable to any gamified health system as long as an adjusted version of the catalog is generated.

## 5.7 Conclusion

This chapter has proposed a reusable requirements catalog for gamified mHealth apps, denominated as GHA-CAT, that can be adapted to various health disciplines. Originated from recommended standards and multiple information sources, this catalog has encompassed the most relevant requirements as regards gamification, functional suitability, usability and security that should be considered in the design and development of effective gamified mHealth apps.

This chapter has also introduced an audit method to harness the utility of the catalog. A checklist has been established to demonstrate the practical applicability of the catalog and the audit method on real gamified mHealth apps. In this respect, two mHealth apps have been selected, namely *Blood Donor* which is a famous app for BD promotion, and *Move it Mama* which focuses on PNC. The checklist that has been used for the evaluation of these two apps, contained 29 requirements that were retrieved from the catalog and plainly apply to the specification of both apps.

The results show that the two apps yielded two different scores, however, both of them had a few issues in terms of usability. Contrary to the important presence of gamification elements in *Blood Donor*, an poor and inadequate implementation of gamification has been perceived in the *Move it Mama* app which has significantly lessen its coverage degree (74.1%). Based on these results, a number of valuable recommendations and encountered deficiencies have been formulated for a better improvement of the overall quality of the apps.

For future work, it is intended to prioritize the catalog items using an appropriate requirements prioritization technique in order to guarantee the usefulness of the catalog even in critical circumstances (i.e. tight deadlines, budgetary constraints). It is also expected to continuously improve the content of the catalog using additional information sources such as new standards or other stakeholders' needs.

## Conclusions and future work

*"It always seems impossible until it's done."*

*- Nelson Mandela*

This chapter summarizes the main findings of the research described in the thesis. The aim and objectives of the research are reviewed and an emphasis is placed on the research achievements and contributions. Moreover, this chapter outlines broad implications for researchers and practitioners, along with some possible directions for future work.

### 6.1 Review of research objectives

This thesis investigated the use of gamification in mHealth solutions. A particular attention has been drawn towards BD and PNC areas. To gain a deep insight into how gamification is being applied to the digital health environment, a thorough SLR has been conducted. In this regard, a number of relevant papers have been selected and critically scrutinized. Moreover, the functionalities and gamification aspects of existing BD apps have been analyzed. The impact of these requirements on the overall quality of the BD app has been calculated using the ISO/IEC 25010 quality model. Besides, a proper understanding of donors' behaviour has been gained through the application of TTM principles. On these grounds, a gamified mobile solution to enhance the recruitment and retention of blood donors has been developed. Another review has been carried out to explore the functionalities and features of available PNC apps. Geared to respond to women's real needs in terms of PNC in Morocco, a comprehensive mobile solution has been developed and fully implemented as part of a collaboration with Maternity Les oranges in Rabat under a research PEER project. Owing to the novelty of gamification PNC context, a practical strategy to implement gamification elements in the PNC solution has been proposed. Based on the foregoing, a

catalog of reusable requirements for gamified mHealth apps has been constructed including key gamification aspects and some important usability and security measures. Finally, an audit approach has been proposed to evaluate the compliance of gamified mHealth apps with the requirements presented the catalog, when applicable.

## 6.2 Achievements

The purpose of the thesis is to develop a greater understanding of applying gamification techniques to mHealth solutions. Hence, this research has produced a number of original scientific contributions that are indicated in the following:

1. **Investigating the use of gamification in the health context.** Chapter 2 has presented the state-of-the-art research on the use of gamification in digital health solutions. Relevant papers in this area, published between 2000 and 2015 were identified. A total of 46 papers were therefore selected. It was noted that the rapid emergence of gamification into healthcare area has gained a major interest among researchers and practitioners in the field. According to the results obtained, it was found that the majority of the papers analyzed were solution proposals or research evaluations. However, almost half of these studies lack some empirical evidence. The findings of this SLR also indicated the particular presence of gamification elements in contexts mostly related to chronic disease management and physical activity. Rewards, feedback and social integration were the gamification elements predominantly investigated. Further, a few challenges facing the use of gamification were pointed out. The predominant concerns as regards gamification were associated to the questionable long-term viability of its effect on the users and to the non-significance of some incentives to the users. In contrast, couple of perceived benefits of gamification were highlighted, of which yielding a regular user's engagement and immersion into the health solution was the mostly stated.
2. **Analyzing functionalities and features of BD apps and PNC apps.** In chapter 3, a review of existing BD apps has been conducted. A total of 10 gamified BD apps were selected out of 801 candidate apps and went through an 8-item questionnaire to assess their functional comprehensiveness. It was found that the majority of these apps included notifications, geolocation feature and social networking as a way to motivate users to donate blood. As regards gamification, various elements were implemented in these apps including points, badges, leaderboards and financial rewards. Chapter 3 has also scrutinized the functionalities and technical features in existing PNC apps. Using the SLR process, a total of 48 apps was analyzed based on a set of 37 assessment questions covering postnatal-related characteristics together with security, usability and internationalization aspects. The findings of this review showed that PNC apps mostly dealt with monitoring the baby's development and providing guidance and

information as regards baby care and postpartum care. Besides, it was noted that the highest assessment score obtained was of 59%, denoting the low compliance of the apps with the characteristics. Accordingly, functionalities related to postpartum care such as weight tracking and mother's sleep diary were not found in the apps analyzed. The privacy policies encountered in 63% of these apps were also studied resulting in an unstandardized guidance and regulation on addressing users' privacy concerns. Moreover, only 12 apps were found to fully conform with the usability features assessed whilst the multi-language support was implemented in merely 8 apps.

3. **Evaluating the influence of BD apps' requirements on SPQ using ISO/IEC 25010.** Chapter 3 has provided a general overview of gamified BD apps' requirements which have been retrieved from literature and existing apps on the market. These requirements were then regrouped in four categories: App's accessibility, donor's personal information, user's actions and app's components. Using the ISO/IEC 25010 quality model, a checklist was established to calculate the degree of impact of these requirements on 30 external sub-characteristics. The results of this study showed a significant variability in the degree of impact of the requirements identified. In particular, users' actions and app's features were the blocks of requirements that reached a very high degree of influence on quality characteristics. Moreover, functional suitability and operability were the mostly influenced quality characteristics contrary to compatibility and transferability who reached a very low degree of influence; 16% and 11% respectively.
4. **Specifying the requirements to develop a stage-matched gamified BD mHealth solution.** Chapter 4 has explored the applicability of TTM constructs to blood donors' behaviour change. A cross-sectional survey was therefore conducted on a sample of 504 Spanish individuals. These respondents shared their perceptions on the factors that likely motivate them and/or discourage them from voluntarily giving blood. The results obtained indicated that most of the TTM constructs differentiated participants across the stages of change, particularly processes of change, self-efficacy and physical cons. Besides, significant correlations were observed between TTM constructs except for the physical cons and the processes of change. Chapter 4 has also presented the requirements and characteristics of a tailored gamified BD apps, denominated 'Blood4Life' which aims at targeting all types of users in terms of their stage of change which defines their readiness and willingness to donate blood. By means of a variety of gamification elements and according to the initial stage of change of the user, the solution is likely to trigger the processes of change that are assumed to encourage users to progress towards later stages.
5. **Developing and implementing a comprehensive mobile solution to promote PNC in Morocco.** In chapter 4, a set of requirements has been identified to build a solution dedicated to assist new mothers during their postnatal period. These requirements were

mainly formulated based on the findings of the review presented in chapter 3 and were, then, enriched with real needs elicited at maternity Les oranges in Rabat. In addition to these functional and non-functional requirements, chapter 4 has also proposed a gamification strategy to boost user engagement and turn the postnatal rollercoaster into a fun, enjoyable and appealing experience. After the analysis and design phases, a pilot version of the solution called 'Mamma&Baby' has been implemented using android framework. Moreover, chapter 4 has presented the core activities and questionnaires to perform an empirical quality evaluation of the solution with real participants.

6. **Constructing a reusable requirements catalog for gamified mHealth apps.** Chapter 5 has presented a catalog of reusable requirements related to gamification, functional suitability, usability and security. These requirements are deemed to be crucial in building effective gamified mHealth apps. A number of international standards, guidelines and multiple information sources were used to formulate these requirements. To illustrate the practical applicability of the catalog, an approach of software audit has been performed. Chapter 5 has therefore outlined the key methodological steps to perform this audit method and it has described the entire audit process. In this vein, a gamified BD app and a gamified PNC app were selected to undergo the audit process. A checklist was generated from the catalog and contained 29 items. The results obtained indicated a noticeable lack of usability aspects in both apps and gamification was poorly integrated in the PNC app. An audit report was elaborated to summarize all details as regards the apps' characteristics, deficiencies, and recommendations for potential improvements.

### 6.3 Implications for research and practice

The research achievements synthesized above arise several implications and recommendations for researchers and practitioners working in the mHealth field.

These implications include:

- The findings of the SLR can be beneficial for researchers to draw considerable attention to the long-term effect of gamification on user engagement through conducting longitudinal empirical studies that are likely to yield more accurate results. On the other hand, practitioners, are advised to be more aware about the possible gaps in the gamified applications that may lead to cheating and overlooking the health outcomes aspired. Whilst involving game-designers in the building process of gamified applications is extremely important, developers should imperatively address the security and privacy issues.
- The analysis of functionalities and features of BD and PNC apps may help researchers and practitioners in the identification of pertinent requirements to develop evidence-

based and tailored solution to promote BD and PNC. Further, the checklist used in the quality evaluation of BD apps can serve as a tool to draw up the essential requirements that help enhance the overall external quality of gamified BD apps.

- The TTM measures developed to understand blood donors' behaviour may be useful in the development of stage-matched interventions aiming at increasing individuals' intention to give blood. Accordingly, practitioners should learn techniques that can potentially drive positive behaviour change and implement them on well-founded theoretical strategies. For instance, developers may combine gamification elements and TTM constructs as proposed in Blood4Life to build solutions geared toward changing behaviour.
- The design of the gamified postnatal mobile solution may be useful for developers and clinical researchers in the digitalization of this crucial reproductive service. In this direction, the requirements specification proposed for this solution can serve as a starting point to develop more persuasive solutions that cater to the needs of both mothers and newborns during the postnatal period.
- Researchers, developers and evaluators can all benefit from the reusable requirements catalog and the audit approach proposed. On the one hand, the requirements catalog may open a wide room of investigation and improvement to researchers as regards the use of gamification in mHealth apps. On the other hand, this catalog may support developers in the elicitation of vital requirements of such apps. Moreover, the audit approach suggested may be useful for all parties. Researchers and developers should focus on the deficiencies encountered in the apps audited as a way to enhance them, and evaluators can benefit from the entire audit process to assess the conformity of other gamified mHealth solutions with some predefined requirements.

## 6.4 Future work

The results in this thesis lay the groundwork for a proper understanding of the use of gamification in mHealth apps. There are some natural and immediately accessible avenues for future research that would help expand and support the results.

Therefore, it is intended to complete the implementation of the BD solution and develop a related facet for blood centers in order to efficiently track eligibility and manage blood appointments of prospective donors. Following implementation, we will perform a longitudinal empirical evaluation with real participants to assess the effectiveness of the solution in BD behavior change and measure its potency in the optimization of donors' recruitment and retention.

As regards the PNC solution, we plan to complete the implementation of the solution



by integrating the gamification elements. Afterwards, we will conduct an empirical evaluation with a group of puerperal women (real users) to gather their perceptions and credible feedback as regards its overall quality and potential. Further features are expected to be continuously included to improve the effectiveness of the solution in facilitating access to PNC such as a geo-targeted feature to locate nearby healthcare providers, pharmacies and street hospitals. Moreover, we plan to enhance the security and privacy measures of the solution.

Future research will also involve the prioritization of the requirements enclosed in the catalog using an adequate prioritization technique in order to ensure the usefulness of the catalog even in critical circumstances (i.e. tight deadlines, budgetary constraints). It is also expected to continuously improve the content of the catalog using additional information sources such as new standards or other stakeholders' needs.

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... every doctoral thesis should have an end. Thus, I rest my case!

# Papers included in this thesis

## Published papers

- Lamyae Sardi, Ali Idri and José Luis Fernández-Alemán. 'A Systematic Review of Gamification in e-Health'. *Journal of Biomedical Informatics* 71. pp. 31-48, 2017. *2019 JCR Impact factor: 3.526.*
- Lamyae Sardi, Ali Idri and José Luis Fernández-Alemán. 'Gamified Mobile Blood Donation Applications'. In the 5th International Conference on Bioinformatics and Biomedical Engineering (IWBBIO), Granada, Spain, April 25-28 (pp. 165-176). Springer, Cham, 2017.
- Ali Idri, Lamyae Sardi and José Luis Fernández-Alemán. 'Quality Evaluation of Gamified Blood Donation Apps'. In the 11th International Conference on Health Informatics (HealthInf 2018), pp. 607-614. Funchal, Madeira, Portugal, 19-21 January 2018. *CORE 2020: C.*
- Lamyae Sardi, Ali Idri, Juan Manuel Carrillo de Gea, Ángel Toval and José Luis Fernández-Alemán. 'Applying Trans-theoretical Model for Blood Donation among Spanish Adults: a Cross-sectional Study'. *BMC Public Health*, 2019, 19(1), p. 1-13. *2018 JCR Impact factor: 2.69.*
- Lamyae Sardi, Manal Kharbouch, Taoufik Rachad, Ali Idri, Juan Manuel Carrillo de Gea and José Luis Fernández-Alemán. 'Blood4life: A Mobile Solution to Recruit and Retain Blood Donors through Gamification and Trans-theoretical Model'. In World Conference on Information Systems and Technologies (WorldCIST) (pp. 3-12). Springer, Cham, April 2019. *CORE 2020: C.*
- Lamyae Sardi, Ali Idri, Leanne M Redman, Hassan Alami, Rachid Bezaoui and José Luis Fernández-Alemán. 'Mobile Health Applications for Postnatal Care: Review and Analysis of Functionalities and Technical Features'. *Computer methods and programs in biomedicine*, 184, pp. 105-114, 2020. *2019 JCR Impact factor: 3.632.*

- Lamyae Sardi, Ali Idri, Taoufik Rachad, Leanne M Redman, and Hassan Alami. 'Gamified e-Health Solution to Promote Postnatal Care in Morocco: Requirements Specification and Experiment Design of Quality Evaluation'. In International Conference on Computational Science and Its Applications ICCSA (pp. 931-946). Cagliari, Italy, 1-4 July, 2020 (Online). *CORE 2020: C*.

### **Submitted papers**

- Lamyae Sardi, Ali Idri, Leanne M Redman, Hassan Alami and José Luis Fernández-Alemán. 'A Reusable Catalog of Requirements for Gamified Mobile Health Applications'. Under revision in a journal.

# Bibliography

- [1] Lars Thurn, Agneta Wikman, Magnus Westgren, and Pelle G Lindqvist. Incidence and risk factors of transfusion reactions in postpartum blood transfusions. *Blood advances*, 3(15):2298–2306, 2019.
- [2] Daniel Surbek, Yvan Vial, Thierry Girard, Christian Breymann, Gabriela Amstad Bencaiova, David Baud, René Hornung, Behrouz Mansouri Taleghani, and Irene Hösli. Patient blood management (pbm) in pregnancy and childbirth: literature review and expert opinion. *Archives of gynecology and obstetrics*, 301(2):627–641, 2020.
- [3] Muhammad Muzzammil Edhi, Hafiz Muhammad Aslam, Zehra Naqvi, and Haleema Hashmi. Post partum hemorrhage: causes and management. *BMC research notes*, 6(1):236, 2013.
- [4] Jerry E Squires. Artificial blood. *Science*, 295(5557):1002–1005, 2002.
- [5] Lorna M Williamson and Dana V Devine. Challenges in the management of the blood supply. *The Lancet*, 381(9880):1866–1875, 2013.
- [6] Robert M Oswalt and Marie Napoliello. Motivations of blood donors and nondonors. *Journal of Applied Psychology*, 59(1):122, 1974.
- [7] Theresa W Gillespie and Christopher D Hillyer. Blood donors and factors impacting the blood donation decision. *Transfusion Medicine Reviews*, 16(2):115–130, 2002.
- [8] Pascale Reich, Paula Roberts, Nancy Laabs, Artina Chinn, Patrick McEvoy, Nora Hirschler, and Edward L Murphy. A randomized trial of blood donor recruitment strategies. *Transfusion*, 46(7):1090–1096, 2006.
- [9] Ilias Fotopoulos, Revekka Palaiologou, Ioannis Kouris, and Dimitrios Koutsouris. Cloud-based information system for blood donation. In *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*, pages 802–807. Springer, 2016.

