Journal of Biomedical Informatics 146 (2023) 104500

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

# Designing personalised mHealth solutions: An overview

Octavio Rivera-Romero [a,b,*], Elia Gabarron [c,d], Jorge Ropero [a], Kerstin Denecke [e,1]

[a] Electronic Technology Department, Universidad de Sevilla, Spain
[b] Instituto de Investigación en Informática de la Universidad de Sevilla, Spain
[c] Norwegian Centre for E-health Research, University Hospital of North Norway, Tromsø, Norway
[d] Department of Education, ICT and Learning, Østfold University College, Halden, Norway
[e] Bern University of Applied Sciences, Bern, Switzerland

ARTICLE INFO

*Keywords:*
Personalisation
mHealth
Design methods
Behavioral change
Review

ABSTRACT

*Introduction:* Mobile health, or mHealth, is based on mobile information and communication technologies and provides solutions for empowering individuals to participate in healthcare. Personalisation techniques have been used to increase user engagement and adherence to interventions delivered as mHealth solutions. This study aims to explore the current state of personalisation in mHealth, including its current trends and implementation.
*Materials and Methods:* We conducted a review following PRISMA guidelines. Four databases (PubMed, ACM Digital Library, IEEE Xplore, and APA PsycInfo) were searched for studies on mHealth solutions that integrate personalisation. The retrieved papers were assessed for eligibility and useful information regarding integrated personalisation techniques.
*Results:* Out of the 1,139 retrieved studies, 62 were included in the narrative synthesis.
Research interest in the personalisation of mHealth solutions has increased since 2020. mHealth solutions were mainly applied to endocrine, nutritional, and metabolic diseases; mental, behavioural, or neurodevelopmental diseases; or the promotion of healthy lifestyle behaviours. Its main purposes are to support disease self-management and promote healthy lifestyle behaviours. Mobile applications are the most prevalent technological solution. Although several design models, such as user-centred and patient-centred designs, were used, no specific frameworks or models for personalisation were followed. These solutions rely on behaviour change theories, use gamification or motivational messages, and personalise the content rather than functionality. A broad range of data is used for personalisation purposes. There is a lack of studies assessing the efficacy of these solutions; therefore, further evidence is needed.
*Discussion:* Personalisation in mHealth has not been well researched. Although several techniques have been integrated, the effects of using a combination of personalisation techniques remain unclear. Although personalisation is considered a persuasive strategy, many mHealth solutions do not employ it.
*Conclusions:* Open research questions concern guidelines for successful personalisation techniques in mHealth, design frameworks, and comprehensive studies on the effects and interactions among multiple personalisation techniques.

## 1. Introduction

In recent years, mobile health (mHealth) has become increasingly popular for delivering healthcare services to individuals. The term mHealth appeared for the first time in scientific publications in the early 2000 s [1–3]. mHealth is defined “as the use of mobile information and communication technology in healthcare” [4]. It involves the use of technology to empower individuals to play a more active role in their health and healthcare, allowing them to make more informed decisions, monitor their progress, and communicate more effectively with healthcare providers [5,6]. Patients’ use of mHealth has the potential to increase patient involvement, which will ultimately enhance their experience and health outcomes.

Research shows that personalisation can increase user engagement and adherence to mHealth solutions [7] as well as the effectiveness of mHealth interventions [7,8]. Personalisation is also a factor that

* Corresponding author at: Electronic Technology Department, Universidad de Sevilla, Spain.
*E-mail address:* orivera@us.es (O. Rivera-Romero).
[1] All authors contributed equally.

https://doi.org/10.1016/j.jbi.2023.104500
Received 28 February 2023; Received in revised form 14 September 2023; Accepted 16 September 2023
Available online 16 September 2023
1532-0464/

influences the adoption and use of mHealth technology. The use of personalisation strategies, as opposed to the “one-size-fits-all” approach, involves tailoring the delivery of healthcare services to meet the unique needs and preferences of each individual. Personalisation in mHealth can take many forms, such as personalised messaging, personalised treatment plans, and personalised data analysis [9].

Although there are multiple available reviews of mHealth applications in the context of specific medical conditions (e.g., mHealth for increasing physical activity [10], medication management [11], and mental health [12]), there is still no complete overview of the implementation of personalisation in mHealth.

Two reviews regarding personalisation were found [9,13], but they were very specific or limited to a certain field within mHealth. Gosetto et al. conducted a scoping review that analysed concepts that could be used to personalise an intervention in mHealth [9], classifying the concepts associated with behavioural changes in mHealth into four dimensions: users, system functionalities, information, and application properties. Monteiro-Guerra et al. performed a scoping review that examined personalisation techniques, theoretical foundations, gamification, and system evaluation [13]; however, the review was limited to real-time personalisation in mobile applications for physical activity coaching. In contrast to these more specific reviews, our overview is the first comprehensive review to address the current state of personalisation in any mHealth solution. To achieve this, we considered numerous characteristics of these solutions, such as design methods, theoretical foundations, motivational strategies, evaluation levels, data used, type of personalisation, and personalised components. We explored the current state of personalisation in mHealth, including current trends and implementation. Additionally, we discuss various techniques and technologies that have been used to develop personalised mHealth services. Based on this, we derive potential future developments in the field.

**Statement of Significance:**

| | |
|---|---|
| **Problem** | Currently, there are no clear views of how personalized mHealth solutions are being designed. |
| **What is Already Known** | Although some reviews have been published on the topic of personalized mHealth solutions, they were focused on specific topics without reporting the design process followed, particularly if any design model or framework specifically defined for personalization was followed in the design of mHealth solutions. |
| **What This Paper Adds** | This paper identifies relevant issues of the design process of these solutions. In this regard, the paper summarizes their focus (conditions or health domain, target population, and main purposes), the most used technology (mobile apps), the design methods followed (User-Centred Design, Patient-Centred Design, and Human-Centred Design) and their theoretical foundations (Behavioral change theories). Regarding personalization, this paper reviews four key components of the personalization strategy: data used to personalise the solution, type of personalization, the personalization techniques implemented, and components of the mHealth solution that were personalised. |

## 2. Materials and methods

### 2.1. Design

This review was conducted according to the PRISMA guidelines [14]. This review aims to analyse the implementation of personalisation in mHealth solutions. Table 1 presents the objectives and research questions addressed in this review.

### 2.2. Search strategy

A systematic search of the scientific literature was performed on 3 November 2022 using the following databases: PubMed, ACM Digital Library, IEEE Xplore, and APA PsycInfo. A combination of keywords involving personalisation, mHealth, and design or development process was used. The search string was “*(“personalised” OR “personalised” OR “personalisation” OR “personalisation”) AND (“mhealth” OR “mobile health” OR “mobile app” OR “smartwatch” OR “wearable”) AND (“design” OR “development”)*”. Bibliographies and reference lists were also scrutinised to identify other relevant studies. The publication year was not used as a search criterion.

