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Abstract:

A large number of mobile mental health apps are available to the public but current knowledge about requirements of designing such solutions is scarce, especially from sociotechnical and user centred points of view. Due to the significant role of mobile apps in the mental health service models, identifying the design requirements of mobile mental health solutions is crucial. Some of those requirements have been addressed individually in the literature, but there are few research studies that show a comprehensive picture of this domain. This exploratory review aims to facilitate such holistic understanding. The main search keywords of the review were identified in a cross-disciplinary requirements workshop. The search was started by finding some core references in the healthcare databases. A wider range of references then has been explored using a snowball method. Findings showed that there is a good understanding of individual design requirements in current literature but there are few examples of implementing a combination of different design requirements in real world products. The design processes specifically developed for mobile mental health apps are also rare. Most studies on operational mobile mental health apps address major mental health issues while prevention and wellbeing areas are underdeveloped. In conclusion, the main recommendations for designing future mobile mental health solutions include: moving towards sociotechnical and open design strategies, understanding and creating shared value, recognizing all dimensions of efficacy, bridging design and medical research and development, and considering an ecosystem perspective.

Keywords: mobile mental health, mobile health, design, design process, user experience, user centred design

1. Introduction

The World Health Organization (WHO) aims to make mental health a global development priority [1]. While 30% of the world's non-fatal disease burden and 10% of the overall disease burden are caused by mental disorders, mental health often does not receive the same attention from authorities as physical health. In addition to being responsible for a significant disease burden, mental health problems can negatively affect the economy and production efficiency [2].

There is increasing recognition that improvements to mental health should become a strategic objective for healthcare policymakers internationally. The focus is increasingly on living well, preventing problems, and supplementing treatment services. For example, the UK's cross-governmental strategy *No health without mental health* supports the idea that: "*fewer people will develop mental health problems – by starting well, developing well, working well, living well and ageing well."[3]*

Current National Health Service (NHS) England strategy, based on the NHS Five Year Forward View [4], builds on this aim and outlines parity of esteem as a goal. Establishing parity of esteem will ensure that mental health problems will be viewed as equally important as physical health problems. This demonstrates the increasing recognition that services, treatment, and funding for mental health problems need to be equal to those provided for physical health. However, the demand for services outstrips current resources and access to services for mental health problems particularly for those who have mild to moderate mental health issues or wish to take a preventative wellbeing focused approach is limited.

Alternative approaches to service provision are required, particularly to cover a wide range of people regardless of their background, economic situation, and age. Providing inclusive mental health services can be expensive and challenging, with estimates suggesting that around one in four adults experience mental illness in a given year [3,5]. Using information and communication technologies to provide support has gained importance in the eyes of policymakers in the last few years. These technologies can make mental health services more cost-effective and more accessible to a wider audience. Moreover, digital solutions are seen as less stigmatizing and this can persuade more people to use them [3].

Local health services have also recognized the need to develop new approaches to using technology. For example, the digital design organization mHabitat's work [6] in the north of England with services like the Yorkshire Centre for Eating Disorders to design new digital solutions shows the role that new technologies can play in changing service delivery.

Another example is WHO's work with the London School of Hygiene and Tropical Medicine and Grand Challenges Canada, who have developed an online platform for supporting mental health innovations around the world - the Mental Health Innovation Network [7]. This network reviewed innovation in this area, finding that mobile technology is mostly used for implementing innovative mental health solutions, especially in low and middle-income countries. This is not a surprise because the penetration rate of mobile devices around the world is 63%. Most internet users around the world access the web from mobile devices [8]. Therefore, mobile solutions seem to have the capacity to be a part of mental health services.

However, there is also a risk of applying technology push models in this domain. Technology push is a centrally driven, rationalistic model of change which focuses on documentation and reporting, and aims to accomplish predefined, relatively inflexible goals. An alternative for technology push model of change is sociotechnical model that focuses on the impacts of implementing a new technology, and the technology is not seen an end in itself. The success of sociotechnical change is being measured by the ultimate impact of the change especially on human beings, and not by technocentric measures like number of users adopted the technology, or the scale of data collected by it. Therefore, while sociotechnical change has a clear objective, its interim goals are being continually redefined and negotiated [9]. Understanding sociotechnical approach can be more important when systems are being expanded beyond the conventional work environments [10,11]. This is quite relevant to mobile health services that can be used in various everyday life settings.