- [10] Robert C Eklund and Gershon Tenenbaum. *Encyclopedia of sport and exercise psychology*. Sage Publications, 2013.
- [11] Mattea Romano, Alessandra Cacciatore, Rosalba Giordano, and Beatrice La Rosa. Postpartum period: three distinct but continuous phases. *Journal of prenatal medicine*, 4(2):22, 2010.
- [12] World Health Organization. A handbook for building skills counselling for maternal and newborn health (updated). <https://bit.ly/2NxxqL0C/>, 2014. Accessed February 18, 2019.
- [13] Julia Chessman, Jillian Patterson, Tanya Nippita, Bradley Drayton, and Jane Ford. Haemoglobin concentration following postpartum haemorrhage and the association between blood transfusion and breastfeeding: a retrospective cohort study. *BMC research notes*, 11(1):686, 2018.
- [14] Étienne V Langlois, Malgorzata Miszkurka, Maria Victoria Zunzunegui, Abdul Ghaffar, Daniela Ziegler, and Igor Karp. Inequities in postnatal care in low-and middle-income countries: a systematic review and meta-analysis. *Bulletin of the World Health Organization*, 93:259–270G, 2015.
- [15] Anam Feroz, Shagufta Perveen, and Wafa Aftab. Role of mhealth applications for improving antenatal and postnatal care in low and middle income countries: a systematic review. *BMC health services research*, 17(1):704, 2017.
- [16] Lindsay S Uman. Systematic reviews and meta-analyses. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, 20(1):57, 2011.
- [17] Khalid S Khan, Regina Kunz, Jos Kleijnen, and Gerd Antes. Five steps to conducting a systematic review. *Journal of the royal society of medicine*, 96(3):118–121, 2003.
- [18] Chitu Okoli. A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems*, 37(1):43, 2015.
- [19] Jon A Krosnick. Survey research. *Annual review of psychology*, 50(1):537–567, 1999.
- [20] Robert M Groves, Floyd J Fowler Jr, Mick P Couper, James M Lepkowski, Eleanor Singer, and Roger Tourangeau. *Survey methodology*, volume 561. John Wiley & Sons, 2011.
- [21] Julie Ponto. Understanding and evaluating survey research. *Journal of the advanced practitioner in oncology*, 6(2):168, 2015.
- [22] Kate Kelley, Belinda Clark, Vivienne Brown, and John Sitzia. Good practice in the conduct and reporting of survey research. *International Journal for Quality in health care*, 15(3):261–266, 2003.

- [23] Vera Toepoel and Matthias Schonlau. Dealing with nonresponse: Strategies to increase participation and methods for postsurvey adjustments. *Mathematical Population Studies*, 24(2):79–83, 2017.
- [24] Daniela Haluza and David Jungwirth. Ict and the future of health care: aspects of health promotion. *International journal of medical informatics*, 84(1):48–57, 2015.
- [25] Stephen James Gentles, Cynthia Lokker, and K Ann McKibbin. Health information technology to facilitate communication involving health care providers, caregivers, and pediatric patients: a scoping review. *Journal of medical Internet research*, 12(2):e22, 2010.
- [26] Steven R Steinhubl, Evan D Muse, and Eric J Topol. The emerging field of mobile health. *Science translational medicine*, 7(283):283rv3–283rv3, 2015.
- [27] Caroline Free, Gemma Phillips, Louise Watson, Leandro Galli, Lambert Felix, Phil Edwards, Vikram Patel, and Andy Haines. The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. *PLoS Med*, 10(1):e1001363, 2013.
- [28] World Health Organization et al. mhealth: new horizons for health through mobile technologies. *mHealth: new horizons for health through mobile technologies.*, 2011.
- [29] Shahriar Akter and Pradeep Ray. mhealth-an ultimate platform to serve the unserved. *Yearbook of medical informatics*, 19(01):94–100, 2010.
- [30] Sapal Tachakra, XH Wang, Robert SH Istepanian, and YH Song. Mobile e-health: the unwired evolution of telemedicine. *Telemedicine Journal and E-health*, 9(3):247–257, 2003.
- [31] Murray Aitken, Brian Clancy, and Deanna Nass. The growing value of digital health: evidence and impact on human health and the healthcare system. *IQVIA Institute for Human Data Science*, page p1, 2017.
- [32] Richard Pankomera and Darelle van Greunen. A model for implementing sustainable mhealth applications in a resource-constrained setting: A case of malawi. *The Electronic Journal of Information Systems in Developing Countries*, 84(2):e12019, 2018.
- [33] Jessica L Baldwin, Hardeep Singh, Dean F Sittig, and Traber Davis Giardina. Patient portals and health apps: Pitfalls, promises, and what one might learn from the other. In *Healthcare*, volume 5, pages 81–85. Elsevier, 2017.
- [34] Oyungerel Byambasuren, Sharon Sanders, Elaine Beller, and Paul Glasziou. Prescribable mhealth apps identified from an overview of systematic reviews. *NPJ digital medicine*, 1(1):1–12, 2018.

- [35] Daniel Johnson, Sebastian Deterding, Kerri-Ann Kuhn, Aleksandra Staneva, Stoyan Stoyanov, and Leanne Hides. Gamification for health and wellbeing: A systematic review of the literature. *Internet interventions*, 6:89–106, 2016.
- [36] Jennifer K Carroll, Anne Moorhead, Raymond Bond, William G LeBlanc, Robert J Petrella, and Kevin Fiscella. Who uses mobile phone health apps and does use matter? a secondary data analytics approach. *Journal of medical Internet research*, 19(4):e125, 2017.
- [37] Ganesh Bhutkar, J Karande, and Manikrao Dhore. Major challenges with mobile healthcare applications. *The British Journal of Healthcare Computing and Information Management*, 9(09), 2009.
- [38] Constantinos K Coursaris and Dan J Kim. A meta-analytical review of empirical mobile usability studies. *Journal of usability studies*, 6(3):117–171, 2011.
- [39] Rosnita Baharuddin, Dalbir Singh, and Rozilawati Razali. Usability dimensions for mobile applications—a review. *Res. J. Appl. Sci. Eng. Technol*, 5(6):2225–2231, 2013.
- [40] Susan D Birkhoff and Helene Moriarty. Challenges in mobile health app research: Strategies for interprofessional researchers. *Journal of Interprofessional Education & Practice*, page 100325, 2020.
- [41] Leysan Nurgalieva, David O’Callaghan, and Gavin Doherty. Security and privacy of mhealth applications: A scoping review. *IEEE Access*, 8:104247–104268, 2020.
- [42] Tobias Dehling, Fangjian Gao, Stephan Schneider, and Ali Sunyaev. Exploring the far side of mobile health: information security and privacy of mobile health apps on ios and android. *JMIR mHealth and uHealth*, 3(1):e8, 2015.
- [43] Marianne Holdener, Alain Gut, and Alfred Angerer. Applicability of the user engagement scale to mobile health: a survey-based quantitative study. *JMIR mHealth and uHealth*, 8(1):e13244, 2020.
- [44] Sebastian Deterding, Rilla Khaled, Lennart E Nacke, Dan Dixon, et al. Gamification: Toward a definition. In *CHI 2011 gamification workshop proceedings*, volume 12. Vancouver BC, Canada, 2011.
- [45] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining "gamification". In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pages 9–15, 2011.
- [46] Yongwen Xu. Literature review on web application gamification and analytics. *Honolulu, HI*, pages 11–05, 2011.
- [47] Gabe Zichermann and Joselin Linder. *Game-based marketing: inspire customer loyalty through rewards, challenges, and contests*. John Wiley & Sons, 2010.

- [48] Kevin Werbach. (re) defining gamification: A process approach. In *International conference on persuasive technology*, pages 266–272. Springer, 2014.
- [49] Juho Hamari and Jonna Koivisto. Social motivations to use gamification: an empirical study of gamifying exercise. 2013.
- [50] Simone de Sousa Borges, Vinicius HS Durelli, Helena Macedo Reis, and Seiji Isotani. A systematic mapping on gamification applied to education. In *Proceedings of the 29th annual ACM symposium on applied computing*, pages 216–222, 2014.
- [51] D Michael and S Chen. Serious games: Games that educate, train, and inform, boston, ma: Thomson. nunnally, jc (1978). psychometric theory, 2006.
- [52] BG Stokes. Videogames have changed: time to considerserious games'? *Development Education Journal*, 11(3):12, 2005.
- [53] Francesco Ricciardi and Lucio Tommaso De Paolis. A comprehensive review of serious games in health professions. *International Journal of Computer Games Technology*, 2014, 2014.
- [54] Damien Djaouti, Julian Alvarez, Jean-Pierre Jessel, and Olivier Rampnoux. Origins of serious games. In *Serious games and edutainment applications*, pages 25–43. Springer, 2011.
- [55] McKeown S. Safety, gamification for healthcare improvement. <https://bit.ly/39bWpIv/>, 2015. Accessed February 10, 2016.
- [56] Hee Jung Park and Jae Hwan Bae. Study and research of gamification design. *International Journal of Software Engineering and Its Applications*, 8(8):19–28, 2014.
- [57] Doug Palmer, Steve Lunceford, and Aaron J Patton. The engagement economy: how gamification is reshaping businesses. *Deloitte Review*, 11, 2012.
- [58] Brian Cugelman. Gamification: what it is and why it matters to digital health behavior change developers. *JMIR serious games*, 1(1):e3, 2013.
- [59] Zeynep Turan, Zeynep Avinc, Kadir Kara, and Yuksel Goktas. Gamification and education: Achievements, cognitive loads, and views of students. *International Journal of Emerging Technologies in Learning (IJET)*, 11(07):64–69, 2016.
- [60] Valentina Rao and Playful Pandas. Designing gamification for behavior change in mental health: challenges and perspectives. *LARSEN Proceedings*, 2013.
- [61] Sumayah Abu-Dawood. The cognitive and social motivational affordances of gamification in e-learning environment. In *2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT)*, pages 373–375. IEEE, 2016.



- [62] Jim Lumsden, Elizabeth A Edwards, Natalia S Lawrence, David Coyle, and Marcus R Munafò. Gamification of cognitive assessment and cognitive training: a systematic review of applications and efficacy. *JMIR serious games*, 4(2):e11, 2016.
- [63] Umar Ruhi. Level up your strategy: Towards a descriptive framework for meaningful enterprise gamification. *Technology Innovation Management Review*, 2015.
- [64] Michael Sailer, Jan Ulrich Hense, Sarah Katharina Mayr, and Heinz Mandl. How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69:371–380, 2017.
- [65] Gabe Zichermann and Christopher Cunningham. *Gamification by design: Implementing game mechanics in web and mobile apps*. " O'Reilly Media, Inc.", 2011.
- [66] Juho Hamari, Jonna Koivisto, and Harri Sarsa. Does gamification work?—a literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences*, pages 3025–3034. Ieee, 2014.
- [67] Markets and markets. Gamification market worth \$ 30.7 billion by 2025. <https://bit.ly/3nietqn/>, 2020. Accessed June 10, 2020.
- [68] Industry ARC. Serious games market - industry analysis, market size, share, trends, application analysis, growth and forecast 2020 - 2025. <https://bit.ly/3462tkb/>, 2020. Accessed June 10, 2020.
- [69] Manuel Oliveira and Sobah Petersen. The choice of serious games and gamification. In *International Conference on Serious Games Development and Applications*, pages 213–223. Springer, 2014.
- [70] Philipp Herzig, Michael Ameling, and Alexander Schill. A generic platform for enterprise gamification. In *2012 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture*, pages 219–223. IEEE, 2012.
- [71] Jon Froehlich. *Gamifying green: gamification and environmental sustainability*, 2015.
- [72] Oliver Vicente, Sandra Vicente, Daniel Martin, Miguel Angel Rodriguez-Florido, and Manuel Maynar. Health gamification. In *Proceedings of the 2014 Summer Simulation Multiconference*, pages 1–7, 2014.
- [73] David Lenihan. Health games: a key component for the evolution of wellness programs. *Games for Health: Research, Development, and Clinical Applications*, 1(3):233–235, 2012.
- [74] Salla Munro, Simon Lewin, Tanya Swart, and Jimmy Volmink. A review of health behaviour theories: how useful are these for developing interventions to promote long-term medication adherence for tb and hiv/aids? *BMC public health*, 7(1):104, 2007.

- [75] Eamonn Ferguson. Predictors of future behaviour: A review of the psychological literature on blood donation. *British Journal of Health Psychology*, 1(4):287–308, 1996.
- [76] Sandy Whitelaw, Steve Baldwin, Robin Bunton, and Darren Flynn. The status of evidence and outcomes in stages of change research. *Health Education Research*, 15(6):707–718, 2000.
- [77] Icek Ajzen. From intentions to actions: A theory of planned behavior. In *Action control*, pages 11–39. Springer, 1985.
- [78] Martin Fishbein and Icek Ajzen. Belief, attitude, intention, and behavior: An introduction to theory and research. 1977.
- [79] Icek Ajzen. Understanding attitudes and predicting social behavior. *Englewood Cliffs*, 1980.
- [80] Icek Ajzen. *Attitudes, personality, and behavior*. McGraw-Hill Education (UK), 2005.
- [81] Albert Bandura, WH Freeman, and Richard Lightsey. Self-efficacy: The exercise of control, 1999.
- [82] Icek Ajzen. Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior 1. *Journal of applied social psychology*, 32(4):665–683, 2002.
- [83] Eamonn Ferguson and Peter A Bibby. Predicting future blood donor returns: Past behavior, intentions, and observer effects. *Health Psychology*, 21(5):513, 2002.
- [84] Melanie Giles, Carol Mcclenahan, Ed Cairns, and J Mallet. An application of the theory of planned behaviour to blood donation: the importance of self-efficacy. *Health education research*, 19(4):380–391, 2004.
- [85] Barbara M Masser, Katherine M White, Melissa K Hyde, Deborah J Terry, and Natalie G Robinson. Predicting blood donation intentions and behavior among australian blood donors: testing an extended theory of planned behavior model. *Transfusion*, 49(2):320–329, 2009.
- [86] Eamonn Ferguson and Susie Chandler. A stage model of blood donor behaviour: Assessing volunteer behaviour. *Journal of health psychology*, 10(3):359–372, 2005.
- [87] James O Prochaska. Self change processes, self efficacy and decisional balance across five stages of smoking cessation. *Prog Clin Biol Res*, 156:131–140, 1984.
- [88] Nicole R Amoyal, Mark L Robbins, Andrea L Paiva, Caitlin Burditt, Debra Kessler, and Beth H Shaz. Measuring the processes of change for increasing blood donation in black adults. *Transfusion*, 53(6):1280–1290, 2013.

- [89] KL Hall and JS Rossi. Examining the transtheoretical model using meta-analytic procedures and integrative analyses. *Research on the transtheoretical model: Where are we now, where are we going*, pages 56–58, 2004.
- [90] Kara L Hall and Joseph S Rossi. Meta-analytic examination of the strong and weak principles across 48 health behaviors. *Preventive medicine*, 46(3):266–274, 2008.
- [91] James O Prochaska, Wayne F Velicer, Carlo C DiClemente, and Joseph Fava. Measuring processes of change: applications to the cessation of smoking. *Journal of consulting and clinical psychology*, 56(4):520, 1988.
- [92] Caitlin Burditt, Mark L Robbins, Andrea Paiva, Wayne F Velicer, Beryl Koblin, and Debra Kessler. Motivation for blood donation among african americans: developing measures for stage of change, decisional balance, and self-efficacy constructs. *Journal of behavioral medicine*, 32(5):429, 2009.
- [93] James O Prochaska and Wayne F Velicer. The transtheoretical model of health behavior change. *American journal of health promotion*, 12(1):38–48, 1997.
- [94] Hiyam Al-Kilidar, Karl Cox, and Barbara Kitchenham. The use and usefulness of the iso/iec 9126 quality standard. In *2005 International Symposium on Empirical Software Engineering, 2005.*, pages 7–pp. IEEE, 2005.
- [95] P Botella, X Burgués, JP Carvallo, X Franch, G Grau, J Marco, and C Quer. Iso/iec 9126 in practice: what do we need to know. In *Software Measurement European Forum*, volume 2004, 2004.
- [96] Yiannis Kanellopoulos, Panos Antonellis, Dimitris Antoniou, Christos Makris, Evangelos Theodoridis, Christos Tjortjis, and Nikos Tsirakis. Code quality evaluation methodology using the iso/iec 9126 standard. *arXiv preprint arXiv:1007.5117*, 2010.
- [97] Rafa E Al-Qutaish. An investigation of the weaknesses of the iso 9126 international standard. In *2009 Second International Conference on Computer and Electrical Engineering*, volume 1, pages 275–279. IEEE, 2009.
- [98] ISO/IEC-25010. *Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models*. 2011.
- [99] ISO/IEC 25022. *Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE)- Measurement of quality in use*. 2016.
- [100] ISO/IEC 25023. *Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Measurement of system and software product quality*. 2016.