**Table 1**
Objectives and research questions.

| Objective | Research Question |
|---|---|
| To analyse research trends on the personalisation of mHealth solutions | RQ1: How have research trends on the personalisation of mHealth solutions evolved over time? |
| To understand the contexts in which personalised mHealth solutions were designed | RQ2: Which health domain or conditions were personalised mHealth solutions designed for? |
| | RQ3: Which target population were personalised mHealth solutions intended for? |
| To explore the designing process of personalised mHealth solutions | RQ4: Which were the main purposes of personalised mHealth solutions? |
| | RQ5: Which technologies were used to develop personalised mHealth solutions? |
| | RQ6: Which design methods and processes were followed to develop personalised mHealth solutions? |
| | RQ7: Which theoretical foundations guided the design of personalised mHealth solutions? |
| | RQ8: Which other motivational strategies were implemented in personalised mHealth solutions? |
| To describe the evaluation level of personalised mHealth solutions | RQ9: Which was the evaluation level of personalised mHealth solutions? |
| To identify the implementation approach of personalisation in mHealth solutions | RQ10: Which data were used to personalise mHealth solutions? |
| | RQ11: Which type of personalisation was implemented in mHealth solutions? |
| | RQ12: Which personalisation techniques were included in mHealth solutions? |
| | RQ13: Which components of mHealth solutions were personalised? |

### 2.3. Eligibility criteria

#### 2.3.1. Inclusion criteria

- Studies referring to mHealth solutions (a mobile app, smartwatch application, or other wearable or mobile information and communication technology using a specific tool) and reporting results.
- Paper presenting an mHealth solution with details (e.g., functionalities).
- An mHealth solution integrating one or more personalisation strategies (personalisation is a process that changes the functionality, interface, content, or distinctiveness of a system to increase its personal relevance).
- Studies published in English language.
- Access to full text.

#### 2.3.2. Exclusion criteria

- Studies not referring to mHealth solutions.
- Studies not presenting details on the mHealth solution.
- Studies that simply apply existing tools (SMS, social media messenger).
- Studies on mHealth solutions where personalisation strategies have not been implemented.

- Studies reporting solutions for monitoring without providing feedback to users, papers reporting only on sensors, and algorithms without integration into an mHealth solution.
- Studies focused on identifying users' preferences without proposing any personalised mHealth solution.
- Review papers, opinion papers, editorials, theses, posters, abstracts, and protocols.

### 2.4. Screening

Two researchers (K.D. and O.R.-R.) conducted the searches according to a defined search strategy. O.R.-R. performed the searches; K.D. checked them and submitted the results to the RAYYAN platform [15]. Duplicate studies were subsequently eliminated. Next, both researchers independently reviewed the titles and abstracts of a sample of results (N = 100) by applying the selection criteria. The criteria were refined, and discrepancies were resolved by consensus involving a third researcher (J.R.). The remaining titles and abstracts were reviewed by one of the researchers, and all studies were filtered by applying the inclusion and exclusion criteria. Full texts of the included studies were obtained. Next, three authors (K.D., O.R.-R., and J.R.) independently reviewed the full texts, excluding those that did not meet the selection criteria. When several studies reported data from the same mHealth system, only one study was included in the analysis. Data from all the included studies were collected.

### 2.5. Data collection and data classification

Two researchers (K.D. and O.R.-R.) defined the data chart to be used in the data extraction stage based on their experience in the fields of mHealth and personalisation. A data chart was designed based on the research questions defined in this study. For each research question, the

**Table 2**
Data extraction chart.

| Item | Description |
|---|---|
| **General** | |
| Publication year | Year in which the study was published. |
| Country | Country in which the study was conducted, as reported by the authors (some studies were conducted in multiple countries). |
| Targeted health conditions or diseases | Following the International Classification of Diseases (ICD) proposed by the World Health Organization [16], two additional groups were added: ***Chronic conditions*** in general (the mHealth solution was focused on chronic conditions in general without specifying a concrete disease) and ***Promotion of healthy lifestyle** behaviours* (mHealth solutions that were designed to obtain and/or maintain a healthy lifestyle to prevent any potential disease). |
| Age | Age of targeted population |
| Gender | Gender of targeted population |
| **System characteristics** | |
| Main purpose | We defined five alternatives:<br>**Promotion of healthy lifestyle**: mHealth solutions that support users in the change and maintenance of a healthy lifestyle.<br>**Communication**: mHealth solutions that are designed for different parties to communicate healthcare professionals, patients, and caregivers.<br>**Rehabilitation**: mHealth solutions that support patients in their rehabilitation.<br>**Self-management**: mHealth solutions that support patients/caregivers in their health management and are intended for patients/caregivers.<br>**Multi-purpose**: mHealth solutions that implement a combination of the aforementioned purposes. |
| Technology used | Three options: **Mobile app**, **Wearable**, or **Platform.** (When the mHealth solution consists of several components, such as a mobile app, a web portal, or an external dashboard, the core functionalities must be implemented in a mobile solution such as a mobile application or a wearable device.) |
| Motivational strategies | If authors explicitly mentioned the implementation of any motivational strategy, such as gamification or motivational messages in the mHealth solution. |
| **System design process** | |
| Design approach | Represents the methodology followed to design the mHealth solution. Some examples of these methodologies are user-centred design (UCD) and patient-centred design (PCD). |
| Design framework | Researchers used a framework to guide the design process of the mHealth solution. These data are collected when authors explicitly identified the framework. Examples of these frameworks are the Integration, Design, and Assess framework (IDEAS) and the Persuasive System Design model. |
| Design methods | Following the methodology identified in the "Design Approach" and the structure defined in the "Design framework", this item identifies the specific methods used to perform the design activities in each phase/stage. Examples of these design methods are interviews, focus groups, and surveys. |
| Stakeholders' involvement | Presents information on stakeholders who were involved in the activities carried out in the design process. |
| Last stage | Identifies the last stage of the design process of the proposed mHealth solution reported in the paper. |
| Evaluation level | The following codification schema was designed by consensus based on the involvement of potential end-users, the required level of the development, and the context in which it is performed and applied to the included studies.<br>**Level 0**: Technical validation, heuristically quality assessment, and/or potential behaviour change. Evaluations included in this level did not involve end-users, were commonly conducted in laboratory or controlled settings, and did not require fully developed solutions.<br>**Level 1**: Usability, satisfaction, and/or user experience. Evaluations included in this level involved end-users, were conducted in laboratory or real settings, and did not require fully developed solutions.<br>**Level 2**: Acceptability or feasibility. Evaluations included in this level involved end-users, were conducted in real settings, and did not require fully developed solutions.<br>**Level 3**: Preliminary effectiveness or efficacy. Evaluations included in this level involved end-users, were conducted in real settings, assessed effectiveness, and did not require fully developed solutions.<br>**Level 4**: Effectiveness. Evaluations included in this level involved end-users, were conducted in real settings, assessed effectiveness, and required fully developed solutions. |
| Theoretical foundations | Theories or models used as basis in the design process when they were explicitly mentioned by the authors. |
| **Personalisation** | |
| Factors | Parameters that were used to personalise the mHealth solution. |
| Type | **Static personalisation**: Represents a situation in which an algorithm made the personalisation using only static data, such as nickname or nationality, that did not change during the use.<br>**Dynamic personalisation**: Represents algorithms using some real-time data or data collected during the use such as physical activity patterns or location. |
| Personalisation techniques | Identifies the personalisation techniques based on the taxonomy proposed by Op den Akker [17] implemented in the mHealth solution (see Glossary). |
| Personalised components | Based on the definition of personalisation proposed by Fan and Poole to identify potential mHealth solution components to be personalised [18]: functionality, interface, content, and distinctiveness. |

researchers proposed a list of relevant information to be reported. The final list was created by consensus. The data included in this chart were grouped into four categories: general characteristics, system design processes, and personalisation. Table 2 lists the items in each category.

The options considered in the "main purpose" item were defined based on an iterative process. Two researchers (O.R.-R. and J.R.) performed this process. Initially, both researchers independently reviewed a sample of the included papers (N = 20), and a first list of options which included three options ("Self-management", "Promotion of healthy lifestyle", and "Rehabilitation") was agreed upon by consensus. Then, both researchers applied this initial classification scheme to a different sample of the included papers (N = 5), and an additional option was included ("Communication"). As the final list was not mutually exclusive, researchers agreed to add a new option ("Multi-purpose") to include all the solutions that could be matched into two or more options. Appendix I provides detailed information on the results of applying this classification scheme.