The current literature tends to give a unidimensional perspective on the effectiveness of mobile solutions. Reviews sometimes give an understanding of the results of using existing mobile solutions from a medical point of view [12] or explore a wide range of technological opportunities and approaches [13]. However, there is little information about the methods and tools for designing effective mobile mental health (mMH) solutions. In addition, it should be noted that unlike many other medical solutions, controlling and regulating mobile

solutions and especially mobile apps is not always feasible because of the large number of products and services available in the market. This is also a problem in assuring the quality and effectiveness of mMH applications. The unsuccessful experience of the NHS approved apps library is a good example of how the need for regulation is recognized but difficult to address[14,15]. Issues around the Samaritans Radar app, initially launched in 2014 and now withdrawn, show that designing an app to support mental health can cause unanticipated problems. Users of the app could receive alerts when others used keywords on Twitter that implied that they were in crisis or at risk; but those involved did not have to give their permission for others to be alerted to the content of their tweets. In this instance, the mining and use of the public data aimed to provide a 'safety net' for vulnerable people in online interactions, but instead was seen as overstepping boundaries of privacy [16]. This presents one example of an organization with good intentions making an error of judgment about standards and norms of ethical behaviour in establishing an online resource which aimed to improve mental health and wellbeing.

The medical perspective can just show us one aspect of the mMH solutions' effectiveness and does not give us much information about the users' personal experiences, usability of solutions, and different use contexts [17]. Having a technocentric approach also cannot guarantee the success of solutions without understanding users and designing proper scenarios of use. Similarly, as shown by [18], users of apps can provide useful feedback on improving their design. The main aim of this article is to review the current knowledge about mMH and evaluate existing solutions from a design perspective, aiming to answer these research questions:

RQ1: What are the key principles of the design process relevant for mMH?

RQ2: To what extent does current research align with these principles?

As a result, this review can provide practical implications for those involved in the design and development of mMH apps and services. We would like to explore human, social and organizational factors in the design of mMH technology in relation to the wider context of mental health services.

To answer the research questions, it is necessary to clearly define the key concepts of review including design for healthcare and mHealth. After explaining these key concepts, an overview of the exploratory literature review method is given. The review then looks at the most important findings about the design requirements of mMH, as well as the research studies on existing designs. Discussion focuses on the main gaps within the reviewed literature and explores some ideas for improving design for mMH. Research limitations highlights the constraints of the exploratory review method and its potential impacts on findings. Finally, answers to research questions and directions for future research and practice are explained in conclusion and practical implications.

2. Key concepts

2.1. Design for healthcare

Design has a wide range of meanings in the context of healthcare so having a clear working definition of design is crucial for the proper literature search. Forming the built environment and artefacts in a way that fulfils the patients' and medical staff needs and requirements is one of the most common definitions of design for healthcare. From this perspective, designers are conventional architects and product designers who create and improve physical spaces and objects. This approach towards healthcare design is often supplemented by an approach to evidence-based medicine or evidence-based practice [19–21]. The principle behind evidence-based medicine is that decisions about the care of individual patients are made using the best available research evidence. Kirk Hamilton applied this concept in architectural design for healthcare facilities by making design decisions based on the best available evidence from primary and secondary data [22]. In this so-called evidence-based design approach, designers should start the design process by collecting and reviewing the available data prior to the practice-based and creative design activities.

Evidence-based design shows that there is a benefit in looking across available tools, with design as a creative problem solving tool for the healthcare system [23]. It has strong connections with human factors engineering and ergonomics, which encourages viewing patients and medical staff as users of the systems by focusing on physical, cognitive, and psychosocial characteristics of people with the aim of designing better systems [24]. This approach considers patients and practitioners as the end users of the designed systems that can be occasionally engaged in the design process [25].