- [101] International Standard ISO/IEC FDIS 25030. *Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Quality requirements framework*. 2019.
- [102] Dharendra Pandey, Ugrasen Suman, and AK Ramani. An effective requirement engineering process model for software development and requirements management. In *2010 International Conference on Advances in Recent Technologies in Communication and Computing*, pages 287–291. IEEE, 2010.
- [103] Pankaj Jalote. *An integrated approach to software engineering*. Springer Science & Business Media, 2012.
- [104] Jawed Siddiqi and M Chandra Shekaran. Requirements engineering: The emerging wisdom. *Ieee Software*, 13(2):15, 1996.
- [105] Patricia Stone. Popping the (pico) question in research and evidence-based practice. *Applied nursing research : ANR*, 15:197–8, 09 2002.
- [106] Belén Cruz Zapata, José Luis Fernández-Alemán, Ali Idri, and Ambrosio Toval. Empirical studies on usability of mhealth apps: a systematic literature review. *Journal of medical systems*, 39(2):1, 2015.
- [107] Core computing research and education, conference portal,. <http://portal.core.edu.au/conf-ranks/>, 2016. Accessed March 15, 2016.
- [108] Roel Wieringa, Neil Maiden, Nancy Mead, and Colette Rolland. Requirements engineering paper classification and evaluation criteria: a proposal and a discussion. *Requirements engineering*, 11(1):102–107, 2006.
- [109] Mary Shaw. What makes good research in software engineering? *International Journal on Software Tools for Technology Transfer*, 4(1):1–7, 2002.
- [110] Joseph A Cafazzo, Mark Casselman, Nathaniel Hamming, Debra K Katzman, and Mark R Palmert. Design of an mhealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of medical Internet research*, 14(3):e70, 2012.
- [111] Ahmed Allam, Zlatina Kostova, Kent Nakamoto, and Peter Johannes Schulz. The effect of social support features and gamification on a web-based intervention for rheumatoid arthritis patients: randomized controlled trial. *Journal of medical Internet research*, 17(1):e14, 2015.
- [112] Jennifer N Stinson, Lindsay A Jibb, Cynthia Nguyen, Paul C Nathan, Anne Marie Maloney, L Lee Dupuis, J Ted Gerstle, Benjamin Alman, Sevan Hopyan, Caron Strahendorf, et al. Development and testing of a multidimensional iphone pain assessment

- application for adolescents with cancer. *Journal of medical Internet research*, 15(3):e51, 2013.
- [113] Cameron Lister, Joshua H West, Ben Cannon, Tyler Sax, and David Brodegard. Just a fad? gamification in health and fitness apps. *JMIR serious games*, 2(2):e9, 2014.
- [114] Ainara Garde, Aryannah Umedaly, S Mazdak Abulnaga, Leah Robertson, Anne Junker, Jean Pierre Chanoine, J Mark Ansermino, and Guy A Dumont. Assessment of a mobile game (“mobilekids monster manor”) to promote physical activity among children. *Games for Health Journal*, 4(2):149–158, 2015.
- [115] Alicia Beltran, Teresia O’Connor, Sheryl Hughes, Janice Baranowski, Theresa A Nicklas, Debbe Thompson, and Tom Baranowski. Alpha test of a videogame to increase children’s vegetable consumption. *GAMES FOR HEALTH: Research, Development, and Clinical Applications*, 1(3):219–222, 2012.
- [116] Kim CM Bul, Ingmar HA Franken, Saskia Van der Oord, Pamela M Kato, Marina Danckaerts, Leonie J Vreeke, Annik Willems, Helga JJ Van Oers, Ria Van den Heuvel, Rens Van Slagmaat, et al. Development and user satisfaction of “plan-it commander,” a serious game for children with adhd. *Games for health journal*, 4(6):502–512, 2015.
- [117] Juho Hamari and Jonna Koivisto. “working out for likes”: An empirical study on social influence in exercise gamification. *Computers in Human Behavior*, 50:333–347, 2015.
- [118] Jonna Koivisto and Juho Hamari. Demographic differences in perceived benefits from gamification. *Computers in Human Behavior*, 35:179–188, 2014.
- [119] Harmen Nauta and Ton AM Spil. Change your lifestyle or your game is over: The design of a serious game for diabetes. In *2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–7. IEEE, 2011.
- [120] Tiago Martins, Vitor Carvalho, Filomena Soares, and M Fatima Moreira. Serious game as a tool to intellectual disabilities therapy: Total challenge. In *2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–7. IEEE, 2011.
- [121] Frederick Imbeault, Bruno Bouchard, and Abdenour Bouzouane. Serious games in cognitive training for alzheimer’s patients. In *2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–8. IEEE, 2011.
- [122] Dario Deponti, Dario Maggiorini, and Claudio E Palazzi. Smartphone’s psychiatric serious game. In *2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–8. IEEE, 2011.

- [123] N Alberto Borghese, Renato Mainetti, Michele Pirovano, and Pier Luca Lanzi. An intelligent game engine for the at-home rehabilitation of stroke patients. In *2013 IEEE 2nd International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–8. IEEE, 2013.
- [124] SJ Lentelink, Antonius AM Spil, T Broens, Hermie J Hermens, and Valerie M Jones. Healthy weight game!: Lose weight together. In *2013 IEEE 2nd International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–8. IEEE, 2013.
- [125] Alaa AlMarshedi, Gary B Wills, and Ashok Ranchhod. The wheel of sukr: a framework for gamifying diabetes self-management in saudi arabia. *Procedia Computer Science*, 63:475–480, 2015.
- [126] Anargyros Chatzitofis, David Monaghan, Edmond Mitchell, Freddie Honohan, Dimitrios Zarpalas, Noel E O’Connor, and Petros Daras. Hearthealth: a cardiovascular disease home-based rehabilitation system. *Procedia Computer Science*, 63:340–347, 2015.
- [127] Sean A Munson and Sunny Consolvo. Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. In *2012 6th international conference on pervasive computing technologies for healthcare (pervasivehealth) and workshops*, pages 25–32. IEEE, 2012.
- [128] Carlos Ferreira, Vânia Guimarães, António Santos, and Inês Sousa. Gamification of stroke rehabilitation exercises using a smartphone. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*, pages 282–285. ICST (Institute for Computer Sciences, Social-Informatics and . . . , 2014.
- [129] Athanasios Vourvopoulos, Ana Lúcia Faria, Kushal Ponnampalani, and Sergi Bermudez i Badia. Rehabcity: design and validation of a cognitive assessment and rehabilitation tool through gamified simulations of activities of daily living. In *Proceedings of the 11th conference on advances in computer entertainment technology*, pages 1–8, 2014.
- [130] Rui Neves Madeira, Patrícia Macedo, Sofia Reis, and João Ferreira. Super-fon: mobile entertainment to combat phonological disorders in children. In *Proceedings of the 11th Conference on Advances in Computer Entertainment Technology*, pages 1–4, 2014.
- [131] Christine Keung, Alexa Lee, Shirley Lu, and Megan O’Keefe. Bunnybolt: a mobile fitness app for youth. In *Proceedings of the 12th International Conference on Interaction Design and Children*, pages 585–588, 2013.
- [132] Alexander Miloff, Arvid Marklund, and Per Carlbring. The challenger app for social anxiety disorder: New advances in mobile psychological treatment. *Internet Interventions*, 2(4):382–391, 2015.

- [133] Tracy A Dennis and Laura J O’Toole. Mental health on the go: Effects of a gamified attention-bias modification mobile application in trait-anxious adults. *Clinical Psychological Science*, 2(5):576–590, 2014.
- [134] Michael P Craven, Zoe Young, Lucy Simons, Holger Schnädelbach, and Alinda Gillott. From snappy app to screens in the wild: Gamifying an attention deficit hyperactivity disorder continuous performance test for public engagement and awareness. In *2014 International Conference on Interactive Technologies and Games*, pages 36–43. IEEE, 2014.
- [135] Mandar Patwardhan, Ryan Stoll, Derek B Hamel, Ashish Amresh, Kevin A Gary, and Armando Pina. Designing a mobile application to support the indicated prevention and early intervention of childhood anxiety. In *Proceedings of the conference on Wireless Health*, pages 1–8, 2015.
- [136] Pedro Pereira, Emília Duarte, Francisco Rebelo, and Paulo Noriega. A review of gamification for health-related contexts. In *International conference of design, user experience, and usability*, pages 742–753. Springer, 2014.
- [137] Christopher Helf and Helmut Hlavacs. Apps for life change: Critical review and solution directions. *Entertainment Computing*, 14:17–22, 2016.
- [138] Aaron S Miller, Joseph A Cafazzo, and Emily Seto. A game plan: Gamification design principles in mhealth applications for chronic disease management. *Health informatics journal*, 22(2):184–193, 2016.
- [139] Aino Ahtinen, Pertti Huuskonen, and Jonna Häkkinä. Let’s all get up and walk to the north pole: design and evaluation of a mobile wellness application. In *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries*, pages 3–12, 2010.
- [140] Oren Zuckerman and Ayelet Gal-Oz. Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity. *Personal and ubiquitous computing*, 18(7):1705–1719, 2014.
- [141] Yu Chen and Pearl Pu. Healthytogether: exploring social incentives for mobile fitness applications. In *Proceedings of the second international symposium of chinese chi*, pages 25–34, 2014.
- [142] Alan Graham Stuart. Exercise as therapy in congenital heart disease—a gamification approach. *Progress in Pediatric Cardiology*, 38(1-2):37–44, 2014.
- [143] Paula Alexandra Silva, Kelly Holden, and Aska Nii. Smartphones, smart seniors, but not-so-smart apps: A heuristic evaluation of fitness apps. In *International Conference on Augmented Cognition*, pages 347–358. Springer, 2014.

- [144] Eliana Prada-Dominguez, Sergio Valdivia-Trujillo, Alvaro Uribe-Quevedo, and Byron Perez-Gutierrez. Lower member complimentary exercise gaming app. In *2014 IEEE Colombian Conference on Communications and Computing (COLCOM)*, pages 1–5. IEEE, 2014.
- [145] Ruofei Hu, Giuseppe Fico, Jorge Cancela, and Maria Teresa Arredondo. Gamification system to support family-based behavioral interventions for childhood obesity. In *IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI)*, pages 181–184. IEEE, 2014.
- [146] Carla V Pereira, Gustavo Figueiredo, Maria Gilda P Esteves, and Jano Moreira de Souza. We4fit: A game with a purpose for behavior change. In *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, pages 83–88. IEEE, 2014.
- [147] Zhao Zhao, S Ali Etemad, and Ali Arya. Gamification of exercise and fitness using wearable activity trackers. In *Proceedings of the 10th international symposium on computer science in sports (ISCSS)*, pages 233–240. Springer, 2016.
- [148] Christian Schönauer, Thomas Pintaric, Hannes Kaufmann, Stephanie Jansen-Kosterink, and Miriam Vollenbroek-Hutten. Chronic pain rehabilitation with a serious game using multimodal input. In *2011 International Conference on Virtual Rehabilitation*, pages 1–8. IEEE, 2011.
- [149] Philipp Brauner, André Calero Valdez, Ulrik Schroeder, and Martina Ziefle. Increase physical fitness and create health awareness through exergames and gamification. In *International Conference on Human Factors in Computing and Informatics*, pages 349–362. Springer, 2013.
- [150] Ashish Amresh, Madhumita Sinha, Rebecca Birr, and Rahul Salla. Interactive cause and effect comic-book storytelling for improving nutrition outcomes in children. In *Proceedings of the 5th International Conference on Digital Health 2015*, pages 9–14, 2015.
- [151] David Whittinghill and Jacob Brown. Gamification of physical therapy for the treatment of pediatric cerebral palsy: A pilot study examining player preferences. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
- [152] Tiago Martins, Vítor Carvalho, and Filomena Soares. A serious game for rehabilitation of neurological disabilities: Preliminary study. In *2015 IEEE 4th Portuguese Meeting on Bioengineering (ENBENG)*, pages 1–5. IEEE, 2015.
- [153] Rui Neves Madeira, Luís Costa, and Octavian Postolache. Physiomate-pervasive physical rehabilitation based on nui and gamification. In *2014 International Conference and Exposition on Electrical and Power Engineering (EPE)*, pages 612–616. IEEE, 2014.



- [154] Phillip J Hartin, Chris D Nugent, Sally I McClean, Ian Cleland, JoAnn Tschanz, Christine Clark, and Maria C Norton. Encouraging behavioral change via everyday technologies to reduce risk of developing alzheimer's disease. In *International Workshop on Ambient Assisted Living*, pages 51–58. Springer, 2014.
- [155] Konstantinos P Michmizos and Hermano Igo Krebs. Serious games for the pediatric anklebot. In *2012 4th IEEE RAS & EMBS international conference on biomedical robotics and biomechatronics (BioRob)*, pages 1710–1714. IEEE, 2012.
- [156] Judd Antin and Elizabeth F. Churchill. Badges in social media: A social psychological perspective. 2011.
- [157] Deborah Richards and Patrina HY Caldwell. Gamification to improve adherence to clinical treatment advice: improving adherence to clinical treatment. In *Handbook of research on holistic perspectives in gamification for clinical practice*, pages 47–77. IGI Global, 2016.
- [158] Claes Wohlin, Martin Höst, and Kennet Henningsson. Empirical research methods in web and software engineering. In *Web engineering*, pages 409–430. Springer, 2006.
- [159] Borja Gamecho, Hugo Silva, José Guerreiro, Luis Gardeazabal, and Julio Abascal. A context-aware application to increase elderly users compliance with physical rehabilitation exercises at home via animatronic biofeedback. *Journal of medical systems*, 39(11):135, 2015.
- [160] Sebastian Deterding, Staffan L Björk, Lennart E Nacke, Dan Dixon, and Elizabeth Lawley. Designing gamification: creating gameful and playful experiences. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pages 3263–3266. 2013.
- [161] Raul Ferrer Conill and Michael Karlsson. The gamification of journalism. In *Emerging research and trends in gamification*, pages 356–383. IGI Global, 2016.
- [162] Voravika Wattanasoontorn, Rubén Jesús García Hernández, and Mateu Sbert. Serious games for e-health care. In *Simulations, Serious Games and Their Applications*, pages 127–146. Springer, 2014.
- [163] Oana M Dan and Jennie W Lai. How am i doing? the effects of gamification and social sharing on user engagement. In *Proc. 68th Ann. Conf. American Assoc. for Public Opinion Research*, 2013.
- [164] Darina Dicheva, Christo Dichev, Gennady Agre, and Galia Angelova. Gamification in education: A systematic mapping study. *Educational Technology and Society*, 18:75–88, 2015.