Data collection was performed by three authors (K.D., O.R.-R., and J. R.). Each researcher reviewed a proportion of the included studies. One of the authors (O.R.-R.) reviewed three articles each from the other two authors. The purpose of this study was to ensure that there were no major discrepancies between authors regarding the criteria for data collection and classification. Minor discrepancies were resolved by a consensus. The same author (O.R.-R.) verified the coherence of the extracted information. Once the data extraction was completed, the factors considered to personalise the solution were coded and grouped. We defined eight groups: demographic data, user characteristics, health-related data, intervention-related data, user preferences, behavioural data, other behavioural change factors, and contextual data. User characteristics included data such as height, psychological factors, and phenotype describing the user, which were not considered in the demographic data. Health-related data included information on health parameters, such as blood pressure and heart rate, and disease information, such as disease type or symptoms. Intervention-related data gathered information on the parameters used in mHealth-based interventions. For example, exercise is delayed during a physical activity intervention. User preferences include information about individual preferences (e.g., the type of food that the user liked the most). Behavioural data were collected on user behaviour, including substance use, physical activity patterns, and food intake. Other behavioural change factors include the level of change awareness, personal goals, and subjective behaviour. Social factors include collected data on social contexts and limitations. The contextual data group included data on the user's context, such as location or weather.

## 3. Results

In total, 1,139 results were obtained from the search. After removing duplicates, the number of studies was reduced to 1,041. A total of 946 papers were filtered for title and abstract reviews. The full texts of the remaining 95 studies were sought, and 88 were obtained. The full texts were then scrutinised by applying the selection criteria, and 62 were eventually included in the study. Of these, 2 studies reported data from the same mHealth solution; hence, only 1 was excluded. Thus, 61 personalised mHealth systems were identified and analysed. The screening process, following the recommendations of the PRISMA guidelines, is shown in Figs. 1, 2. Appendix I provides detailed information on the collected data.

### 3.1. RQ1: How have research trends on the personalisation of mHealth solutions evolved over time?

Overall, 5 out of 61 studies were conducted in several countries [19–23]. 4 studies did not report the country in which the study was conducted [24–27]. The included studies were performed in 26 countries: United States of America (N = 22, [20,21,28–47]]), United Kingdom (N = 7, [19,21–23,48–50]), China (N = 4, [21,23,51,52]), Spain (N = 3, [53–55]), Netherlands (N = 3, [21,56,57]), Republic of Korea (N = 3, [58–60]), Belgium (N = 2, [61,62]), Denmark (N = 2, [23,63]), France (N = 2, [23,64]), Germany (N = 2, [21,65]), Australia (N = 2, [19,66]), Canada (N = 2, [20,67]), Taiwan (N = 2, [68,69]), Cyprus (N = 1, [70]), Luxemburg (N = 1, [71]), Norway (N = 1, [22]), Portugal (N = 1, [72]), Sweden (N = 1, [73]), Switzerland (N = 1, [74]), Mexico (N = 1, [75]), Iran (N = 1, [76]), Malaysia (N = 1, [23]), Qatar (N = 1, [77]), Russia (N = 1, [78]), Singapore (N = 1, [79]), and New Zealand (N = 1, [19]). Regarding continents, America hosted 26 studies, Europe 26 studies, Asia 14 studies, and Oceania 4 studies. Despite the potential benefits of using mHealth solutions, no African countries nor least developed countries [80] were represented in the studies.

Regarding the year of publication, the included studies were published between 2013 and 2022. Fig. 2 shows the distribution of included studies by publication year. The number of published papers focusing on personalised mHealth solutions has increased during the last three years, accumulating more than half of the included studies and demonstrating the current trend in this field.

### 3.2. RQ2: Which health domain or conditions were personalised mHealth solutions designed for?

A wide variety of diseases and health conditions have been targeted using personalised mHealth solutions. Using the ICD-11 classification, 10 different categories of diseases were targeted by the included solutions: endocrine, nutritional, or metabolic diseases (N = 10); mental, behavioural, or neurodevelopmental disorders (N = 10); diseases of the circulatory system (N = 6); certain infectious or parasitic disease (N = 5); neoplasms (N = 3); pregnancy, childbirth, or the puerperium (N = 2); diseases of the nervous system (N = 2); diseases of the musculoskeletal system or connective tissue (N = 1); diseases of the respiratory system (N = 1); and symptoms, signs, or clinical findings not elsewhere classified (N = 1).

Two additional groups were added to the ICD-11, as previously mentioned: chronic conditions in general (N = 2) and lifestyle modification or maintenance (N = 18). Table 3 lists the specific conditions and diseases targeted by these solutions.

### 3.3. RQ3: Which target population were personalised mHealth solutions intended for?

Most of the included studies (N = 51 [19,21–29,32–34,39,43,44, 50,51,53–55,57,60–65,67–69,73–78]) focused on adults, including young adults (N = 11 [20,30,38,41,42,45,47,48,56,58,59,70]) and older adults or elderly people (N = 4 [40,49,66,72]). Additionally, 3 of 61 solutions focused on adolescents [31,37,71]. Of these solutions, 2 addressed problems related to a disease (cancer [31] or asthma [37]), whereas the remaining solution aimed to promote physical activity [71]. Only 1 study addressed obesity in children [52]. Finally, 4 studies did not report data regarding the age of the target population [35,36,46,79].

Most of the included solutions were designed for people without gender distinctions (N = 50, [22,24–27,29–47,49,53,55–58,60–69, 71–76,78,79,81]). Overall, 3 of the 61 solutions were designed exclusively for young males addressing HIV [38,45,47]; another 3 solutions were designed for pregnant women [28], women with breast cancer [54], and women with gestational diabetes [78]; and 5 studies did not specify the sex of the participants [25,26,35,36,51].

### 3.4. RQ4: Which were the main purposes of personalised mHealth solutions?

Most of the included systems (N = 31, [21,23,24,26,29,30,32,33,39, 41–43,46–50,52,54–56,64,66,67,70–72,74,75,77,79]) were classified as "promoting healthy lifestyle behaviours". 15 out of 61 were classified as self-management[22,25,27,28,34,35,37,40,45,51,53,59,69,76,7823,