Evidence-based design has the potential to develop solutions for improving process and quality in the healthcare system [26] as a system that encompasses a variety of tangible and intangible environments, products, services, user interfaces, information architectures, and medical devices [24,27], all of which would benefit from being well-designed. One issue here is that this approach may miss the subjective and hard to measure aspects of the interactions between people and the healthcare system. Design is not limited to usability and performance of the system, it also relates to meanings and emotions [28,29].

In his book *The Science of the Artificial*, Herbert A. Simon defines design as a course of actions aimed at changing existing situations into preferred ones [30]. Attempts to describe, analyse and change clinical pathways in healthcare often aim to achieve this in practice [31]. Taking a holistic approach to design can address multiple layers of interaction between people and the healthcare system, including those mentioned before; the evidence-based design of physical environments and objects, quality and process, system usability, meanings, and emotions. Jones [32] believes that this holistic perspective can also solve the problem of the fragmentation of design practice and engagement across the different healthcare sectors. If people who use the healthcare system be viewed as the owners rather than patients, the system will move towards a human centred configuration and organizational innovation will be facilitated.

Drawing together these concepts and definitions in the context of mental health, and building on Herbert A. Simon's definition, design in this study is being defined as a course of actions aimed at changing existing situations in mental health services into preferred ones. Therefore, the so-called design solutions are not limited to the ones that created by designers or authorities, but also include the ones that are generated by communities. Our definition of design covers many aspects, from tangible products to intangible services and processes.

2.2. mHealth

The term mHealth gradually became popular in the early 1990s [33], but there has been significant ambiguity in the way that this term has been used. For some, healthcare solutions accessible through mobile phones and especially smartphones are being called as mHealth solutions. Based on this approach, Adibi [34] defines mHealth as an evolved branch of eHealth. The eHealth concept was first shaped in the 1990s when telecommunication systems and electronic processes were used for supporting healthcare practices for the first time. According to Adibi [34], mHealth solutions in preventive and curative medicine practices may follow different strategies and may be more or less strongly tied into existing healthcare systems. mHealth can play an important role in some demanding areas of healthcare, especially ageing and mental health. From the technological point of view, new technological solutions such as cloud computing will affect the way that people use mobile applications and consequently future mHealth solutions. The sociocultural contexts of use are amongst the most challenging aspects of developing mHealth solutions. Technology acceptance and adoption, the role of users in designing services and solutions, and geographic and cultural differences are amongst the most important sociocultural factors that need to be understood before developing any mHealth solution.

Another perspective suggests that mHealth is not limited to mobile phone applications but also includes all mobile practices supported by any mobile device or mobile network such as body sensor networks and swallowed health monitors [35,36]. The recent developments in areas such as nanotechnology, compact biosensors, wearable, pervasive and ubiquitous computing systems will contribute to the growth of empowered healthcare on the move within the next few years [37]. From this point of view, mHealth would be the biggest technology breakthrough for addressing existing healthcare challenges [38] which can displace prior ways of doing things in healthcare systems at much lower costs. Most mHealth solutions seem to face relatively low adoption resistance for patients and are ideal for covering the social groups which are less engaged from conventional healthcare systems [35]. Therefore, unlike what Adibi [34] believes; the wide range of technological platforms and the pervasive nature of this definition of mHealth suggest that eHealth, telehealth, telemedicine and biomedical sensing systems can be also considered as mHealth solutions [37]. Of course, both approaches address opportunities for more inclusive health services.

Although the latter approach is more holistic and can cover a wider range of solutions including those which will be available in the future, this article will focus on mHealth solutions based on mobile phones as these devices are the most accessible and feasible mobile platforms for providing mental health services, simply because of their high penetration rate and affordability.

3. Method

Design for mMH domain is relatively a young domain from both research and practice perspectives. However, due to the nature of digital mobile technology and high penetration rate of mobile devices, the number of mMH apps and consequently the number of users is growing exponentially which makes keeping track of the developments challenging. Therefore, we decided to apply an exploratory literature review approach which provides a broad appreciation of the existing directions in the field to secure the breadth [39] and to facilitate further in-depth research studies. The exploratory review is also a way for bridging design practice and existing evidences in the literature, especially because designers are not always relying on rigorous scientific findings through their practice and their assumptions and interests also play an important role [40].