- [165] Oscar Pedreira, Félix García, Nieves Brisaboa, and Mario Piattini. Gamification in software engineering—a systematic mapping. *Information and Software Technology*, 57:157–168, 2015.
- [166] Amon Rapp. A qualitative investigation of gamification: Motivational factors in online gamified services and applications. In *Gamification: Concepts, Methodologies, Tools, and Applications*, pages 32–48. IGI Global, 2015.
- [167] Tania di Mascio, Rosella Gennari, A Melonio, and Pierpaolo Vittorini. Gamify your field studies for learning about your learners. In *Methodologies and Intelligent Systems for Technology Enhanced Learning*, pages 135–142. Springer, 2014.
- [168] Elie A Akl, Kay M Sackett, Richard Pretorius, Paranthaman Seth S Bhoopathi, Reem Mustafa, Holger Schünemann, and William S Erdley. Educational games for health professionals. *Cochrane Database of Systematic Reviews*, (1), 2008.
- [169] Nina Buscemi, Lisa Hartling, Ben Vandermeer, Lisa Tjosvold, and Terry P Klassen. Single data extraction generated more errors than double data extraction in systematic reviews. *Journal of clinical epidemiology*, 59(7):697–703, 2006.
- [170] David Moher, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G Altman. Preferred reporting items for systematic reviews and meta-analyses: the prisma statement. *Annals of internal medicine*, 151(4):264–269, 2009.
- [171] Nathalie Charlier, Nele Zupancic, Steffen Fieuws, Kris Denhaerynck, Bieke Zaman, and Philip Moons. Serious games for improving knowledge and self-management in young people with chronic conditions: a systematic review and meta-analysis. *Journal of the American Medical Informatics Association*, 23(1):230–239, 2016.
- [172] Shaidah Jusoh. A survey on trend, opportunities and challenges of mhealth apps. *International Journal of Interactive Mobile Technologies (ijIM)*, 11(6):73–85, 2017.
- [173] Suman Sarkar. Artificial blood. *Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine*, 12(3):140, 2008.
- [174] WHO. More voluntary blood donors needed. <https://bit.ly/2UrF1J6/>, 2013. Accessed September 1, 2016.
- [175] Euro.who.int. Blood safety, data and statistics. <https://bit.ly/38MLB5w/>, 2011. Accessed September 1, 2016.
- [176] M.S Williams. Gamification in blood donation. <https://bit.ly/3nuYxAK/>, 2012. Accessed September 2, 2016.

- [177] Mukhammad Andri Setiawan and Heru Hangtry Putra. Bloodhub: A context aware system to increase voluntary blood donors' participation. In *2015 International Conference on Science and Technology (TICST)*, pages 231–235. IEEE, 2015.
- [178] Marcus Foth, Christine Satchell, Jan Seeburger, and Rebekah Russell-Bennett. Social and mobile interaction design to increase the loyalty rates of young blood donors. In *Proceedings of the 6th International Conference on Communities and Technologies*, pages 64–73, 2013.
- [179] Aaron Smith. *Smartphone ownership-2013 update*, volume 12. Pew Research Center Washington, DC, 2013.
- [180] Kai Huotari and Juho Hamari. Defining gamification: a service marketing perspective. In *Proceeding of the 16th international academic MindTrek conference*, pages 17–22, 2012.
- [181] Alessandro Liberati, Douglas G Altman, Jennifer Tetzlaff, Cynthia Mulrow, Peter C Gøtzsche, John PA Ioannidis, Mike Clarke, Philip J Devereaux, Jos Kleijnen, and David Moher. The prisma statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*, 151(4):W–65, 2009.
- [182] Sofia Ouhbi, José Luis Fernández-Alemán, Ambrosio Toval, Ali Idri, and José Rivera Pozo. Free blood donation mobile applications. *Journal of medical systems*, 39(5):52, 2015.
- [183] Sofia Ouhbi, José Luis Fernández-Alemán, José Rivera Pozo, Manal El Bajta, Ambrosio Toval, and Ali Idri. Compliance of blood donation apps with mobile os usability guidelines. *Journal of medical systems*, 39(6):63, 2015.
- [184] Mariam Bachiri, Ali Idri, José Luis Fernández-Alemán, and Ambrosio Toval. Mobile personal health records for pregnancy monitoring functionalities: Analysis and potential. *Computer methods and programs in biomedicine*, 134:121–135, 2016.
- [185] Statistica. Us mobile smartphone os market share 2012–2016. <http://goo.gl/z0V51w/>, 2016. Accessed August 10, 2016.
- [186] M. Martínez. Contingency planning for natural disasters. *ISBT Science Series*, 6:212 – 215, 05 2011.
- [187] World Health Organization. Blood donor selection: Guidelines on assessing donor suitability for blood donation. <https://goo.gl/0PpBhG/>, 2012. Accessed September 4, 2016.
- [188] Jack Euan Ross McMillan, William Bradley Glisson, and Michael Bromby. Investigating the increase in mobile phone evidence in criminal activities. In *2013 46th Hawaii International Conference on System Sciences*, pages 4900–4909. IEEE, 2013.

- [189] Alastair Pennycook. *The cultural politics of English as an international language*. Taylor & Francis, 2017.
- [190] Adelbert B James, Cassandra D Josephson, Beth H Shaz, George B Schreiber, Christopher D Hillyer, and John D Roback. The value of area-based analyses of donation patterns for recruitment strategies. *Transfusion*, 54(12):3051–3060, 2014.
- [191] KPH Lemmens, Charles Abraham, RAC Ruiter, IJT Veldhuizen, AER Bos, and HP Schaalma. Identifying blood donors willing to help with recruitment. *Vox sanguinis*, 95(3):211–217, 2008.
- [192] André Smith, Ralph Matthews, and Jay Fiddler. Recruitment and retention of blood donors in four Canadian cities: an analysis of the role of community and social networks. *Transfusion*, 53:180S–184S, 2013.
- [193] Maged N Kamel Boulos and Stephen P Yang. Exergames for health and fitness: the roles of gps and geosocial apps, 2013.
- [194] Red cross launches rapidpass online health history system. <https://goo.gl/PyUVQ/>, 2015. Accessed October 3, 2016.
- [195] Donorpass. <https://goo.gl/111jtk/>, 2014. Accessed October 3, 2016.
- [196] Sebastian Deterding. Situated motivational affordances of game elements: A conceptual model. In *Gamification: Using game design elements in non-gaming contexts, a workshop at CHI*, volume 10, 2011.
- [197] Chetan Sundarde, Suhani Jain, and Eram Shaikh. Advancement of blood donation application. 2015.
- [198] Muhammad Ibrar and Owais Khan. The impact of reward on employee performance (a case study of malakand private school). *International letters of social and humanistic sciences*, 52:95–103, 2015.
- [199] Central. It’s not about cash: Research-based facts on employee engagement. <https://goo.gl/cAxut2/>, 2015. Accessed October 5, 2016.
- [200] Charmian Reynoldson, Catherine Stones, Matthew Allsop, Peter Gardner, Michael I Bennett, S José Closs, Rick Jones, and Peter Knapp. Assessing the quality and usability of smartphone apps for pain self-management. *Pain medicine*, 15(6):898–909, 2014.
- [201] Belén Cruz Zapata, Antonio Hernández Niñirola, Ali Idri, José Luis Fernández-Alemán, and Ambrosio Toval. Mobile phrs compliance with android and ios usability guidelines. *Journal of medical systems*, 38(8):81, 2014.

- [202] Juliana Chen, Janet E Cade, and Margaret Allman-Farinelli. The most popular smart-phone apps for weight loss: a quality assessment. *JMIR mHealth and uHealth*, 3(4):e104, 2015.
- [203] Stoyan R Stoyanov, Leanne Hides, David J Kavanagh, Oksana Zelenko, Dian Tjondronegoro, and Madhavan Mani. Mobile app rating scale: a new tool for assessing the quality of health mobile apps. *JMIR mHealth and uHealth*, 3(1):e27, 2015.
- [204] Shan Yuan, Shelley Chang, Kasie Uyeno, Gay Almquist, and Shirong Wang. Blood donation mobile applications: are donors ready? *Transfusion*, 56(3):614–621, 2016.
- [205] Daniela CL Domingos, Luis FSG Lima, Thiago F Messias, José VL Feijó, Anthony AR Diniz, and Heliana B Soares. Blood hero: An application for encouraging the blood donation by applying gamification. In *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pages 5624–5627. IEEE, 2016.
- [206] Alvedi Chandra Sabani, Ida Bagus Kerthyayana Manuaba, and Erwin Adi. Gamification: blood donor apps for ios devices. *Journal Games, Game Arts and Gamification (JGGAG)*, 1(1), 2016.
- [207] Muhammad Fahim, Halil Ibrahim Cebe, Jawad Rasheed, and Farzad Kiani. mhealth: Blood donation application using android smartphone. In *2016 Sixth International Conference on Digital Information and Communication Technology and its Applications (DICTAP)*, pages 35–38. IEEE, 2016.
- [208] Sultan Turhan. An android application for volunteer blood donors. *Computer Science & Information Technology (CS & IT)*, pages 23–30, 2013.
- [209] Lamyae Sardi, Ali Idri, and José Luis Fernández-Alemán. Gamified mobile blood donation applications. In *International Conference on Bioinformatics and Biomedical Engineering*, pages 165–176. Springer, 2017.
- [210] Ali Idri, Karima Moumane, and Alain Abran. On the use of software quality standard iso/iec9126 in mobile environments. In *2013 20th Asia-Pacific Software Engineering Conference (APSEC)*, volume 1, pages 1–8. IEEE, 2013.
- [211] Sofia Ouhbi, Ali Idri, José Luis Fernández Alemán, Ambrosio Toval, and Halima Benjelloun. Applying iso/iec 25010 on mobile personal health records. In *HEALTHINF*, pages 405–412, 2015.
- [212] Ali Idri, Mariam Bachiri, and José Luis Fernández-Alemán. A framework for evaluating the software product quality of pregnancy monitoring mobile personal health records. *Journal of medical systems*, 40(3):50, 2016.

- [213] Azham Hussain and Emmanuel OC Mkpojiogu. An application of the iso/iec 25010 standard in the quality-in use assessment of an online health awareness system. *Jurnal Teknologi*, 77(5):9–13, 2015.
- [214] Almetwally M Mostafa, Ahmed E Youssef, and Gamal Alshorbagy. A framework for a smart social blood donation system based on mobile cloud computing. *arXiv preprint arXiv:1412.7276*, 2014.
- [215] Borja Martínez-Pérez, Isabel De La Torre-Díez, and Miguel López-Coronado. Privacy and security in mobile health apps: a review and recommendations. *Journal of medical systems*, 39(1):181, 2015.
- [216] Juris Klonovs, C Kjeldgaard Petersen, Henning Olesen, and A Hammershøj. Development of a mobile eeg-based biometric authentication system. In *WWRF Meeting*, 2012.
- [217] Ali Abdulwahab Ali Al-Habsi and Henry Lee Seldon. A communication module for mobile personal health record. In *2013 IEEE 7th International Power Engineering and Optimization Conference (PEOCO)*, pages 727–731. IEEE, 2013.
- [218] Shefaly Shorey, Yen Yen Yang, and Cindy-Lee Dennis. A mobile health app-based postnatal educational program (home-but not alone): descriptive qualitative study. *Journal of medical Internet research*, 20(4):e119, 2018.
- [219] World Health Organization. Who recommendations on postnatal care of the mother and newborn. <https://bit.ly/3mh7DBg/>, 2014. Accessed February 10, 2019.
- [220] Adetokunbo O Lucas, Barbara J Stoll, Judith R Bale, et al. *Improving birth outcomes: meeting the challenge in the developing world*. National Academies Press, 2003.
- [221] Murtaza Mustafa, IM Yusof, MS Jeffree, EI Iiizam, KA Lukman, and SS Husain. Maternal health and mortality in developing countries: Challenges of achieving millennium development goals. 2016.
- [222] Nice guideline. Postnatal care up to 8 weeks after birth. <https://bit.ly/2Dui29t/>, 2006. Accessed January 22, 2019.
- [223] Nicole Fogel. The inadequacies in postnatal health care. *Current Medicine Research and Practice*, 7(1):16–17, 2017.
- [224] Jane Katusiime and Niels Pinkwart. Supporting maternal health education in developing countries using mobile phones-results of a pilot study. In *Proceedings of the First African Conference on Human Computer Interaction*, pages 48–57, 2016.

- [225] Pearl Brereton, Barbara A Kitchenham, David Budgen, Mark Turner, and Mohamed Khalil. Lessons from applying the systematic literature review process within the software engineering domain. *Journal of systems and software*, 80(4):571–583, 2007.
- [226] World Health Organization. Who recommendations on postnatal care of the mother and newborn. <https://bit.ly/2YoZYVi/>, 2013. Accessed February 02, 2019.
- [227] World Health Organization. Postpartum care of the mother and newborn: a practical guide. <https://bit.ly/2R0dDCX/>, 1998. Accessed January 25, 2019.
- [228] World Health Organization. Pregnancy, childbirth, postpartum and newborn care: a guide for essential practice. <https://bit.ly/2SZTv0t/>, 2015. Accessed January 31, 2019.
- [229] Statista. Number of apps available in leading app stores as of 3rd quarter 2018. <https://bit.ly/2dycQpS/>, 2019. Accessed February 07, 2019.
- [230] World Health Organization. Who recommendations on postnatal care of the mother and newborn. <https://bit.ly/2YoZYVi/>, 2013. Accessed February 02, 2019.
- [231] Melvyn WB Zhang, Roger CM Ho, Alvona Loh, Tracey Wing, Olivia Wynne, Sally Wai Chi Chan, Josip Car, and Daniel Shuen Sheng Fung. Current status of postnatal depression smartphone applications available on application stores: an information quality analysis. *BMJ open*, 7(11):e015655, 2017.
- [232] Shashi Rai, Abhishek Pathak, and Indira Sharma. Postpartum psychiatric disorders: Early diagnosis and management. *Indian journal of psychiatry*, 57(Suppl 2):S216, 2015.
- [233] Sanjay Datta, Bhavani Shankar Kodali, and Scott Segal. Maternal physiological changes during pregnancy, labor, and the postpartum period. In *Obstetric Anesthesia Handbook*, pages 1–14. Springer, 2010.
- [234] Michelle F Mottola. Exercise in the postpartum period: practical applications. *Current sports medicine reports*, 1(6):362–368, 2002.
- [235] Constance Guille, Roger Newman, Leah D Fryml, Clay K Lifton, and C Neill Epperson. Management of postpartum depression. *Journal of midwifery & women’s health*, 58(6):643–653, 2013.
- [236] Telake Azale, Abebaw Fekadu, Girmay Medhin, and Charlotte Hanlon. Coping strategies of women with postpartum depression symptoms in rural ethiopia: a cross-sectional community study. *Bmc Psychiatry*, 18(1):41, 2018.
- [237] Uzma Syed, Sk Asiruddin, Md SI Helal, Imteaz I Mannan, and John Murray. Immediate and early postnatal care for mothers and newborns in rural bangladesh. *Journal of health, population, and nutrition*, 24(4):508, 2006.

- [238] Unicef. Key messages booklet. the community infant and young child feeding counselling package,. <https://uni.cf/2Yn4ML9/>, 2012. Accessed February 18, 2019.
- [239] World Health Organization. A handbook for building skills. counselling for maternal and newborn health care,. <https://bit.ly/2xmvkjE/>, 2013. Accessed January 31, 2019.
- [240] World Health Organization. Unicef. A handbook for building skills. counselling for maternal and newborn health care,. <https://bit.ly/2Nn7u2c/>, 2013. Accessed February 18, 2019.
- [241] Sahbanathul Missiriya. Knowledge and practice of postnatal mothers regarding personal hygiene and newborn care. *International Journal of Pharmaceutical Sciences*, 40(1):89–93, 2016.
- [242] VB Bangal, SK Borawake, SP Gavhane, and KH Aher. Use of mobile phone for improvement in maternal health: a randomized control trial. *Int J Reprod, Contracept, Obstet Gynecol*, 6(12):5458–63, 2017.
- [243] Brenda Baker and Irene Yang. Social media as social support in pregnancy and the postpartum. *Sexual & Reproductive Healthcare*, 17:31–34, 2018.
- [244] Shu-Shya Heh. Relationship between social support and postnatal depression. *The Kaohsiung Journal of Medical Sciences*, 19(10):491–495, 2003.
- [245] Urs-Vito Albrecht. *Chances and Risks of Mobile Health Apps (CHARISMHA)*. Universitätsbibliothek der Technischen Universität Braunschweig, 2016.
- [246] Ali Sunyaev, Tobias Dehling, Patrick L Taylor, and Kenneth D Mandl. Availability and quality of mobile health app privacy policies. *Journal of the American Medical Informatics Association*, 22(e1):e28–e33, 2015.
- [247] Sofia Ouhbi, José Luis Fernández-Alemán, Juan Manuel Carrillo-de Gea, Ambrosio Toval, and Ali Idri. E-health internationalization requirements for audit purposes. *Computer methods and programs in biomedicine*, 144:49–60, 2017.
- [248] Karima Moumane, Ali Idri, and Alain Abran. Usability evaluation of mobile applications using iso 9241 and iso 25062 standards. *SpringerPlus*, 5(1):548, 2016.
- [249] Belén Cruz Zapata, José Luis Fernández-Alemán, Ambrosio Toval, and Ali Idri. Reusable software usability specifications for mhealth applications. *Journal of medical systems*, 42(3):45, 2018.
- [250] Imran Ahmed, Niall Safir Ahmad, Shahnaz Ali, Shair Ali, Anju George, Hiba Saleem Danish, Encarl Uppal, James Soo, Mohammad H Mobasheri, Dominic King, et al.