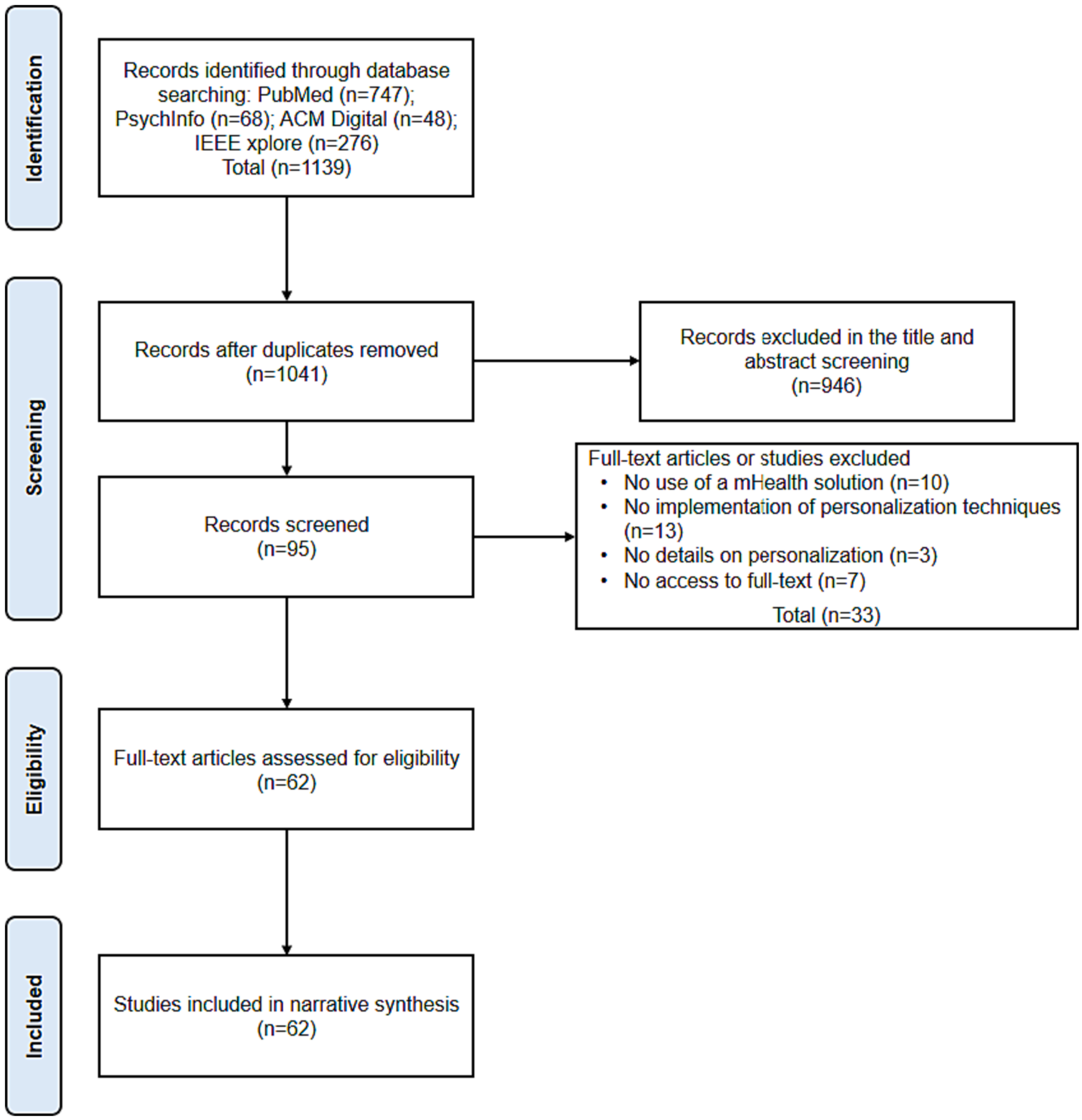


**Fig. 1.** PRISMA flowchart.

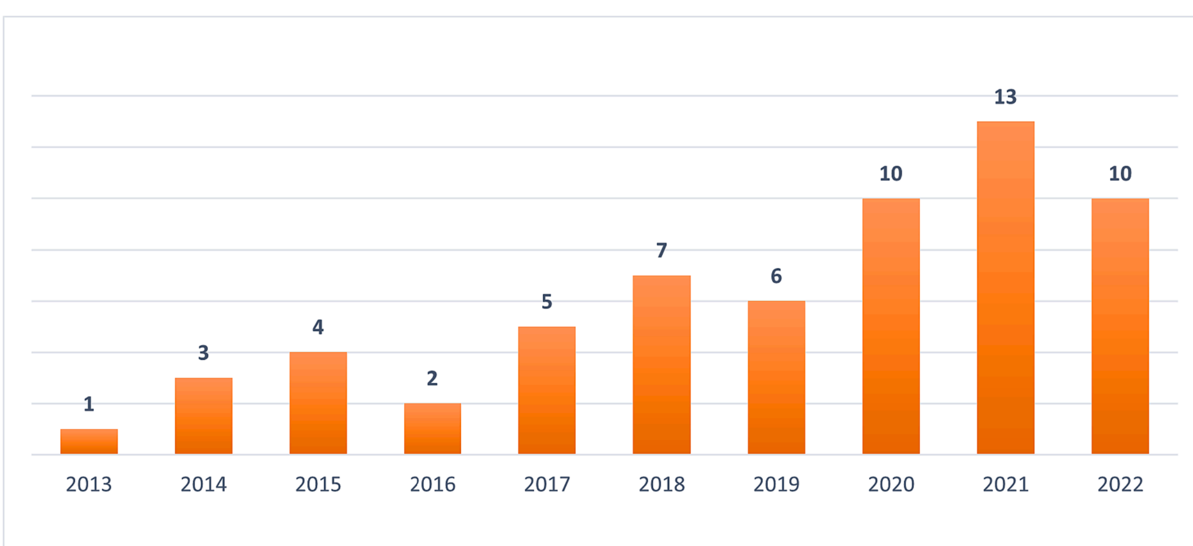


**Fig. 2.** Distribution of included studies by publication year (n = 61).

**Table 3**
Targeted diseases and classification (n = 61 solutions).

| Group | N | Specific condition/disease |
|---|---|---|
| Endocrine, nutritional, or metabolic diseases | 10 | Diabetes (N = 2) [29,35,81]<br>Obesity (N = 2) [24,73]<br>Type 2 Diabetes (N = 2) [72,74]<br>Gestational diabetes (N = 1) [78]<br>Metabolic syndrome (N = 1) [68]<br>Prediabetes (N = 1) [33]<br>Type 1 Diabetes (N = 1) [76] |
| Mental, behavioural, or neurodevelopmental disorders | 10 | Mental health (N = 3) [42,59,70]<br>Smoking (N = 2) [58,66]<br>Alcohol abuse (N = 1) [50]<br>Brain health (N = 1) [55]<br>Depression (N = 1) [63]<br>Schizophrenia (N = 1) [20]<br>Well-Being (N = 1) [43] |
| Diseases of the circulatory system | 6 | Atrial fibrillation (N = 1) [67]<br>Cardiovascular disease (N = 1) [64]<br>Coronary artery disease (N = 1) [62]<br>Heart failure (N = 1) [34]<br>Hypertension and type 2 diabetes (N = 1) [39]<br>Peripheral arterial disease (N = 1) [40] |
| Certain infectious or parasitic disease | 5 | HIV (N = 5) [30,38,45,47,51] |
| Neoplasms | 3 | Breast cancer (N = 2) [54,60]<br>Cancer or undergoing blood and marrow transplantation (N = 1) [31] |
| Diseases of the nervous system | 2 | Multiple Sclerosis (N = 2) [53,61] |
| Pregnancy, childbirth, or the puerperium | 2 | Baby's healthy development (N = 1) [21]<br>Pregnancy (N = 1) [28] |
| Diseases of the musculoskeletal system or connective tissue | 1 | Shoulder impingement syndrome (N = 1) [65] |
| Diseases of the respiratory system | 1 | Asthma (N = 1) [37] |
| Symptoms, signs, or clinical findings not elsewhere classified | 1 | Low back pain (N = 1) [22] |
| Promotion of healthy lifestyle behaviours | 18 | Physical activity (N = 7) [41,49,52,56,57,71,77]<br>Nutrition (N = 3) [23,26,79]<br>Weight management (N = 2) [19,32]<br>Alcohol use (N = 1) [48]<br>Medication (N = 1) [69]<br>Monitoring health condition (N = 1) [27]<br>Physical activity and sleep (N = 1) [36]<br>Physical activity and nutrition (N = 1) [46]<br>Sun protection (N = 1) [75] |
| Chronic conditions in general | 2 | [25,44] |

26,28,29,35,36,38,41,46,52,54,60,70,77,79]. 12 of the 61 studies were categorised as multi-purpose [19,20,38,44,57,58,61–63,65,68,73]. Only 1 of the included systems focused on communication [31], and 1 other focused on rehabilitation [60]. Finally, 1 study did not report its purpose [36]. Fig. 3 shows the distribution of personalised mHealth solutions according to the targeted disease/condition and purpose.