The nature of healthcare services is emergence of unpredictable and unique events through patients' unique trajectories [41], therefore looking at design in such contexts require exploration. Systematic reviews are strong in terms of their scientific rigour and generalization of what is being studied, but may not be the best method when researchers aim to explore and discover new ideas [42]. Exploratory reviews have an open-ended approach towards data collection because they often demonstrate a gap in both literature and practice. Therefore, such reviews often start with looking at the references that come closest to researcher's scope to show that those references have not fully explored certain aspects of the subject. This is in contrast with common approach towards literature review which often sees the past work as something which is done at the confirmatory level [42].

The three steps of the exploratory literature review include identifying the relevant literature, structuring the review, and theoretical development. This method regarded as a simple yet effective way of exploring the information technology literature as an interdisciplinary domain [43,44].

3.1. Identifying the relevant literature

To apply an exploratory approach, we started the review by finding a core group of relevant references with a focus on design for mMH. Using the Medical Subject Headings (MESH) in the medical database Medline, and Web of Science an initial search identified relevant papers indexed with the topic 'mobile applications' (defined in MESH as computer programs or software installed on mobile electronic devices which support a wide range of functions and uses which include television, telephone, video, music, word processing, and Internet service) and the keyword 'mental health'. Among the results, there were several articles focused on physical health conditions including asthma and weight management which were not examined further. Finally, 64 were judged relevant to a further investigation. These papers were used as the key references from a medical perspective. Using a snowball method, references from this literature were examined to identify further relevant papers. Few core references from perspectives across the disciplines, including major review articles about mMH and digital MH were also included in the review.

3.2. Structuring the review

The concepts can play an important role in classifying the contents and organizing the framework of a review [45]. In this article, design is defined as a course of actions for improving situations, without limiting the scope of review to any discipline or technology. With such a wide perspective towards design, it was not possible to identify clear borders between various disciplines, and it was also difficult to structure the review using the concepts. To overcome this challenge, we used concept mapping. Concept mapping is a useful tool for making sense of complex nature of knowledge [46], identifying the key concepts of a research areas, and clarifying the structure of the review [47,48].

Concept maps are organized and visual representations of knowledge, often by showing various concept as well as relationships between them. Concepts can be defined as perceived regularities in events or objects, or records of events or objects, which are also specified by a label or code [49,50]. In the context of this review, this definition of the concept may best correspond to design requirements.

According to Ralph and Wand [51], artefacts should possess design requirements to accomplish their assigned purposes. Therefore, design requirements can be viewed as attributes by which design itself can be formulated and structured. Therefore, a set of design requirements has been identified to find relevant concepts for structuring the review.

Due to the interdisciplinary nature of design for mMH, authors preferred to perform concept mapping by conducting a cross disciplinary requirements' workshop, as one of the proven techniques for identifying system requirements [52]. It should be noted that, the main aim of structuring the review by concept mapping was to broaden the cross disciplinary perspective, and not to generalize the outcomes of the workshop.

The participants of this workshop were researchers and practitioners from design, human computer interaction, and mental health domains. Eight experts attended the workshop from whom three had worked in mental health services as practitioners and therapists, two had experiences in designing digital mental health services, and the rest were academic researchers with experiences in areas like qualitative research in healthcare, mobile user experience design, and sociotechnical design.

This was a full day event which was structured around few themes including problems and users that can be addressed by mMH apps, feasibility of designs, context of use, service models, and sociocultural impact. A facilitator was responsible for taking record of discussions, concepts, and requirements, as well as classifying and mapping them through the session. The collected data was in form visual maps showing the design requirements identified in the discussions and the connections between them. Looking at these maps, a number of core design requirements were identified. Table 1 exhibits a summary of discussions and the design requirements extracted from them.

To validate these core design requirements, a summary of discussions and the identified design requirements were presented to the experts. After discussions and amendments, six core design requirements and their definitions were approved. These design requirements were then used for structuring the review.

As table 1 shows, most discussions are linked to more than one core design requirement. This means that design requirements should be viewed as interdependent concepts. For example, an empathic design strategy would impact the overall quality of user experience, as it changes the way that designers understand target users. An integrated approach towards design also can help designers to understand the requirements of a broader range of organizations and people, which potentially can improve the inclusiveness and user experience of the solution.