- Medication adherence apps: review and content analysis. *JMIR mHealth and uHealth*, 6(3):e62, 2018.
- [251] Julia Martin, Lesley MacDonald-Wicks, Alexis Hure, Roger Smith, and Clare E Collins. Reducing postpartum weight retention and improving breastfeeding outcomes in overweight women: a pilot randomised controlled trial. *Nutrients*, 7(3):1464–1479, 2015.
- [252] Laura Creti, Eva Libman, Dorrie Rizzo, Catherine S Fichten, Sally Bailes, Dieu-Ly Tran, and Phyllis Zelkowitz. Sleep in the postpartum: characteristics of first-time, healthy mothers. *Sleep disorders*, 2017, 2017.
- [253] Research 2 Guidance. mhealth economics 2017 – current status and future trends in mobile health. <https://bit.ly/2zqtJMS/>, 2017. Accessed March 04, 2019.
- [254] Patricia A Janssen, Paul Thiessen, Michael C Klein, Michael F Whitfield, Ying C MacNab, and Sue C Cullis-Kuhl. Standards for the measurement of birth weight, length and head circumference at term in neonates of european, chinese and south asian ancestry. *Open Medicine*, 1(2):e74, 2007.
- [255] Niranjana Bidargaddi, Timothy Pituch, Haitham Maaieh, C Short, and Victor Strecher. Predicting which type of push notification content motivates users to engage in a self-monitoring app. *Preventive medicine reports*, 11:267–273, 2018.
- [256] Karla Santo, Clara K Chow, Aravinda Thiagalingam, Kris Rogers, John Chalmers, and Julie Redfern. Medication reminder apps to improve medication adherence in coronary heart disease (medapp-chd) study: a randomised controlled trial protocol. *BMJ open*, 7(10):e017540, 2017.
- [257] B Thirumala Rao et al. A study on data storage security issues in cloud computing. *Procedia Computer Science*, 92:128–135, 2016.
- [258] Rahul Aralikkatte, Giriprasad Sridhara, Neelamadhav Gantayat, and Senthil Mani. Fault in your stars: an analysis of android app reviews. In *Proceedings of the ACM India Joint International Conference on Data Science and Management of Data*, pages 57–66, 2018.
- [259] Mark Harman, Yue Jia, and Yuanyuan Zhang. App store mining and analysis: Msr for app stores. In *2012 9th IEEE working conference on mining software repositories (MSR)*, pages 108–111. IEEE, 2012.
- [260] Hammad Khalid. *On the link between mobile app quality and user reviews*. PhD thesis, 2014.

- [261] Paolo Guiddi, Sara Alfieri, Elena Marta, and Vincenzo Saturni. New donors, loyal donors, and regular donors: Which motivations sustain blood donation? *Transfusion and apheresis science*, 52(3):339–344, 2015.
- [262] Barbara M Masser, Katherine M White, Melissa K Hyde, and Deborah J Terry. The psychology of blood donation: current research and future directions. *Transfusion medicine reviews*, 22(3):215–233, 2008.
- [263] Eda Karacan, Guldane Cengiz Seval, Zeynep Aktan, Meltem Ayli, and Refia Palabiyikoglu. Blood donors and factors impacting the blood donation decision: motives for donating blood in turkish sample. *Transfusion and Apheresis Science*, 49(3):468–473, 2013.
- [264] Ilona Buciuniene, Laimutė Stonienė, Aurelija Blazeviciene, Ruta Kazlauskaite, and Vida Skudiene. Blood donors' motivation and attitude to non-remunerated blood donation in lithuania. *BMC Public Health*, 6(1):166, 2006.
- [265] Timothy C Bednall and Liliana L Bove. Donating blood: a meta-analytic review of self-reported motivators and deterrents. *Transfusion medicine reviews*, 25(4):317–334, 2011.
- [266] WHO. Blood safety and availability. <https://bit.ly/2A4CAFR/>. Accessed September 13, 2018.
- [267] Christopher J Armitage and Mark Conner. Social cognitive determinants of blood donation. *Journal of applied social psychology*, 31(7):1431–1457, 2001.
- [268] The University of Rhode Island. Home of the transtheoretical model, measures. <https://web.uri.edu/cprc/measures/>. Accessed January 19, 2018.
- [269] J Ma, NM Betts, T Horacek, C Georgiou, and A White. Assessing stages of change for fruit and vegetable intake in young adults: a combination of traditional staging algorithms and food-frequency questionnaires. *Health Education Research*, 18(2):224–236, 2003.
- [270] Stephen Sutton. Back to the drawing board? a review of applications of the transtheoretical model to substance use. *Addiction*, 96(1):175–186, 2001.
- [271] AJ Romain, V Attalin, A Sultan, C Boegner, C Gernigon, and A Avignon. Experiential or behavioral processes: which one is prominent in physical activity? examining the processes of change 1 year after an intervention of therapeutic education among adults with obesity. *Patient education and counseling*, 97(2):261–268, 2014.

- [272] Gaston Godin, Mark Conner, Paschal Sheeran, Ariane Bélanger-Gravel, and Marc Germain. Determinants of repeated blood donation among new and experienced blood donors. *Transfusion*, 47(9):1607–1615, 2007.
- [273] Carlo C DiClemente, James O Prochaska, Scott K Fairhurst, Wayne F Velicer, Mary M Velasquez, and Joseph S Rossi. The process of smoking cessation: an analysis of pre-contemplation, contemplation, and preparation stages of change. *Journal of consulting and clinical psychology*, 59(2):295, 1991.
- [274] James O Prochaska, John C Norcross, Carlo C DiClemente, et al. Applying the stages of change. *Psychotherapy in Australia*, 19(2):10, 2013.
- [275] James M Raczynski and Ralph J DiClemente. *Handbook of health promotion and disease prevention*. Springer Science & Business Media, 2013.
- [276] Chantal Kroll, Roger Keller, Urte Scholz, and Sonja Perren. Evaluating the decisional balance construct of the transtheoretical model: are two dimensions of pros and cons really enough? *International journal of public health*, 56(1):97–105, 2011.
- [277] Sarah J Cockell, Josie Geller, and Wolfgang Linden. The development of a decisional balance scale for anorexia nervosa. *European Eating Disorders Review: The Professional Journal of the Eating Disorders Association*, 10(5):359–375, 2002.
- [278] Kusum D Jashnani, Laxmi N Patil, et al. Blood donor deferrals: Can this be reduced. *Asian J Transfus Sci*, 5(1):60, 2011.
- [279] Caroline C Horwath, Susan M Schembre, Robert W Motl, Rod K Dishman, and Claudio R Nigg. Does the transtheoretical model of behavior change provide a useful basis for interventions to promote fruit and vegetable consumption? *American Journal of Health Promotion*, 27(6):351–357, 2013.
- [280] Young-Ho Kim. Application of the transtheoretical model to identify psychological constructs influencing exercise behavior: A questionnaire survey. *International journal of nursing studies*, 44(6):936–944, 2007.
- [281] Johannes Brug, Mark Conner, Niki Harre, Stef Kremers, Susan McKellar, and Sandy Whitelaw. The transtheoretical model and stages of change: a critique: observations by five commentators on the paper by adams, j. and white, m.(2004) why don't stage-based activity promotion interventions work? *Health education research*, 20(2):244–258, 2005.
- [282] Frances K Del Boca and Jane A Noll. Truth or consequences: the validity of self-report data in health services research on addictions. *Addiction*, 95(11s3):347–360, 2000.
- [283] Meghan E Short, Ron Z Goetzl, Xiaofei Pei, Maryam J Tabrizi, Ronald J Ozminkowski, Teresa B Gibson, Dave M DeJoy, and Mark G Wilson. How accurate are self-reports?

- an analysis of self-reported healthcare utilization and absence when compared to administrative data. *Journal of occupational and environmental medicine/American College of Occupational and Environmental Medicine*, 51(7):786, 2009.
- [284] Sallie A Newell, Afaf Girgis, Rob W Sanson-Fisher, and Nina J Savolainen. The accuracy of self-reported health behaviors and risk factors relating to cancer and cardiovascular disease in the general population: a critical review. *American journal of preventive medicine*, 17(3):211–229, 1999.
- [285] Lamyae Sardi, Ali Idri, and José Luis Fernández-Alemán. A systematic review of gamification in e-health. *Journal of biomedical informatics*, 71:31–48, 2017.
- [286] Jemma Looyestyn, Jocelyn Kernot, Kobie Boshoff, Jillian Ryan, Sarah Edney, and Carol Maher. Does gamification increase engagement with online programs? a systematic review. *PloS one*, 12(3), 2017.
- [287] IEEE 29148 Standard. *Systems and software engineering — Life cycle processes — Requirements engineering*. 2011.
- [288] Ali Idri, Mariam Bachiri, José Luis Fernández-Alemán, and Ambrosio Toval. Iso/iec 25010 based evaluation of free mobile personal health records for pregnancy monitoring. In *2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC)*, volume 1, pages 262–267. IEEE, 2017.
- [289] Ali Idri, Lamyae Sardi, and José Luis Fernández Alemán. Quality evaluation of gamified blood donation apps using iso/iec 25010 standard. In *HEALTHINF*, pages 607–614, 2018.
- [290] Noureddine ELKHOUDRI, Abdellatif BAALI, et al. Postnatal care: levels and determinants in morocco. *Iranian Journal of Public Health*, 46(2):242, 2017.
- [291] Manal Kharbouch, Ali Idri, Taoufiq Rachad, Hassan Alami, Leanne Redman, and Youssef Stelate. Mycontraception: An evidence-based contraception mpher for better contraceptive fit. In *World Conference on Information Systems and Technologies*, pages 86–94. Springer, 2020.
- [292] Lamyae Sardi, Ali Idri, Leanne M Redman, Hassan Alami, Rachid Bezaad, and José Luis Fernández-Alemán. Mobile health applications for postnatal care: Review and analysis of functionalities and technical features. *Computer methods and programs in biomedicine*, 184:105114, 2020.
- [293] John Cox and Jeni Holden. *Perinatal mental health: A guide to the Edinburgh Postnatal Depression Scale (EPDS)*. Royal College of Psychiatrists, 2003.

- [294] Android Developers. Reference android design guidelines. <https://developer.android.com/design/>. Accessed February 12, 2020.
- [295] Ilham Kadi, Ali Idri, and Sofia Ouhbi. Quality evaluation of cardiac decision support systems using iso 25010 standard. In *2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*, pages 1–8. IEEE, 2016.
- [296] Sofia Ouhbi, Ali Idri, Rachid Hakmi, Halima Benjelloun, José Luis Fernández-Alemán, and Ambrosio Toval. Requirements specification of an e-health solution to improve cardiovascular healthcare services in morocco. In *2016 11th International Conference on Intelligent Systems: Theories and Applications (SITA)*, pages 1–6. IEEE, 2016.
- [297] Moisés Rodríguez, Jesús Ramón Oviedo, and Mario Piattini. Evaluation of software product functional suitability: a case study. *Software Quality Professional*, 18(3):18, 2016.
- [298] Amina Souag, Raúl Mazo, Camille Salinesi, and Isabelle Comyn-Wattiau. Reusable knowledge in security requirements engineering: a systematic mapping study. *Requirements Engineering*, 21(2):251–283, 2016.
- [299] Nigel Bevan. Quality in use: Meeting user needs for quality. *Journal of systems and software*, 49(1):89–96, 1999.
- [300] Juan Antonio Vargas Enríquez. Evaluating the quality in use of gamified software... evaluación de la calidad en el uso del software gamified. 2016.
- [301] Hafehd Mili, Fatma Mili, and Ali Mili. Reusing software: Issues and research directions. *IEEE transactions on Software Engineering*, 21(6):528–562, 1995.
- [302] Cristina Palomares, Carme Quer, and Xavier Franch. Requirements reuse and requirement patterns: a state of the practice survey. *Empirical Software Engineering*, 22(6):2719–2762, 2017.
- [303] Mohsin Irshad, Kai Petersen, and Simon Poulding. A systematic literature review of software requirements reuse approaches. *Information and Software Technology*, 93:223–245, 2018.
- [304] C Pacheco, I Garcia, José Antonio Calvo-Manzano, and M Arcilla. Reusing functional software requirements in small-sized software enterprises: a model oriented to the catalog of requirements. *Requirements Engineering*, 22(2):275–287, 2017.
- [305] Sofia Ouhbi, José Luis Fernández-Alemán, Ambrosio Toval, Jose Rivera Pozo, and Ali Idri. Sustainability requirements for connected health applications. *Journal of Software: Evolution and Process*, 30(7):e1922, 2018.

- [306] Sofia Ouhbi, José Luis Fernández Alemán, Ali Idri, Ambrosio Toval, José Rivera Pozo, and Manal El Bajta. A reusable requirements catalog for internationalized and sustainable blood donation apps. In *ENASE*, pages 285–292, 2017.
- [307] Mariam Bachiri, Ali Idri, Leanne M Redman, Jose Luis Fernandez-Aleman, and Ambrosio Toval. A requirements catalog of mobile personal health records for prenatal care. In *International Conference on Computational Science and Its Applications*, pages 483–495. Springer, 2019.
- [308] Jostein Jensen, Inger Anne Tøndel, Martin Gilje Jaatun, Per Håkon Meland, and Herbjørn Andresen. Reusable security requirements for healthcare applications. In *2009 International Conference on Availability, Reliability and Security*, pages 380–385. IEEE, 2009.
- [309] Mariana Peixoto and Carla Silva. A gamification requirements catalog for educational software: results from a systematic literature review and a survey with experts. In *Proceedings of the Symposium on Applied Computing*, pages 1108–1113, 2017.
- [310] Ambrosio Toval, Joaquín Nicolás, Begoña Moros, and Fernando García. Requirements reuse for improving information systems security: a practitioner’s approach. *Requirements Engineering*, 6(4):205–219, 2002.
- [311] Dominic King, Felix Greaves, Christopher Exeter, and Ara Darzi. ‘gamification’: Influencing health behaviours with games, 2013.
- [312] Scott Thiebes, Sebastian Lins, and Dirk Basten. Gamifying information systems—a synthesis of gamification mechanics and dynamics. 2014.
- [313] Darius Ašeriškis and Robertas Damaševičius. Gamification patterns for gamification applications. *Procedia Computer Science*, 39:83–90, 2014.
- [314] Benedikt Morschheuser, Juho Hamari, Karl Werder, and Julian Abe. How to gamify? a method for designing gamification. In *Proceedings of the 50th Hawaii International Conference on System Sciences 2017*. University of Hawai’i at Manoa, 2017.
- [315] Ali Darejeh and Siti Salwah Salim. Gamification solutions to enhance software user engagement—a systematic review. *International Journal of Human-Computer Interaction*, 32(8):613–642, 2016.
- [316] Donald Firesmith. Specifying reusable security requirements. *J. Object Technol.*, 3(1):61–75, 2004.
- [317] ISO/IEC 25040. *Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Evaluation process*. 2011.
- [318] ISO/IEC 27799. *Health Informatics — Information Security Management in Health usign ISO/IEC 27002*. 2016.