### *3.5. RQ5: Which technologies were used to develop personalised mHealth solutions?*

Most of the included solutions consisted of a mobile application (N = 48, [21–26,28,30,31,33–35,37–41,43,45–54,56–66]), 11 included platforms ([19, 32, 39, 42, 44, 55, 67, 68, 78, 79, 81]), and 2 included wearable devices ([27, 36]). Among these applications, 24 focused on promoting healthy lifestyle behaviours, 13 on self-management, 9 on multiple purposes, 1 on communication, and 1 on rehabilitation. Of the 11 solutions categorised as platforms, 3 focused on multiple purposes, 7 on promoting healthy lifestyle behaviours, and 1 on self-management.

### *3.6. RQ6: Which design methods and processes were followed to develop personalised mHealth solutions?*

Of the 61 included studies, 25 did not report any design approach used in the development process [26,27,30,32,33,35,36,38,40,43, 47,49–51,55,56,60,61,64,65,69,71,75–77]. The most commonly used design approach was UCD (N = 23, [19–21,23,28,29,31,34,37,41, 42,45,46,48,53,54,57,59,63,68,70,72,74,78]), followed by patient-centred design (PCD; N = 8, [22,25,39,44,58,62,66,67]), and human-centred design (HCD; N = 4, [24,52,73,79]). Duffy et al. described these design approaches and discussed the challenges of applying them to the development of digital health interventions [82].

Of the included studies, 6 mentioned a specific design framework used to guide the development process. These design frameworks were the Integrate, Design, Assess, and Share (IDEAS) framework [83] (N = 2, [57,67]), the Persuasive System Design model (PSDm) [84] (N = 2, [26,62]), the Multiphase Optimisation STrategy (MOST) framework [85] (N = 1, [50]), and Shah's methodological framework [86] (N = 1, [54]). The IDEAS and MOST frameworks are intended to develop health interventions. Shah's framework focuses on the design of medical devices, whereas PSDm focuses on the design of persuasive systems. The latter is the only framework that includes personalisation (and tailoring) as a design principle.

32 of the 61 included mHealth solutions were designed using participatory methods. 6 different participatory methods were used: interviews (N = 23, [19–23,28,29,31,34,37,39,41,46,52–54,57,58,62, 63,67,68]); focus groups (N = 12, [19,20,21,29,37,45,48,51, 53,57,58,71]); co-design (N = 11, [19,29–31,45,46,57,59,63,70,78]); participatory workshops (N = 4, [24,29,31,59]); surveys (N = 2, [21,22]); and crowdsourcing (N = 1, [37]).

36 of the included studies reported the involvement of stakeholders in the mHealth solution design process. The most frequently involved stakeholders were patients (or potential end-users in case of promotion of healthy lifestyle behaviours (N = 31, [19,20,22–25,28–31, 37–39,42,44,48,49,52–54,57–59,62,63,66–68,70,72,74,78]), followed by healthcare professionals (N = 23, [19–21,28,29,31,34,37,39, 51,53,57,60,62,63,65,67,68,72–74]), caregivers/family (N = 4,

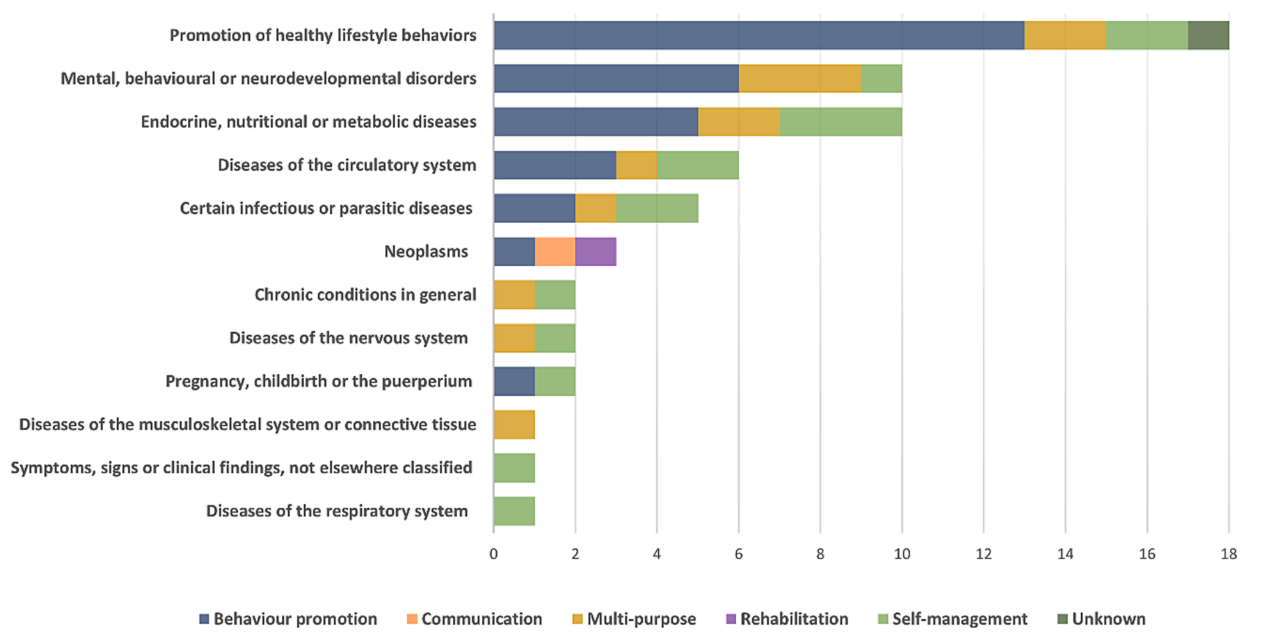


**Fig. 3.** Distribution of personalised mHealth solutions by targeted disease/condition and purpose (n = 61).

[21,37,42,52]), and other stakeholders (N = 3, [29,51,77]).

### 3.7. RQ7: Which theoretical foundations guided the design of personalised mHealth solutions?

39 of the included studies did not explicitly report any theoretical foundation [21–25,27,28,31,33–37,40–45,47,50,52,55,58–61,64–66,68,69,71,72,75–79]. A total of 22 theories, models, and/or principles were reported as being used as the basis in the remaining studies. Most of these foundations are behavioural change theories or models. Among them, the social cognitive theory (N = 5, [32,38,54,56,73]) and self-determination theory (N = 5, [20,53,54,67,74]) were the most used, followed by the theory of planned behaviour (N = 3, [19,32,53]). Additionally, an mHealth solution was designed using a set of behavioural change techniques, although the authors did not mention a specific theory that served as the basis for the design process [70]. In addition to these behavioural change theories and models, five of the analysed mHealth solutions were designed following the principles of persuasive technology (N = 2, [57,62]), the principles of just-in-time adaptive interventions (N = 1, [30]), the principles of reflective practice (N = 1, [26]), and a set of symptom management models (N = 1, [51]).

### 3.8. RQ8: Which other motivational strategies were implemented in personalised mHealth solutions?

Apart from these theoretical foundations, some solutions included other motivational strategies, such as gamification (N = 8, [38,53,54,65,66,70,72,74]) or motivational messages (N = 5, [30,87–90]). Focusing on the gamified solutions, 10 different game elements were implemented: feedback (N = 7, [53,54,65,66,70,72,74]), goal setting (N = 6, [38,53,54,66,70,74]), rewards (N = 5, [38,65,70,72,74]), points (N = 4, [38,65,70,72]), badges (N = 4, [65,66,70,72]), challenges (N = 3, [38,65,70]), leaderboards (N = 2, [70,72]), avatars (N = 1, [54]), social interaction (N = 1, [72]), and themes (N = 1, [53]). Goal-setting and feedback were also implemented in all solutions that included motivational messages.