Table 1. *Summary of concept mapping and requirements gathering activity*

Summary of discussions	Core design requirements (concepts)					
	High quality user experience	Demonstrating efficacy	Empathic design process	Integrated	Inclusive	Open
There are many concerns about privacy and security, and therefore any technology mediated service model should be participatory, transparent, and open.				●		●
It's hard to prove that commercial mMH apps can do what they claim to be able to do.		●				
It seems that many app developers are interested in ideas like mood tracking. For majority of users, apps that constantly "pester" for information are not favourable. They would like a more natural and empathic way of communication.	●		●			
Small developers of mobile apps often do not have enough resources for conducting research but are quite fast in launching new products. Public organizations benefit from a wide range of information and knowledge, while they are too slow in implementing solutions. We need an ecosystem view for designing apps in which all these heterogeneous organizations can work together.				●		
Mobile apps have short lifespans, therefore regulating apps is not feasible, especially considering the lengthy bureaucratic processes in public organizations. There is need for a more collaborative and participatory approach in which developers, service providers and regulatory organizations work together to improve design processes, which can in return improve the quality and efficacy of resultant mMH apps.				●		
Mental health service should not be managed by a top-to-down approach. It needs to be "open" to facilitate open and distributed innovation. Due to their high penetration rates, smartphones can facilitate that service model transformation.				●	●	
The fact that many mMH apps are being designed using a "fitness app model" shows that designers do not fully immersed in the context of use.			●			
Codesign, participatory design, and open innovation might be frequently used terms in academic literature, but they are not common methods for designing mMH apps in Small and Medium-sized Enterprises (SMEs) and start-ups.				●	●	●
Many of mMH apps are just transformed versions of existing commercial apps: e.g. Using self-tracking for taking record of mood, as it is common in diet and exercise apps. The problem is, mental health is a different concept which requires different product models. mMH cannot be viewed as stand-alone solutions like fitness apps.				●		
Mobile apps may encourage an individualistic approach towards mental health. That can be a threat, as active participation of family, friends, and community is necessary in course of any intervention.	●		●	●		
Measuring and/or proving efficacy of mMH apps is a matter of debate		●				
Clinical trials are not similar to everyday use. Patients may give up treatment if user experience is poor.	●	●				
A mobile application cannot be the ultimate solution. It cannot replace a treatment supervised by a therapist.				●		

Mobile apps can bring opportunities for overcoming issues like language and cultural barriers.	●		●		●	
Everybody needs mental health support in areas like coping, problem solving, and facing changes. Current service model does not cover that kind of broad support and mHealth can be an opportunity.				●	●	
It has been proven that conventional mental health service models are not inclusive as some specific social and demographic groups are less-benefited from them. Mobile service models should consider this limitation and facilitate a more inclusive access.					●	
It's good that smartphones are becoming more and more affordable and using them do not require any specific technical knowledge.					●	
The privacy of mobile apps can be an opportunity for providing mental health services to people from cultures which mental health is still a sensitive topic.			●		●	
There is a difference between mental health illness and living in a poor mental health condition. Apps often do not address the wellbeing and prevention aspect of mental health.					●	

3.3. Theoretical development

After structuring the review using design requirements of mMH solutions, the final step of the literature review comprised theoretical development. We did this by looking at what literature says about the identified requirements, as well as exploring the studies on existing mMH designs. As the research questions suggest, the first action in this step was explaining the role of design in the development of existing mMH solutions. Then, the less explored areas of design and mMH research were highlighted. These findings helped us to discuss possible ways of incorporating design thinking in developing mMH solutions particularly in problematic or less developed areas of research. Such incorporation would facilitate the mMH innovation by cultivating users' experience [53] and holistic understanding of system design considering all other interrelated systems and contexts [54]. An overview of the review method can be seen in figure 1.