- [319] ISO/IEC 27799. *Health Informatics — Measures for Ensuring the Patient safety of Health Software*. 2007.
- [320] ISO 9241-210. *Ergonomics of Human-System Interaction — Part 210: Human-Centred Design for Interactive Systems*. 2019.
- [321] W3C. Roadmap of web applications on mobile. <http://w3.org/2019/04/web-roadmaps/mobile/>, 2019. Accessed June 19, 2019.
- [322] Phillip A Laplante. *Requirements engineering for software and systems*. CRC Press, 2017.
- [323] Edward L Deci and Richard M Ryan. Overview of self-determination theory: An organismic dialectical perspective. *Handbook of self-determination research*, pages 3–33, 2002.
- [324] Gustavo Fortes Tondello, Hardy Premasukh, and Lennart Nacke. A theory of gamification principles through goal-setting theory. Hawaii International Conference on System Sciences, 2018.
- [325] Burrhus Frederic Skinner. *Contingencies of reinforcement: A theoretical analysis*, volume 3. BF Skinner Foundation, 2014.
- [326] Jonathan Leventhal. *Autonomy in video games and gamification*. 2018.
- [327] Daniel H Pink. *Drive: The surprising truth about what motivates us*. Penguin, 2011.
- [328] Mikko Rajanen and Dorina Rajanen. Usability benefits in gamification. In *GamiFIN*, pages 87–95, 2017.
- [329] Masaaki Kurosu and Kaori Kashimura. Apparent usability vs. inherent usability: experimental analysis on the determinants of the apparent usability. In *Conference companion on Human factors in computing systems*, pages 292–293, 1995.
- [330] Maissom Qanber Abbasi, Jingnong Weng, Yunhong Wang, Irfan Rafique, Xinran Wang, and Philip Lew. Modeling and evaluating user interface aesthetics employing iso 25010 quality standard. In *2012 Eighth International Conference on the Quality of Information and Communications Technology*, pages 303–306. IEEE, 2012.
- [331] Louis S Wheatcraft, Michael J Ryan, and Jeremy Dick. On the use of attributes to manage requirements. *Systems Engineering*, 19(5):448–458, 2016.
- [332] Balasubramaniam Ramesh and Matthias Jarke. Toward reference models for requirements traceability. *IEEE transactions on software engineering*, 27(1):58–93, 2001.
- [333] Miguel A Martínez, Joaquín Lasheras, Eduardo Fernández-Medina, Ambrosio Toval, and Mario Piattini. A personal data audit method through requirements engineering. *Computer Standards & Interfaces*, 32(4):166–178, 2010.

- [334] Robert B Cialdini and Noah J Goldstein. Social influence: Compliance and conformity. *Annu. Rev. Psychol.*, 55:591–621, 2004.
- [335] Lei Shi and Alexandra I Cristea. Motivational gamification strategies rooted in self-determination theory for social adaptive e-learning. In *International Conference on Intelligent Tutoring Systems*, pages 294–300. Springer, 2016.
- [336] Paul Marchbank, Margaret Ross, and Geoff Staples. Achieving software quality in development and in use. 2017.
- [337] Android Developers. Reference android design guidelines. <https://bit.ly/1nKBw8N/>. Accessed January 10, 2020.
- [338] Apple Developer. Human interface guidelines. <https://apple.co/2KAUovk/>. Accessed January 08, 2020.
- [339] Mervi Ollikainen. On gamification. Master’s thesis, 2013.
- [340] Binh Pham. Design for aesthetics: interactions of design variables and aesthetic properties. In *Human Vision and Electronic Imaging IV*, volume 3644, pages 364–371. International Society for Optics and Photonics, 1999.
- [341] American Red Cross. Red cross blood donor app. <https://rcblood.org/2W3o1dA/>, 2019. Accessed November 12, 2019.
- [342] Move it mama. <https://www.moveitmama.de/app/>. Accessed March 01, 2020.
- [343] Apple app store. Blood donor american red cross. <https://apple.co/3iR6XBk/>. Accessed November 13, 2019.
- [344] Apple app store. Move it mama. the new mama fitness guide. <https://apple.co/2W3Fvq4/>. Accessed March 01, 2020.
- [345] Steven E Kaplan, Edward F O’Donnell, and Barbara M Arel. The influence of auditor experience on the persuasiveness of information provided by management. *Auditing: A journal of practice & theory*, 27(1):67–83, 2008.



# Appendix **A**

## Complementary data on postnatal care apps

This appendix provides all the assessment results of the postnatal apps selected in Chapter 3.

APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

Table A.1: Review of postnatal care apps: Characteristics of the 48 apps evaluated for postnatal care

| Application name                                   | OS             | Category                      | Latest update          | Free /Paid      | App website/ URL   | Country of origin |
|--|----------------|-------------------------------|------------------------|-----------------|--|-------------------|
| ovia Parenting: Baby Tracker, Breastfeeding Timer  | Android<br>iOS | Medical                       | 07-Jan-19<br>24-Jan-19 | Free            | <a href="https://www.oviahealth.com/">https://www.oviahealth.com/</a>  | USA               |
| WellMama free post pregnancy yoga poses            | Android<br>iOS | Health & Fitness              | 31-Mar-18<br>05-Apr-18 | Free            | <a href="http://www.behappymum.com/">http://www.behappymum.com/</a>  | UK                |
| FitMama Lite 5Min                                  | Android<br>iOS | Health & Fitness              | 15-Jan-18              | Free            | <a href="http://www.behappymum.com/">http://www.behappymum.com/</a>  | UK                |
| Glow Baby Newborn Tracker App                      | Android<br>iOS | Parenting<br>Medical          | 23-Jan-19<br>18-Dec-18 | In-app purchase | <a href="https://glowing.com/">https://glowing.com/</a>  | USA               |
| Baby tracker - Newborn Feeding, Diaper, Sleep log  | Android<br>iOS | Parenting<br>Medical          | 11-Mar-18<br>10-Dec-18 | In-app purchase | <a href="http://nighp.com/babytracker/">http://nighp.com/babytracker/</a>  | Hong Kong         |
| Baby manager                                       | Android<br>iOS | Parenting<br>Medical          | 13-Jun-18<br>25-Apr-18 | Paid            | <a href="http://babymanagerapp.tumblr.com/">http://babymanagerapp.tumblr.com/</a>  | Canada            |
| Baby+  | Android<br>iOS | Parenting<br>Medical          | 26-Sep-18<br>20-Sep-18 | Free            | <a href="https://www.health-and-parenting.com/">https://www.health-and-parenting.com/</a>                                      | Netherlands       |
| Fit Mommy Project Challenge                        | Android<br>iOS | Health & Fitness              | 06-Dec-18<br>20-Mar-18 | Paid            | <a href="https://www.kimmysmithfit.com/">https://www.kimmysmithfit.com/</a>  | USA               |
| Postnatal workouts                                 | Android<br>iOS | Health & Fitness              | 21-May-18<br>01-Jun-18 | In-app purchase | <a href="https://bit.ly/2Nx3xnK">https://bit.ly/2Nx3xnK</a><br><a href="https://apple.co/2IfR62">https://apple.co/2IfR62</a>   | USA               |
| BabyTime   | Android<br>iOS | Parenting<br>Medical          | 28-Jan-19<br>15-Jan-19 | In-app purchase | <a href="https://www.babytime.care/">https://www.babytime.care/</a>  | Republic of Korea |
| WebMD Baby   | Android<br>iOS | Health & Fitness              | 24-Jan-19<br>12-Dec-18 | Free            | <a href="https://wb.md/2H9W50D">https://wb.md/2H9W50D</a>  | USA               |
| Breastfeeding Tracker Baby Log                     | iOS<br>Android | Medical<br>Parenting          | 26-Feb-18<br>30-Nov-18 | In-app purchase | <a href="https://apple.co/2RA8XjF">https://apple.co/2RA8XjF</a><br><a href="https://bit.ly/2NToVUm">https://bit.ly/2NToVUm</a> | USA               |
| Moment Health                                      | Android<br>iOS | Health & Fitness              | 23-Jul-18<br>06-Jul-18 | In-app purchase | <a href="https://momenthealth.io/">https://momenthealth.io/</a>  | UK                |
| Baby tracker - feeding, sleep and diaper           | Android<br>iOS | Parenting<br>Health & Fitness | 24-Jan-19<br>20-Nov-18 | In-app purchase | <a href="https://amila.io/">https://amila.io/</a>  | Canada            |
| MH motherhood                                      | Android<br>iOS | Medical                       | 11-Oct-18<br>03-Oct-18 | Free            | <a href="https://bit.ly/2EmtQJm">https://bit.ly/2EmtQJm</a>  | USA               |
| Baby loggy -newborn log                            | iOS            | Medical                       | 03-Jan-19              | In-app purchase | <a href="http://babyloggy.com/">http://babyloggy.com/</a>  | USA               |
| 30-day fit mommy Challenge                         | iOS            | Health & Fitness              | 22-Dec-18              | In-app purchase | <a href="https://apple.co/2Vu562X">https://apple.co/2Vu562X</a>  | USA               |
| Oh baby! Mom and baby exercise                     | iOS            | Health & Fitness              | 02-Mar-18              | In-app purchase | <a href="https://apple.co/2tGmsn5">https://apple.co/2tGmsn5</a>  | USA               |
| Caring for a newborn baby                          | iOS            | Health & Fitness              | 17-Apr-18              | Paid            | <a href="https://apple.co/2UbUDyz">https://apple.co/2UbUDyz</a>  | USA               |
| MyMedela   | iOS            | Health & Fitness              | 15-Nov-18              | Free            | <a href="https://apple.co/2SwUG6v">https://apple.co/2SwUG6v</a>  | Switzerland       |
| Postnatal pilates                                  | iOS            | Health & Fitness              | 18-Jan-18              | Paid            | <a href="https://apple.co/2EmTaPh">https://apple.co/2EmTaPh</a>  | Australia         |
| Postnatal pilates by reform                        | iOS            | Health & Fitness              | 01-Oct-18              | Paid            | <a href="https://apple.co/2EDEDzW">https://apple.co/2EDEDzW</a>  | Ireland           |
| Sprout Baby  | iOS            | Health & Fitness              | 16-Jan-19              | In-app purchase | <a href="https://apple.co/2UaF8XG">https://apple.co/2UaF8XG</a>  | USA               |
| Guide to newborn care                              | Android        | Parenting                     | 13-Nov-18              | Free            | <a href="https://bit.ly/2Nz3kk9">https://bit.ly/2Nz3kk9</a>  | India             |
| After birth exercise                               | Android        | Health & Fitness              | 08-Jan-18              | In-app purchase | <a href="https://www.rueckbildung-app.de/">https://www.rueckbildung-app.de/</a>  | Germany           |
| Pregnancy, parenting advice & baby care tips app   | Android        | Parenting                     | 19-Jan-19              | Free            | <a href="https://www.parentune.com/">https://www.parentune.com/</a>  | India             |
| Bleeding after birth                               | Android        | Health & Fitness              | 02-Oct-18              | Free            | <a href="https://bit.ly/2TpHt3O">https://bit.ly/2TpHt3O</a>  | Egypt             |
| Burn fat after pregnancy - weight loss             | Android        | Health & Fitness              | 24-Oct-18              | Free            | <a href="https://bit.ly/2T92jvB">https://bit.ly/2T92jvB</a>  | N/A               |
| Losing weight after pregnancy                      | Android        | Health & Fitness              | 24-Sep-18              | Free            | <a href="https://bit.ly/2IL4R7U">https://bit.ly/2IL4R7U</a>  | Pakistan          |
| Telfair baby                                       | Android        | Health & Fitness              | 7-Apr-18               | Free            | <a href="https://www.sjchs.org/default.aspx">https://www.sjchs.org/default.aspx</a>  | USA               |
| Post pregnancy recovery                            | Android        | Health & Fitness              | 19-Jun-18              | Free            | <a href="https://bit.ly/2EDEOLI">https://bit.ly/2EDEOLI</a>  | Kenya             |
| Growth Chart, Development Milestones & Vaccination | Android        | Parenting                     | 07-Dec-18              | Free            | <a href="https://www.growthbookapp.com/">https://www.growthbookapp.com/</a>  | India             |
| LactApp+   | Android        | Health & Fitness              | 28-Feb-18              | Free            | <a href="https://bit.ly/2XqT026">https://bit.ly/2XqT026</a>  | Philippines       |
| NKCH moments                                       | Android        | Medical                       | 21-Oct-18              | Free            | <a href="https://www.customizedinc.com/">https://www.customizedinc.com/</a>  | USA               |
| Parentlove: baby feeding tracker, diapers, pumping | Android        | Parenting                     | 13-Jan-19              | In-app purchase | <a href="https://parentlove.me/">https://parentlove.me/</a>  | USA               |
| Maternal & newborn care plans                      | Android        | Medical                       | 10-Oct-18              | Free            | <a href="https://bit.ly/2NxSWct">https://bit.ly/2NxSWct</a>  | Singapore         |
| Essentia baby                                      | Android        | Medical                       | 26-Jan-18              | Free            | <a href="https://www.essentiahealth.org/">https://www.essentiahealth.org/</a>  | USA               |

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## APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

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| Application name                      | OS      | Category         | Latest update | Free /Paid      | App website/ URL  | Country of origin |
|---------------------------------------|---------|------------------|---------------|-----------------|---|-------------------|
| <b>Your baby's birth &amp; beyond</b> | Android | Health & Fitness | 11-Oct-18     | Free            | <a href="https://www.pinnaclehealth.org/">https://www.pinnaclehealth.org/</a> | USA               |
| <b>Baby care plus</b>                 | Android | Medical          | 29-Jan-18     | Paid            | <a href="https://bit.ly/2TmQBpP">https://bit.ly/2TmQBpP</a>                   | China             |
| <b>The postpartum cure</b>            | Android | Health & Fitness | 12-Jul-18     | Paid            | <a href="http://thepostpartumcure.com/">http://thepostpartumcure.com/</a>     | USA               |
| <b>UWBaby</b>                         | Android | Medical          | 21-Oct-18     | Free            | <a href="https://bit.ly/2EGhWeR">https://bit.ly/2EGhWeR</a>                   | USA               |
| <b>Skin care after pregnancy</b>      | Android | Health & Fitness | 18-Sep-18     | Free            | <a href="https://bit.ly/2IH190g">https://bit.ly/2IH190g</a>                   | India             |
| <b>Elebaby simple</b>                 | Android | Parenting        | 07-Aug-18     | In-app purchase | <a href="https://bit.ly/2hPsL2">https://bit.ly/2hPsL2</a>                     | USA               |
| <b>Baby Tracker - Newborn Log</b>     | Android | Parenting        | 24-Nov-18     | In-app purchase | <a href="https://bit.ly/2H8ZkW9">https://bit.ly/2H8ZkW9</a>                   | Netherlands       |
| <b>Mother and baby 2019</b>           | Android | Parenting        | 05-Oct-18     | Free            | <a href="https://bit.ly/2EnJz5">https://bit.ly/2EnJz5</a>                     | Egypt             |
| <b>C-section recovery</b>             | Android | Health & Fitness | 13-Oct-18     | Free            | <a href="https://bit.ly/2EjDwEf">https://bit.ly/2EjDwEf</a>                   | India             |
| <b>You+Baby</b>                       | Android | Medical          | 26-Jan-18     | Free            | <a href="http://www.gundersenhealth.org/">http://www.gundersenhealth.org/</a> | USA               |
| <b>Baby&amp; me</b>                   | Android | Health & Fitness | 26-Feb-18     | Free            | <a href="https://www.slnh.org/">https://www.slnh.org/</a>                     | USA               |

## APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

Table A.2: Review of postnatal care apps: Extra features of the apps selected.