### 3.9. RQ9: Which was the evaluation level of personalised mHealth solutions?

Regarding the proposed level of evaluation, 3 solutions only reached the lowest level (level 0) [26,37,40]. 12 of the included mHealth solutions reached level 1 of the evaluation [21,28,44,45,48,52–54,57,64,69,78]. Level 2 was evaluated in 16 of the included mHealth applications [19,22,25,31,38,42,43,47,49,50,55,63,66–68,70]. The preliminary effectiveness of the mHealth solution was evaluated for 8 of the included solutions (level 3) [29,30,33,34,39,61,71,75]. Level 4 was assessed in 7 cases [20,41,46,59,62,74,77]. The remaining 15 mHealth solutions were not evaluated in this study.

6 out of the 7 mHealth solutions whose effectiveness was tested were designed to promote healthy lifestyle behaviours: 3 focused on lifestyle modification or maintenance (CalFit, MotiFit, and MyBehavior); 1 on mental, behavioural, or neurodevelopmental disorders (PRIME); 1 on diseases of the circulatory system (HeartHab); 1 on endocrine, nutritional, or metabolic diseases; and 1 on self-management of mental, behavioural, or neurodevelopmental disorders (MEndorphins).

### 3.10. RQ10: Which data were used to personalise mHealth solutions?

57 factors considered in personalisation of mHealth solutions were identified. Fig. 4 shows the frequency of use of the defined groups. Fig. 5 shows the frequency of use for each feature considered.

The user characteristics group was the most frequently used, followed by demographic and health-related data. Regarding the frequency of data use, age was the most frequently used, followed by weight, gender, physical activity level, user preferences, and location. Of the 57 factors considered, 32 were used only in one mHealth solution.

### 3.11. RQ11: Which type of personalisation was implemented in mHealth solutions?

21 of the 61 mHealth solutions did not report enough information to determine the type of personalisation implemented. Most of the mHealth solutions used a dynamic personalisation strategy (N = 31, [26,27,29–31,33,34,36,40–42,44,47,49,52,53,55–59,63,64,66,71,74,75,77–80]). The

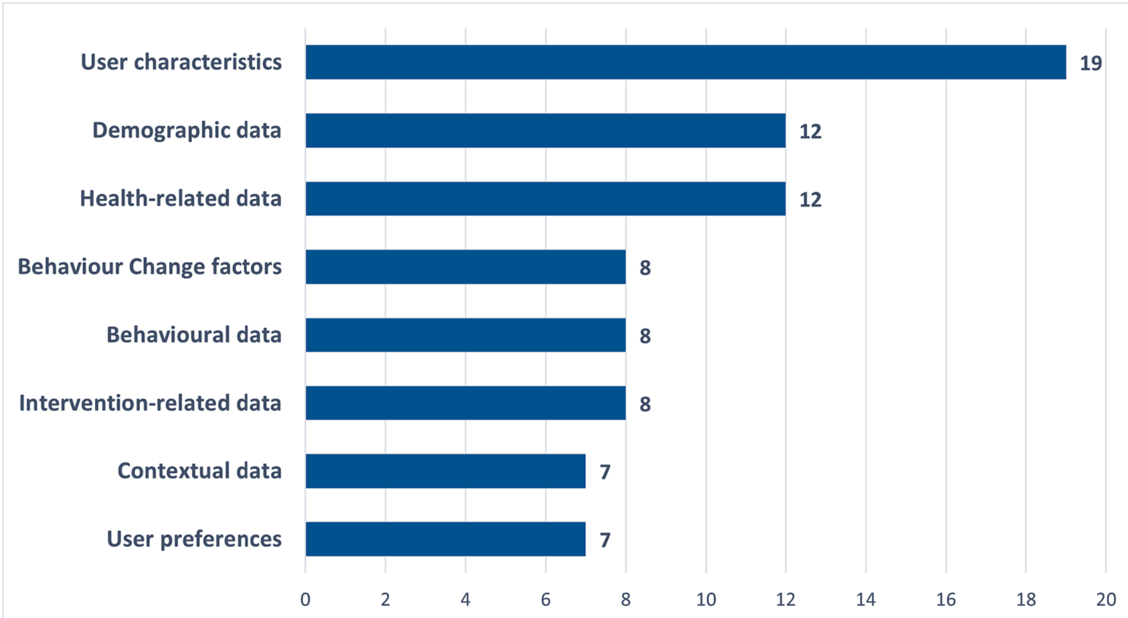


**Fig. 4.** Groups of factors used for personalisation in 61 mHealth solutions.

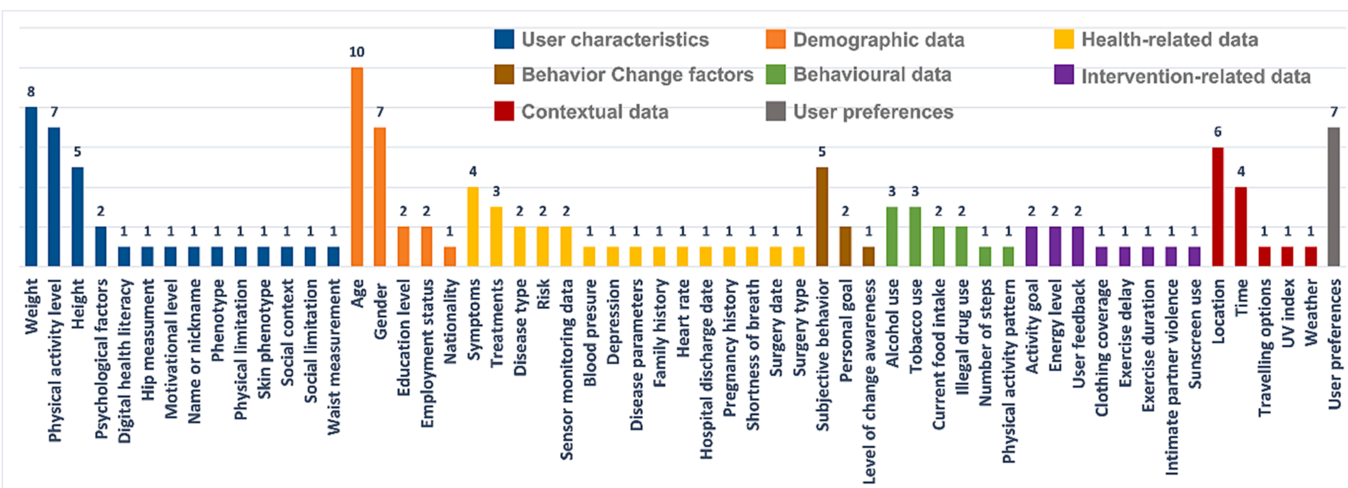


**Fig. 5.** Factors used for personalisation in 61 mHealth solutions.

remaining 9 mHealth solutions implemented a static personalisation strategy [19,21,22,44,49,53,60,61,69].

### 3.12. RQ12: Which personalisation techniques were included in mHealth solutions?

Table 4 shows the number of mHealth solutions that implemented each personalisation technique, according to Akker [17]. Feedback was the most implemented personalisation technique among the mHealth solutions studied. 31 of 61 solutions were implemented. Another widely used technique is goal setting, which has been implemented in 28 mHealth solutions.

16 of the studied mHealth solutions implemented only one personalisation technique. The most common strategy was to implement at least two personalisation techniques (N = 19). Three personalisation techniques were implemented in 11 of the studied mHealth solutions. Only 1 solution implemented all the personalisation techniques.