| Application name                                   | Extra features   |
|--|--|
| Ovia Parenting: Baby Tracker, Breastfeeding Timer  | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Support multiple children.</li> <li>- Track developmental milestones.</li> </ul>  |
| Glow Baby Newborn Tracker App                      | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Plot growth measures.</li> <li>- Support multiple children.</li> <li>- Export data into PDF report.</li> </ul>  |
| Baby tracker - Newborn Feeding, Diaper, Sleep log  | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Compare growth measures against World Health Organization averages.</li> <li>- Plot growth measures.</li> <li>- Adjust growth chart for premature baby.</li> <li>- Support multiple children.</li> <li>- Export data via email.</li> </ul>  |
| Baby manager                                       | <ul style="list-style-type: none"> <li>- Plot growth measures, feeding, diapering and pumping.</li> <li>- Support multiple children.</li> <li>- Export data into CSV file.</li> </ul>  |
| Baby+  | <ul style="list-style-type: none"> <li>- Activities and Toys by Age information.</li> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Support multiple children.</li> <li>- Create a yearbook.</li> <li>- Lullabies and white noise to help baby sleep.</li> <li>- Compare growth measures against World Health Organization averages.</li> <li>- Doctor visit planner.</li> </ul> |
| Postnatal workouts                                 | <ul style="list-style-type: none"> <li>- Workout challenges.</li> </ul>  |
| BabyTime   | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Health record information.</li> <li>- MusicBox to help baby sleep.</li> <li>- Plot growth measures, feeding, diapering and pumping.</li> <li>- Support multiple children and caregivers.</li> <li>- Export data.</li> </ul>   |
| WebMD Baby   | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Support multiple children and caregivers.</li> </ul>  |
| Breastfeeding Tracker Baby Log                     | <ul style="list-style-type: none"> <li>- Take or upload pictures (newborn's special moments).</li> <li>- Plot growth measures.</li> <li>- Track location to know where the baby has been fed.</li> <li>- Support multiple children and caregivers.</li> <li>- Export data into CSV or HTML format.</li> </ul>  |
| Baby tracker - feeding, sleep and diaper           | <ul style="list-style-type: none"> <li>- Plot growth measures.</li> </ul>  |
| Baby loggy -newborn log                            | <ul style="list-style-type: none"> <li>- Support multiple children.</li> <li>- Send an email summary of all the baby's care to a caregiver or a doctor.</li> <li>- Apple watch support.</li> </ul>   |
| MyMedela   | <ul style="list-style-type: none"> <li>- Upload baby's picture.</li> <li>- Breastfeeding Confidence Assessment.</li> </ul>   |
| Sprout Baby  | <ul style="list-style-type: none"> <li>- Plot growth measures.</li> <li>- Compare growth measures against WHO averages.</li> <li>- Support multiple children.</li> <li>- Export data via email.</li> </ul>   |
| Growth Chart, Development Milestones & Vaccination | <ul style="list-style-type: none"> <li>- Plot growth measures.</li> </ul>  |
| LactApp+   | <ul style="list-style-type: none"> <li>- Plot growth measures, feeding, diapering.</li> <li>- Back to work preparation.</li> </ul>   |
| Baby care plus                                     | <ul style="list-style-type: none"> <li>- Support multiple children.</li> <li>- Plot growth measures.</li> <li>- Export data into CSV file.</li> </ul>  |
| Skin care after pregnancy                          | <ul style="list-style-type: none"> <li>- Tips to take care of the skin after having a baby.</li> </ul>   |
| Elebaby simple                                     | <ul style="list-style-type: none"> <li>- Support Android wear watch.</li> <li>- Plot growth measures.</li> <li>- Support multiple children and caregivers.</li> </ul>  |
| Baby Tracker - Newborn Log                         | <ul style="list-style-type: none"> <li>- Plot growth measures.</li> <li>- Take or upload pictures (newborn's special moments).</li> </ul>  |
| C-section recovery                                 | <ul style="list-style-type: none"> <li>- Information about pregnancy, labour and birth.</li> </ul>   |
| MH motherhood                                      | <ul style="list-style-type: none"> <li>- Pregnancy monitoring.</li> </ul>  |
| Telfair baby                                       | <ul style="list-style-type: none"> <li>- Information on labor and birth.</li> </ul>  |
| NKCH moments                                       |  |
| Your baby's birth and beyond                       |  |
| UW Baby  |  |
| You+Baby   |  |
| Baby&me  |  |
| Essentia Baby                                      |  |

APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

Table A.3: Review of postnatal care apps: Assessment results

| Application name   | PN1 | PN2 | PN3 | PN4 | PN5 | PN6 | PN7 | PN8 | PN9 | PC10 |
|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Ovia Parenting: Baby Tracker, Breastfeeding Timer              | Y   | N   | N   | N   | N   | Y   | N   | N   | Y   | N    |
| WellMama free post pregnancy yoga poses                        | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| FitMama Lite 5Min  | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Glow Baby Newborn Tracker App - Breastfeeding Timer Diaper Log | Y   | N   | N   | N   | N   | N   | Y   | Y   | Y   | N    |
| Baby tracker - Newborn Feeding, Diaper, Sleep log              | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Baby manager   | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Baby+  | Y   | N   | N   | N   | Y   | N   | Y   | N   | N   | Y    |
| Fit Mommy Project Challenge                                    | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Postnatal workouts   | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| BabyTime   | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| WebMD Baby   | Y   | N   | N   | N   | Y   | Y   | Y   | Y   | Y   | N    |
| Breastfeeding Tracker Baby Log                                 | Y   | N   | N   | N   | N   | N   | N   | N   | Y   | N    |
| Moment Health  | Y   | N   | N   | N   | N   | Y   | N   | N   | N   | N    |
| Baby tracker - feeding, sleep and diaper                       | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| MH motherhood  | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Baby loggy -newborn log  | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| 30-day fit mommy Challenge                                     | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Oh baby! Mom and baby exercise                                 | Y   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Caring for a newborn baby                                      | N   | N   | N   | N   | N   | N   | Y   | N   | N   | N    |
| MyMedela   | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Postnatal pilates  | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Postnatal pilates by reform                                    | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Sprout Baby  | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Guide to newborn care  | N   | N   | N   | N   | N   | N   | Y   | Y   | Y   | N    |
| After birth exercise   | N   | N   | N   | N   | Y   | N   | N   | N   | N   | N    |
| Pregnancy, parenting advice & baby care tips app               | Y   | Y   | N   | N   | Y   | Y   | Y   | Y   | Y   | Y    |
| Bleeding after birth   | N   | N   | Y   | N   | N   | N   | N   | N   | N   | N    |
| Burn fat after pregnancy - weight loss                         | N   | N   | N   | Y   | Y   | N   | N   | N   | N   | N    |
| Losing weight after pregnancy                                  | N   | N   | N   | N   | Y   | N   | N   | N   | N   | Y    |
| Telfair baby   | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Post pregnancy recovery  | N   | Y   | Y   | Y   | Y   | Y   | N   | N   | N   | Y    |
| Growth Chart, Development Milestones & Vaccination             | Y   | N   | N   | N   | N   | N   | N   | N   | Y   | N    |
| LactApp+   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| NKCH moments   | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Parentlove: baby feeding tracker, diapers, pumping             | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Maternal & newborn care plans                                  | N   | N   | Y   | N   | N   | N   | N   | Y   | N   | N    |
| Essentia baby  | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Your baby's birth & beyond                                     | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Baby care plus   | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| The postpartum cure  | N   | N   | N   | N   | Y   | N   | N   | N   | N   | Y    |
| UWBaby   | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Skin care after pregnancy                                      | N   | Y   | N   | N   | N   | N   | N   | N   | N   | Y    |
| Elebaby simple   | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Baby Tracker - Newborn Log                                     | Y   | N   | N   | N   | N   | N   | N   | N   | N   | N    |
| Mother and baby 2019   | N   | N   | N   | N   | N   | N   | N   | Y   | N   | N    |
| C-section recovery   | N   | Y   | N   | N   | Y   | N   | N   | N   | N   | Y    |
| You+Baby   | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Baby& me   | Y   | Y   | Y   | Y   | N   | Y   | N   | Y   | Y   | Y    |
| Total (N)  | 28  | 12  | 11  | 10  | 18  | 13  | 6   | 14  | 15  | 15   |
| Total (%)  | 58% | 25% | 23% | 21% | 38% | 27% | 13% | 29% | 31% | 31%  |

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APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

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| Application name   | PC11 | PC12 | PC13 | PC14 | PC15 | R16 | R17 | R18 | R19 | N20 |
|--|------|------|------|------|------|-----|-----|-----|-----|-----|
| Ovia Parenting: Baby Tracker, Breastfeeding Timer              | Y    | Y    | Y    | Y    | Y    | N   | N   | N   | Y   | Y   |
| WellMama free post pregnancy yoga poses                        | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| FitMama Lite 5Min  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Glow Baby Newborn Tracker App - Breastfeeding Timer Diaper Log | N    | N    | N    | N    | N    | N   | N   | N   | N   | Y   |
| Baby tracker - Newborn Feeding, Diaper, Sleep log              | N    | N    | N    | N    | N    | N   | N   | N   | N   | Y   |
| Baby manager   | N    | N    | N    | N    | N    | N   | Y   | Y   | Y   | Y   |
| Baby+  | N    | Y    | Y    | N    | N    | Y   | Y   | N   | N   | Y   |
| Fit Mommy Project Challenge                                    | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Postnatal workouts   | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| BabyTime   | N    | N    | N    | N    | N    | N   | N   | N   | N   | Y   |
| WebMD Baby   | Y    | Y    | Y    | N    | N    | N   | N   | Y   | Y   | Y   |
| Breastfeeding Tracker Baby Log                                 | N    | N    | N    | N    | N    | Y   | Y   | N   | Y   | N   |
| Moment Health  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Baby tracker - feeding, sleep and diaper                       | N    | N    | N    | N    | N    | N   | N   | Y   | N   | Y   |
| MH motherhood  | N    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | N   |
| Baby loggy -newborn log  | N    | N    | N    | N    | N    | N   | Y   | N   | Y   | Y   |
| 30-day fit mommy Challenge                                     | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Oh baby! Mom and baby exercise                                 | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Caring for a newborn baby                                      | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| MyMedela   | N    | Y    | Y    | N    | N    | N   | N   | N   | Y   | Y   |
| Postnatal pilates  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Postnatal pilates by reform                                    | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Sprout Baby  | N    | N    | N    | N    | N    | Y   | N   | N   | Y   | Y   |
| Guide to newborn care  | Y    | Y    | Y    | N    | N    | N   | N   | N   | N   | N   |
| After birth exercise   | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Pregnancy, parenting advice & baby care tips app               | Y    | Y    | Y    | N    | N    | N   | N   | N   | N   | N   |
| Bleeding after birth   | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Burn fat after pregnancy - weight loss                         | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Losing weight after pregnancy                                  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Telfair baby   | N    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | N   |
| Post pregnancy recovery  | N    | Y    | N    | Y    | N    | N   | N   | N   | N   | N   |
| Growth Chart, Development Milestones & Vaccination             | N    | N    | N    | N    | N    | N   | N   | N   | Y   | N   |
| LactApp+   | N    | Y    | Y    | N    | N    | N   | N   | N   | N   | N   |
| NKCH moments   | N    | Y    | Y    | N    | N    | N   | N   | N   | Y   | Y   |
| Parentlove: baby feeding tracker, diapers, pumping             | N    | N    | N    | N    | N    | Y   | N   | Y   | Y   | Y   |
| Maternal & newborn care plans                                  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| Essentia baby  | N    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | N   |
| Your baby's birth & beyond                                     | N    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | N   |
| Baby care plus   | N    | N    | N    | N    | N    | Y   | Y   | Y   | Y   | Y   |
| The postpartum cure  | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| UWBaby   | N    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | N   |
| Skin care after pregnancy                                      | N    | Y    | N    | N    | N    | N   | N   | N   | N   | N   |
| Elebaby simple   | N    | N    | N    | N    | N    | N   | N   | N   | N   | Y   |
| Baby Tracker - Newborn Log                                     | N    | N    | N    | N    | N    | N   | N   | N   | N   | Y   |
| Mother and baby 2019   | Y    | Y    | Y    | N    | N    | N   | N   | N   | N   | N   |
| C-section recovery   | N    | N    | N    | N    | N    | N   | N   | N   | N   | N   |
| You+Baby   | Y    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | Y   |
| Baby& me   | Y    | Y    | Y    | Y    | N    | Y   | N   | N   | Y   | Y   |
| Total (N)  | 7    | 18   | 16   | 9    | 1    | 12  | 5   | 5   | 18  | 18  |
| Total (%)  | 15%  | 38%  | 33%  | 19%  | 2%   | 25% | 10% | 10% | 38% | 38% |

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| Application name   | N21 | N22 | N23 | N24 | N25 | S26 | S27 | S28 | A29 | A30 |
|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ovia Parenting: Baby Tracker, Breastfeeding Timer              | N   | Y   | N   | N   | N   | N   | N   | Y   | Y   | Y   |
| WellMama free post pregnancy yoga poses                        | N   | N   | N   | N   | N   | Y   | Y   | N   | N   | Y   |
| FitMama Lite 5Min  | N   | N   | N   | N   | N   | N   | Y   | N   | N   | Y   |
| Glow Baby Newborn Tracker App - Breastfeeding Timer Diaper Log | Y   | Y   | Y   | N   | N   | N   | N   | Y   | Y   | Y   |
| Baby tracker - Newborn Feeding, Diaper, Sleep log              | Y   | N   | Y   | Y   | N   | Y   | Y   | N   | N   | Y   |
| Baby manager   | Y   | N   | Y   | N   | N   | Y   | N   | Y   | N   | Y   |
| Baby+  | Y   | Y   | Y   | Y   | N   | Y   | Y   | N   | Y   | Y   |
| Fit Mommy Project Challenge                                    | N   | N   | N   | N   | N   | N   | N   | Y   | N   | Y   |
| Postnatal workouts   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| BabyTime   | Y   | N   | Y   | N   | N   | Y   | Y   | N   | Y   | Y   |
| WebMD Baby   | N   | Y   | Y   | N   | N   | N   | N   | N   | Y   | Y   |
| Breastfeeding Tracker Baby Log                                 | Y   | N   | Y   | N   | N   | N   | N   | N   | Y   | Y   |
| Moment Health  | N   | N   | N   | N   | N   | N   | Y   | Y   | Y   | N   |
| Baby tracker - feeding, sleep and diaper                       | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| MH motherhood  | Y   | N   | Y   | N   | N   | Y   | N   | N   | N   | N   |
| Baby loggy -newborn log  | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | N   |
| 30-day fit mommy Challenge                                     | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Oh baby! Mom and baby exercise                                 | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Caring for a newborn baby                                      | N   | N   | N   | N   | N   | Y   | N   | N   | N   | N   |
| MyMedela   | N   | N   | Y   | N   | N   | Y   | Y   | N   | Y   | Y   |
| Postnatal pilates  | N   | N   | N   | Y   | N   | Y   | Y   | Y   | Y   | N   |
| Postnatal pilates by reform                                    | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Sprout Baby  | Y   | Y   | Y   | N   | N   | Y   | N   | N   | N   | Y   |
| Guide to newborn care  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| After birth exercise   | N   | N   | N   | Y   | N   | N   | Y   | N   | N   | N   |
| Pregnancy, parenting advice & baby care tips app               | N   | Y   | N   | Y   | N   | Y   | N   | Y   | Y   | Y   |
| Bleeding after birth   | N   | N   | N   | N   | N   | N   | N   | N   | N   | Y   |
| Burn fat after pregnancy - weight loss                         | N   | N   | N   | N   | N   | N   | N   | N   | N   | Y   |
| Losing weight after pregnancy                                  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Telfair baby   | N   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| Post pregnancy recovery  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Growth Chart, Development Milestones & Vaccination             | Y   | Y   | Y   | N   | N   | Y   | N   | N   | Y   | Y   |
| LactApp+   | N   | N   | N   | N   | N   | Y   | N   | Y   | Y   | Y   |
| NKCH moments   | N   | N   | Y   | N   | N   | N   | N   | N   | N   | N   |
| Parentlove: baby feeding tracker, diapers, pumping             | N   | N   | Y   | N   | N   | Y   | N   | N   | Y   | Y   |
| Maternal & newborn care plans                                  | N   | N   | N   | N   | N   | N   | N   | N   | N   | Y   |
| Essentia baby  | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | N   |
| Your baby's birth & beyond                                     | N   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| Baby care plus   | N   | N   | Y   | N   | N   | Y   | N   | N   | N   | Y   |
| The postpartum cure  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| UWBaby   | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| Skin care after pregnancy                                      | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Elebaby simple   | N   | N   | N   | N   | N   | N   | N   | N   | Y   | N   |
| Baby Tracker - Newborn Log                                     | N   | N   | N   | N   | N   | N   | N   | N   | N   | Y   |
| Mother and baby 2019   | N   | Y   | N   | N   | N   | N   | N   | N   | N   | Y   |
| C-section recovery   | N   | N   | N   | N   | N   | N   | N   | N   | N   | Y   |
| You+Baby   | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| Baby& me   | Y   | N   | Y   | N   | N   | N   | N   | N   | N   | Y   |
| Total (N)  | 15  | 8   | 22  | 5   | 0   | 15  | 9   | 8   | 14  | 30  |
| Total (%)  | 31% | 17% | 46% | 10% | 0%  | 31% | 19% | 17% | 29% | 63% |