### 3.13. RQ13: Which components of mHealth solutions were personalised?

Of the studied mHealth solutions, 4 did not clearly report which components were personalised. 49 of the analysed solutions personalised their content, 20 personalised their functionality, and 9 personalised their interface. 41 of these solutions personalised only one component, 11 personalised two, and 5 personalised all three components. Table 5 shows the distribution of the mHealth solutions that implemented a personalisation technique for personalising certain components. More than 75% of mHealth solutions implemented adaptation, feedback, goal setting, interhuman interaction, or user-targeting personalised content. Additionally, more than 75% of the mHealth solutions personalised their interface-implemented feedback.

**Table 4**
Number of solutions that implemented personalisation techniques as described by Akker [17] (n = 61).

| Personalisation technique | Number of solutions | mHealth solutions |
|---|---|---|
| Feedback | 31 | [20,21,23,25,27,29,30,32–35,37,42,43,46,47,49,50,53,55,57,58,60,63,64,71,73,75,79,80,82] |
| Goal setting | 28 | [20,21,23,25,26,32–34,38–40,42,50,53,55–60,63,68,72,75,77,80] |
| Adaptation | 24 | [24–26,28–31,35,39,42,47,49,50,52,54–56,59,65,70,71,75,79] |
| User targeting | 19 | [22,27,30,33,36,41,42,48,50,55–57,63,66,77] |
| Context awareness | 10 | [21,41,49,54,56,57,62,63,70,77] |
| Inter-human interaction | 9 | [20,32,35,54–56,61,71,73] |
| Self-learning | 6 | [19,26,53–56] |

**Table 5**
Distribution of mHealth solutions by personalisation techniques and components. * Some of the mHealth solutions implement several personalisation techniques and/or personalise several components.

| Personalisation technique | Personalisation of content | Personalisation of functionality | Personalisation of Interface | Total number of mHealth solutions * |
|---|---|---|---|---|
| Adaptation | 19 | 9 | 3 | 24 |
| Context awareness | 7 | 6 | 1 | 10 |
| Feedback | 25 | 14 | 7 | 31 |
| Goal setting | 26 | 11 | 4 | 28 |
| Inter-human interaction | 8 | 2 | 1 | 9 |
| Self-learning | 4 | 4 | 1 | 9 |
| User targeting | 16 | 7 | 1 | 19 |
| Total number of mHealth solutions* | 49 | 20 | 9 | |

## 4. Discussion

### *4.1. Principal findings*

This review shows the increased interest in research on personalisation in mHealth since 2020, which has concentrated on interventions distributed via mobile applications. The solutions mainly target three groups of health or medical conditions: endocrine, nutritional, and metabolic diseases; mental, behavioural, and neurodevelopmental diseases; and lifestyle modifications or maintenance. The focus of these studies and solutions is on adults who are supported in disease self-management and behavioural promotion as a target group. Accordingly, behavioural change theories and models as well as motivation strategies were included in the solutions. Development follows a participatory approach, involving users in the design and development phases.

A multitude of data is used to realise personalisation. These data can be categorised as user characteristics, demographics, and health-related data. Personalised content is provided or functionalities are adapted according to the user profile. Precise information on personalisation strategies and algorithms is often not reported in the literature. Frequently used personalisation techniques include feedback provision and goal setting, which are also known from behaviour-change theories. Table 6 summarises the answers to the research questions.

**Table 6**
Answers to the research questions.

| Research Question | Answers found in our review |
|---|---|
| RQ1: How have research trends on the personalisation of mHealth solutions evolved over time? | A raise in research interest in the years 2020–2022; most studies were published in the U.S. |
| RQ2: Which health domain or conditions were personalised mHealth solutions designed for? | Mainly endocrine, nutritional, and metabolic diseases; mental, behavioural, or neurodevelopmental diseases; and promotion of healthy lifestyle behaviours |
| RQ3: Which target population were personalised mHealth solutions intended for? | Adults |
| RQ4: Which were the main purposes of personalised mHealth solutions? | Disease self-management and promotion of lifestyle behaviours |
| RQ5: Which technologies were used to develop personalised mHealth solutions? | Mobile applications most prevalent, systems, wearable devices |
| RQ6: Which design methods and processes were followed to develop personalised mHealth solutions? | UCD, PCD, HCD (not specific framework or model for personalisation) |
| RQ7: Which theoretical foundations guided the design of personalised mHealth solutions? | Behavioural change theories |
| RQ8: Which other motivational strategies were implemented in personalised mHealth solutions? | Gamification and motivational messages |
| RQ9: Which was the evaluation level of personalised mHealth solutions? | Mainly level 2 (acceptance or feasibility);<br>there is still a need for evaluating the effectiveness of personalised mHealth solutions to generate scientific evidence. |
| RQ10: Which data were used to personalise mHealth solutions? | Demographic data, user characteristics, health-related data, behaviour change factors, behavioural data, intervention-related data, contextual data, user preferences |
| RQ11: Which type of personalisation was implemented in mHealth solutions? | Dynamic, but often not clearly described |
| RQ12: Which personalisation techniques were included in mHealth solutions? | Feedback, goal setting, adaptation, user targeting, context awareness, inter-human interaction |
| RQ13: Which components of mHealth solutions were personalised? | Most frequently the content is personalised; less frequently functionalities are personalised. |

### *4.2. Research and practical implications*

During the last few decades, mHealth has evolved greatly. This is reflected in the thousands of research papers listed on PubMed when searching for mHealth. In 2019, 4,880 results were retrieved, and in 2020, the search string resulted in 9,144 papers. The COVID-19 pandemic is a possible reason for this [91] as it is recognised as a catalyst for digitalisation in healthcare. Many mHealth-based interventions have been designed in recent years, and some have generated evidence of their efficacy. The most promising solutions have been reported using theoretical foundations (mostly behaviour change theories) to support the achievement of the desired behaviour change or objective. Although these theoretical solutions are promising, there is still a need to define design frameworks that allow for the development of solutions that increase user motivation and engagement. Neither best practices nor guidelines facilitating the development of solutions are available. These tools provide high levels of user motivation and engagement. Personalisation is a persuasive principle that can be applied in this sense.

We found that the implemented set of personalisation techniques (e.g., feedback, goal setting, adaptation, and user targeting) is very common and that often more than one technique is included. Although this could improve user experience and increase engagement, implementing more than one technique could result in a more complex system.

Common measures for evaluating personalised mHealth solutions include the assessment of usability, user satisfaction, user experience, and acceptance or feasibility. Further research on personalised mHealth could consider additional evaluation measures that are being used in the evaluation of mHealth solutions, such as the volume of interactions, analysis of patient-gathered self-management data, users' physical and psychological wellbeing, behavioural and cognitive impact of mHealth on users, and security and privacy [92,93].

### *4.3. Personalised mHealth for conditions*

Both "Mental, behavioural, or neurodevelopmental disorders" and "Endocrine, nutritional, or metabolic diseases" are currently the ICD groups with more personalised mHealth solutions. Conditions belonging to these two ICD groups (anxiety and depression disorders, depression, alcohol use disorders, schizophrenia, and diabetes) are some of the principal causes of global disability-adjusted life years in adults [5,94,95]. Therefore, it seems precise that personalised mHealth solutions target high-morbidity conditions. Although diabetes is the leading cause of mortality and reduced life expectancy [95], our study identified only five mHealth solutions focusing on this condition that considered personalisation as a persuasive principle in the design [29,35,72,74,76]. Eberle et al. identified 28 mHealth solutions targeting individuals with diabetes between January 2008 and October 2020 [96]. Martinez-Millana et al. have recognised that "personalised and tailored empowerment features should be included in commercial applications for the large-scale assessment of potential in the self-management of type 1 diabetes" [97]. However, our results do not confirm that this direction is being followed.