Continued on next page

APPENDIX A. COMPLEMENTARY DATA ON POSTNATAL CARE APPS

Continued from previous page

| Application name   | A31 | A32 | A33 | A34 | A35 | A36 | A37 | Total (N) | Total (%) |
|--|-----|-----|-----|-----|-----|-----|-----|-----------|-----------|
| ovia Parenting: Baby Tracker, Breastfeeding Timer              | N   | N   | N   | Y   | N   | Y   | Y   | 17        | 46%       |
| WellMama free post pregnancy yoga poses                        | N   | N   | N   | Y   | N   | Y   | N   | 6         | 16%       |
| FitMama Lite 5Min  | N   | N   | N   | Y   | N   | Y   | N   | 5         | 14%       |
| Glow Baby Newborn Tracker App - Breastfeeding Timer Diaper Log | N   | N   | Y   | Y   | N   | N   | Y   | 14        | 38%       |
| Baby tracker - Newborn Feeding, Diaper, Sleep log              | N   | N   | Y   | N   | N   | Y   | N   | 10        | 27%       |
| Baby manager   | N   | N   | Y   | Y   | N   | Y   | Y   | 14        | 38%       |
| Baby+  | N   | Y   | Y   | Y   | N   | Y   | Y   | 22        | 59%       |
| Fit Mommy Project Challenge                                    | N   | N   | N   | Y   | Y   | Y   | Y   | 7         | 19%       |
| Postnatal workouts   | N   | Y   | N   | N   | Y   | Y   | Y   | 5         | 14%       |
| BabyTime   | N   | N   | Y   | Y   | N   | Y   | Y   | 12        | 32%       |
| WebMD Baby   | N   | N   | N   | Y   | N   | N   | Y   | 18        | 49%       |
| Breastfeeding Tracker Baby Log                                 | Y   | N   | Y   | Y   | N   | N   | Y   | 13        | 35%       |
| Moment Health  | N   | N   | N   | Y   | N   | N   | Y   | 7         | 19%       |
| Baby tracker - feeding, sleep and diaper                       | Y   | N   | Y   | Y   | N   | Y   | Y   | 11        | 30%       |
| MH motherhood  | N   | N   | N   | Y   | Y   | Y   | Y   | 20        | 54%       |
| Baby loggy -newborn log  | N   | N   | Y   | N   | N   | Y   | N   | 8         | 22%       |
| 30-day fit mommy Challenge                                     | N   | N   | N   | Y   | Y   | Y   | Y   | 5         | 14%       |
| Oh baby! Mom and baby exercise                                 | N   | N   | N   | Y   | Y   | N   | Y   | 5         | 14%       |
| Caring for a newborn baby                                      | N   | N   | N   | Y   | Y   | N   | N   | 4         | 11%       |
| MyMedela   | N   | Y   | Y   | Y   | N   | Y   | Y   | 15        | 41%       |
| Postnatal pilates  | N   | N   | Y   | Y   | Y   | N   | N   | 9         | 24%       |
| Postnatal pilates by reform                                    | N   | N   | N   | Y   | N   | N   | Y   | 3         | 8%        |
| Sprout Baby  | N   | Y   | Y   | Y   | N   | Y   | Y   | 14        | 38%       |
| Guide to newborn care  | N   | N   | N   | Y   | Y   | N   | N   | 8         | 22%       |
| After birth exercise   | N   | N   | Y   | Y   | N   | Y   | Y   | 7         | 19%       |
| Pregnancy, parenting advice & baby care tips app               | N   | Y   | N   | Y   | N   | Y   | Y   | 21        | 57%       |
| Bleeding after birth   | N   | N   | N   | N   | Y   | N   | Y   | 4         | 11%       |
| Burn fat after pregnancy - weight loss                         | N   | N   | N   | Y   | Y   | N   | Y   | 7         | 19%       |
| Losing weight after pregnancy                                  | N   | N   | N   | Y   | Y   | N   | Y   | 5         | 14%       |
| Telfair baby   | N   | N   | N   | Y   | Y   | Y   | Y   | 19        | 51%       |
| Post pregnancy recovery  | N   | N   | N   | Y   | Y   | N   | N   | 10        | 27%       |
| Growth Chart, Development Milestones & Vaccination             | N   | Y   | N   | Y   | N   | N   | N   | 11        | 30%       |
| LactApp+   | N   | N   | N   | N   | Y   | N   | Y   | 8         | 18%       |
| NKCH moments   | N   | N   | N   | Y   | Y   | Y   | Y   | 17        | 39%       |
| Parentlove: baby feeding tracker, diapers, pumping             | Y   | N   | Y   | Y   | N   | Y   | Y   | 14        | 33%       |
| Maternal & newborn care plans                                  | N   | N   | N   | N   | Y   | N   | Y   | 5         | 14%       |
| Essentia baby  | N   | N   | N   | Y   | Y   | Y   | Y   | 19        | 51%       |
| Your baby's birth & beyond                                     | N   | N   | N   | Y   | Y   | Y   | Y   | 19        | 51%       |
| Baby care plus   | Y   | Y   | Y   | Y   | Y   | Y   | Y   | 16        | 43%       |
| The postpartum cure  | N   | N   | N   | Y   | N   | N   | Y   | 4         | 11%       |
| UWBaby   | N   | N   | N   | Y   | Y   | Y   | Y   | 20        | 54%       |
| Skin care after pregnancy                                      | N   | N   | N   | Y   | Y   | N   | Y   | 6         | 16%       |
| Elebaby simple   | N   | N   | N   | N   | N   | Y   | Y   | 5         | 14%       |
| Baby Tracker - Newborn Log                                     | N   | N   | Y   | N   | Y   | N   | Y   | 6         | 16%       |
| Mother and baby 2019   | N   | Y   | N   | Y   | Y   | Y   | Y   | 11        | 30%       |
| C-section recovery   | N   | N   | N   | Y   | Y   | N   | N   | 6         | 16%       |
| You+Baby   | N   | N   | N   | Y   | Y   | Y   | Y   | 22        | 59%       |
| Baby& me   | N   | N   | N   | Y   | Y   | Y   | Y   | 22        | 59%       |
| Total (N)  | 4   | 8   | 15  | 40  | 26  | 28  | 38  |           |           |
| Total (%)  | 8%  | 17% | 31% | 83% | 54% | 58% | 79% |           |           |



# Appendix **B**

## TTM Questionnaire

This appendix presents the survey questionnaire on the application of Trans-Theoretical Model on blood donation behaviour as discussed in Chapter 4.



| <b>Blood Donation Processes of Change Scale</b>   |          |
|---|----------|
| <p><b>PLEASE READ EACH STATEMENT AND RATE HOW OFTEN YOU MAKE USE OF A PARTICULAR SITUATION OR THOUGHT TO HELP YOU DONATE BLOOD. THERE ARE FIVE POSSIBLE RESPONSES TO THE ITEMS OF THIS QUESTIONNAIRE:</b></p> <p><b>1=Never</b><br/> <b>2=Seldom</b><br/> <b>3=Occasionally</b><br/> <b>4=Frequently</b><br/> <b>5=Repeatedly</b></p> |          |
|   | Response |
| 1) I can expect to be praised and appreciated by others for donating blood.   |          |
| 2) I make sure I know when and where nearby blood drives are held.  |          |
| 3) I am aware that society is actively encouraging and supporting people to become blood donors.  |          |
| 4) I am considering the idea that I could save lives by donating blood.   |          |
| 5) I think that being a blood donor supports my view of myself as a caring and responsible person.  |          |
| 6) I notice that there are more opportunities to donate blood in my community.  |          |
| 7) I recall articles, posts and/or TV messages about donating blood.  |          |
| 8) Portrayals of people whose lives are saved by blood donation affect me emotionally.  |          |
| 9) I stop to think about how donating blood would be beneficial for people in my community.   |          |
| 10) I share with someone my thoughts and feelings about blood donation.   |          |
| 11) I feel respected in society for being a blood donor.  |          |
| 12) I keep in mind that blood donation is a simple and safe process to overcome the fear of donating.   |          |
| 13) There are special people around me that encourage me and improve my willpower to continue donating blood.   |          |
| 14) I see more companies and organizations hosting and sponsoring blood drives.   |          |
| 15) I am moved by a person who helped save lives by donating blood.   |          |
| 16) I feel very competent and proud when I (decide to) donate blood.  |          |
| 17) I look for information related to blood donation process.   |          |
| 18) When I am hesitant to donate blood, I remind myself that it helps save lives.   |          |
| 19) I make commitments to myself to donate blood.   |          |
| 20) I reward myself with a treat after donating blood.  |          |
| 21) I recognize I have the energy needed to be a blood donor.   |          |
| 22) Whenever I feel tempted to reassess being a blood donor, I begin to think about all the health benefits it offers.  |          |
| 23) I tell myself that I can be a blood donor despite the fact that my relatives and friends don't support my decision.   |          |
| 24) I realize that people who donate blood are a great source of inspiration to others.   |          |
| 25) I seek out groups of people who can raise my awareness about how to become a blood donor.   |          |
| 26) I schedule my blood appointments.   |          |
| 27) I keep around any source of information associated with blood donation to reconsider my reasons for donating blood.   |          |
| 28) Being a non-donor makes me feel disappointed and helpless.  |          |
| 29) I get upset when I hear stories about people whose lives depend on regular blood transfusions.  |          |
| 30) I have a friend on whom I can count to come with me when I want to donate blood.  |          |

Figure B.2: TTM applied to BD: Survey questionnaire (Page 2)

| <b>Blood Donation Self-Efficacy Scale</b>  |          |
|--|----------|
| <p><b>A NUMBER OF SITUATIONS ARE DESCRIBED BELOW THAT CAN MAKE IT HARD TO DONATE BLOOD. PLEASE RATE HOW CONFIDENT YOU ARE IN YOUR ABILITY TO DONATE BLOOD IN THE FACE OF THESE SITUATIONS. THERE ARE FIVE POSSIBLE RESPONSES TO THE ITEMS OF THIS QUESTIONNAIRE:</b></p> <p><b>1 = Not at all confident</b><br/> <b>2 = Not very confident</b><br/> <b>3 = Moderately confident</b><br/> <b>4 = Very confident</b><br/> <b>5 = Extremely confident</b></p> |          |
|  | Response |
| 1) When I am very anxious and stressed.  |          |
| 2) When I am feeling a physical discomfort.  |          |
| 3) When I witness a bad blood donation experience (e.g. Someone fainting).   |          |
| 4) When I realize I have not donated for a long while.   |          |
| 5) During or after experiencing personal problems (e.g. family, financial).  |          |
| 6) When I have other time commitments.   |          |
| 7) When I remember having a negative reaction to donating that caused me light-headedness and nausea.  |          |
| 8) After recovering from an illness or an injury.  |          |
| <b>Blood Donation Decisional Balance Scale</b>   |          |
| <p><b>THE FOLLOWING STATEMENTS REPRESENT DIFFERENT OPTIONS ABOUT BLOOD DONATION. PLEASE RATE HOW IMPORTANT EACH STATEMENT IS TO YOUR DECISION TO DONATE BLOOD ACCORDING TO THE FOLLOWING FIVE POINT SCALE</b></p> <p><b>1=Not important at all</b><br/> <b>2=Slightly important</b><br/> <b>3=Moderately important</b><br/> <b>4=Very important</b><br/> <b>5=Extremely important</b></p>  |          |
|  | Response |
| 1) The blood bank might reject my blood due to low level of my Haemoglobin.  |          |
| 2) I may help save someone's life.   |          |
| 3) I am likely to faint at the sight of blood.   |          |
| 4) Donating blood will reduce the risk of getting serious health conditions.   |          |
| 5) I will get a free of cost health check-up.  |          |
| 6) I may find out I have a disease.  |          |
| 7) Donating blood depletes the calcium levels in the body.   |          |
| 8) Donating blood will help me burn calories.  |          |
| 9) I might be told I am not eligible to donate blood.  |          |
| 10) Donating blood is an uncomfortable experience because I am afraid of needles.  |          |
| 11) I will be helping to prevent blood shortages.  |          |
| 12) I will set a good example and inspiration for people around me.  |          |

Figure B.3: TTM applied to BD: Survey questionnaire (Page 3)

# Appendix C

## Audit report

This appendix provides the detailed audit report of *Move it Mama* and *Blood Donor* apps using the reusable requirements catalog presented in Chapter 5.

Table C.1: Requirements catalog for gamified eHealth apps: Audit summary.

|  |   |  |
|--|---|--|
| <b>Actors</b>  |   |  |
| <b>Auditor:</b>  | Lamyae Sardi  |  |
| <b>RE team:</b>  | Lamyae Sardi, Ali Idri and José Luis Fernández-Alemán |  |
| <b>Application information</b>   |   |  |
| <b>Name:</b>   | Blood Donor   | Move it Mama   |
| <b>Developer:</b>  | American Red Cross                                    | MO BIG GmbH  |
| <b>Price:</b>  | Free  | Paid (7-days trial)  |
| <b>Mobile OS:</b>  | Android/iOS   | Android/iOS  |
| <b>Audit summary</b>   |   |  |
| Carried out on March 5, 2020.  |   |  |
| Both applications were installed in an iPhone X, iOS 13.3.1.   |   |  |
| The purpose of this audit is to evaluate the apps' compliance with the requirements stated in the GHA-CAT regarding gamification and relevant quality characteristics in gamified health systems namely Functional suitability, usability and security. These characteristics' assessment has been limited in a small number of attributes that have been found to be significantly influenced in gamified health systems. The audit was conducted using the audit method previously described.  |   |  |
| <b>- Blood Donor app</b>   |   |  |
| In general, the application fulfills most of the assessed characteristics. In terms of gamification, various game elements (points, badges, leaderboards and redeemable rewards) are seamlessly incorporated into the application which largely enhance the playfulness of the application and encourage social interaction. On the other hand, the features and functionalities of the application are well-integrated and the color scheme and fonts match exactly the main purpose of the application which lies in promoting blood donation. Besides, the design of the application is very intuitive and considerably eases the navigation throughout the application's sections. With regards the security of users' personal data, the application is endowed with a strong authentication mechanism and it is tightly linked to American Red Cross blood drives.                       |   |  |
| <b>- Move it Mama</b>  |   |  |
| On the whole, the application does not comply with more than half of the assessed characteristics. First, the application is fairly gamified as it only includes levels and badges as a game element. With the absence of gamification's central pillars, it is roughly impossible to achieve gamification goals consisting of playfulness, fun, social interaction and others. Second, the features and functionalities of the application are not very well integrated and can be even confusing for users. Although, the application is very limited in terms of functional content, there is no clear structure of the application's content and the lack of a help section makes the whole application a bit challenging to comprehend. Third, the application does not enable users to change their preferences with regards language settings which, therefore, restrains its wide use. |   |  |
| <b>Coverage score</b>  |   |  |
| Total questions: 29.   | Yes: 26. No: 3.<br>$26 \times 100/29 = 89.7\%$        | Yes: 18. No: 5. Not Applicable (N/A): 2. Partially: 4<br>$20 \times 100/27 = 74.1\%$ |
| <b>Deficiencies</b>  |   |  |
| <b>- Blood Donor app</b>   |   |  |
| D1. The application does not adapt to screen orientation (portrait and landscape).   |   |  |
| D2. The application does not support multiple languages.   |   |  |
| D3. The privacy policy presented in the application repository (Apple store) is not included in the app.   |   |  |
| <b>- Move it Mama app</b>  |   |  |
| D1. The application does not include various gamification elements.  |   |  |
| D2. The application does not harness social interaction and group influence.   |   |  |
| D3. Although there is a limited number of functionalities in the application, the overall layout is not well designed which substantially affects accessibility and efficiency of use.   |   |  |
| D4. The application is not multilingual.   |   |  |
| D5. The application lacks in-app help and support.   |   |  |
| <b>Recommendations</b>   |   |  |
| <b>- Blood Donor app</b>   |   |  |
| R1. The application shall handle screen change orientations to make the text easily readable by users with low vision.   |   |  |
| R2. Despite being dedicated solely for American citizens, an exhaustive list of the main preferred languages to this audience shall be supported by the application.   |   |  |
| R3. A detailed and well-described privacy policy shall be included in the application to inform users on how their personal data are being stored, used and shared.  |   |  |

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**Recommendations**

**– Move it Mama app**

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**R1.** To enhance the playfulness of the application, the application shall enrich its instant reward system and feedback through the integration of a points system and a progress tracking (e.g. Users can therefore earn a certain amount of points according to their daily performance, at the end of each day, the sum of their collected points is interpreted on a curve to display users' progress).

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**R2.** The application shall embed at least one social mechanism to initiate interaction between users and keep them engaged within the app (e.g. easy-to-share action, friends' referral, in-app community, etc.)

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**R3.** The layout of the application shall be revised to avoid redundancy and ambiguous content. The exercises and phases sections look similar but are different in terms of accessibility, in that, one is fully accessible and flexible while the other one is regulated by the pregnancy or postnatal phase of the user.

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**R4.** The application shall be tailored for various languages to target potential users whose first language is not English.

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**R5.** An in-app help and support section that is consistent and clear shall be included in the application to instruct and display help for users.

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