We have not found much research on personalised mHealth solutions targeting other leading causes of disability-adjusted life-years in adults. These include, but are not limited to, ischaemic heart disease, COPD, lung cancer, gynaecological diseases, and headache disorders [95]. Further research could consider personalising mHealth solutions for these conditions and for other ICD groups that have not yet been represented by personalised mHealth research (such as diseases of the immune system, sleep-wake disorders, diseases of the visual system, diseases of the ear or mastoid process, diseases of the digestive system, and diseases of the skin).

### *4.4. Development and implementation of personalised mHealth solutions*

mHealth solutions are often developed using user-, patient-, and human-centred design approaches, which are based on situating individuals at the centre of the design. Thus, individuals must be considered or participate in the design process. Another similarity among these approaches is that they define an iterative design process consisting of several phases. Some of these phases focus on understanding the problem, including the individual's needs and preferences and the contexts in which the solution will be used. The other phases focused on idealising and designing potential solutions. Additionally, these approaches define the final phase, aimed at testing the designed solution by considering specific metrics. On the other side, the main difference among these design approaches is the central focus. UCD seeks to design digital solutions that build validation and satisfaction around the end-user by understanding people, needs, preferences, and environments. The PCD aims to design solutions that meet patients' needs and preferences and improve their experience, empowering them to assume leadership roles in the management of their health. Finally, HCD situates the "human" in the centre of the design process, prioritising the aspirations and experience of people holistically. In this sense, it focuses on a broader social and organizational perspective, seeking to capture collective experiences involving different stakeholders (patients, caregivers, healthcare professionals, etc.). Thus, individuals must be included in the design process. An appropriate design approach (UCD, PCD, or HCD) must be selected according to the focus of the solution. Involving users and healthcare professionals is consistent with the recommendations of ISO/TS 82304–2:2021 [98]. Almost half of the included studies did not report their solution design approaches.

38 of the 61 analysed mHealth solutions implemented a set of personalisation techniques rather than just one. The objective behind this fact could be to improve user experience and increase engagement, as shown in previous research [99,100]. However, implementing more than one technique can result in a more complex system (not speaking about usability, but about how to demonstrate the effect of a specific technique). The use of a combination of techniques is typical of other motivational strategies, such as gamification. This combination can result in increased interest among more users. However, studies on the effects of combining personalisation techniques are lacking. Are they weakening or strengthening their adherence to and acceptance of an mHealth solution? Are they in conflict with one another?

We found that content and functionality were the most often subject to personalisation, with 49 of the 61 analysed mHealth solutions personalised content and 22 personalised functionalities. Beyond adapting to user preferences, adapting the functionality and interface of a solution may be required when a user has physical or cognitive limitations or disabilities. Many diseases may result in temporal or permanent limitations that should be considered in personalisation strategies. Additionally, personalisation should adapt to each individual to ensure that progress can be made continuously.

### *4.5. Comparison to other studies*

Although there are few reviews on the personalisation of mHealth solutions and they are very specific, we attempt to compare some of the results obtained below.

Gosetto et al. selected 27 articles on personalisation in applications and classified them into four dimensions: user, information, system functionalities, and application properties [9]. In our review, we considered the personalised components of the mHealth solution, which include content, functionality, and interfaces (similar to the last three categories). Considering that Gosetto et al.'s review was published in 2020, we observed a significant increase in the personalised components of the solutions. Furthermore, the personalisation techniques used for each component were extracted. We classified user dimensions separately as factors considered for personalising a solution and found a much greater variety of factors.

The review by Monteiro-Guerra et al. considered aspects more similar to ours, although it was limited to real-time physical activity applications [13]. They analysed 28 studies and extracted information from 17 real-time physical activity coaching applications. Feedback and goal setting were used by most of the applications (17 and 15 out of 17, respectively) based on the type of personalisation. In our study, feedback and goal setting were also widely used, but they were only implemented in approximately half of the solutions (31 and 28 out of 61, respectively). Similar results were observed for other techniques, such as user targeting, inter-human interaction, self-learning, and context awareness, although these techniques were more prevalent in physical activity applications than in general mHealth solutions. However, there was a significant difference in the usage of adaptation, which was rarely employed in physical activity applications (2 out of 17) but was much more common in mHealth solutions (24 out of 61).

Additionally, we noticed lower utilisation of gamification in general mHealth solutions. In the study by Monteiro-Guerra et al., gamification was used by 6 out of 17 physical activity applications, whereas in our study, it was implemented in 8 out of 61 solutions. Monteiro–Guerra et al. focused solely on effectiveness, whereas our study examined different levels of evaluation. Effectiveness was analysed in 10 of 22 studies for physical activity applications, while only 7 of 61 mHealth solutions achieved a level 4 evaluation (effectiveness). Most studies have only reached the acceptability level for evaluation.

Finally, some studies explicitly mentioned the theoretical foundations employed. Behaviour change techniques were utilised by 6 out of 17 physical activity applications, while their usage has increased in mHealth solutions (24 out of 61).

### *4.6. Limitations of this work and future directions*

Our review has some limitations. We have focused on papers published in the English language only and have not included grey literature. Therefore, we may have missed relevant publications on this topic. We included studies that did not use specific terminology to describe personalisation techniques and strategies. For example, only a few papers specifically mentioned that they adopted “user-centred design”. Often, we must classify a described procedure according to our definitions. Missing information may have led to misinterpretation by the data extractors. This limitation can be overcome when the reporting guidelines for mHealth solutions become available. This will ensure standard reporting of all relevant information related to a technical solution.

We found no studies conducted in Africa or South America. One reason might be that SMS solutions are the most common forms of mHealth applications in both high-and low-income countries, while application solutions are mostly used in high-income countries [101]. We excluded studies that simply used SMS messaging as a solution; therefore, such solutions may have been missed.

## 5. Conclusions

In this study, we explored the current state of personalisation in mHealth, including the current trends and implementations. Additionally, various techniques and technologies used to develop personalised mHealth services were discussed. Future research should address the following key areas to fully realise the potential benefits of personalisation in mHealth.

- Develop design frameworks that provide solutions that increase users’ motivation and engagement.
- Develop guidelines for including personalisation into mHealth solutions.
- Develop guidelines for reporting on mHealth solutions.
- Study the effects of personalisation techniques and their combinations.
- Study how to use personalisation techniques to adapt accessibility for different user groups.

## 6. Glossary

**Adaptation:** Adaptation “attempts to direct messages to individuals’ status on key theoretical determinants (knowledge, outcome expectations, normative beliefs, efficacy and/or skills) of the behavior of interest” [102].

**Context awareness:** “A system is context-aware if It uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task” [103].

**Feedback:** “Feedback involves presenting individuals with information about themselves, obtained during assessment or elsewhere” [17].

**Goal-setting:** “Goal setting is a technique used to present the user with short-term, as well as long-term goals that can instil a feeling of progress over the course of an intervention or the day” [17].

**Inter-human interaction:** “The support for any form of interaction with other real human beings” [17].

**Self-learning:** “A self-learning application is able to update its internal model of the user by recording and learning from the various interactions the user has with the application” [17].

**User targeting:** “User targeting attempts to increase attention or motivation to process messages by conveying, explicitly or implicitly, that the communication is designed specifically for ‘you’” [102].

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This study received funding from the Spanish Ministry of Science and Innovation “Proyecto PID2021-125528OB-I00 financiado por MCIN/ AEI /10.13039/501100011033/ y por FEDER Una manera de hacer Europa”.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbi.2023.104500.

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