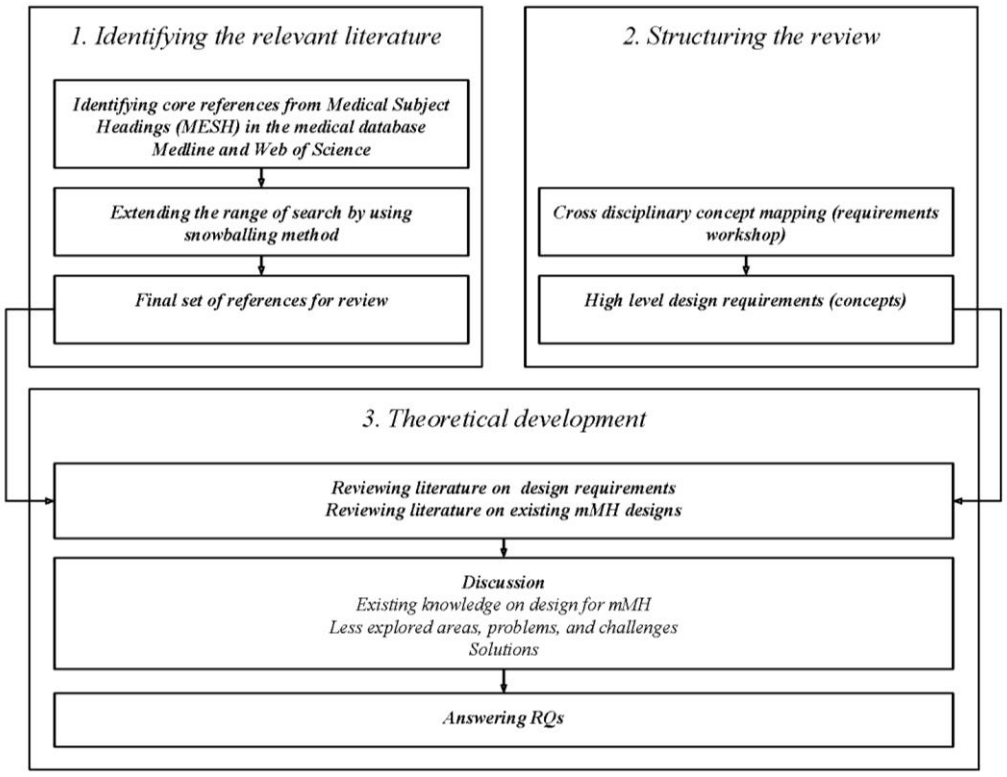

Fig.1 *Review method*

4. Design requirements

The design requirements identified by concept mapping are as follows:

- *High quality user experience:* mMH solutions should not only be medically approved based on their effectiveness. The users' experience through the process of use should also be reviewed. For example, an mMH app with poor usability may not have an identifiable negative side effect on users, but this poor experience may stop those users from accepting and adopting new mobile solutions in future [17,55].
- *Demonstrating efficacy:* Any mMH solution should demonstrate provable results. This may seem a very basic and obvious requirement, but the reality is that many mMH apps do not represent such results.
- *Empathic design process:* In most cases, improving mental health or coping with a mental health issue requires users' attachment to an mMH solution for a certain period. To build this attachment, mMH solutions should be desirable and empathic.
- *Open:* Open innovation can be defined as utilizing both purposive inflows and outflows of knowledge in order to grow internal innovation as well as the use of innovation outside the organization [56]. Some scholars believe that regardless of the context in which innovation may take place, open innovation models often have clear advantages over conventional closed innovation models [57]. This model is among the most promising innovation strategies in the mobile industry [58,59] and has significant advantages in healthcare domain [60], while still faces acceptance and implementation challenges [61].
- *Integrated:* A mMH app should not be viewed as a standalone tool which can be used individually. Mental health services require collaboration among practitioners, other components of the healthcare service, communities, caregivers, patients, and their dependents [62]. In this complex network of relationships, mobile solutions often act as facilitators. This requirement represents the core principle of sociotechnical design for healthcare systems that encourage designers to concurrently consider all interrelated and interdependent dimensions of the system including infrastructures, clinical contents, people, human-computer interfaces, workflow and communications, internal features, external rules and regulations, and measurement and monitoring [63]. Sociotechnical design in healthcare solution remains challenging as there is not much clear guidance on how to address the gap between social requirements and technical affordances [64].
- *Inclusive:* Inclusive access to health care system including mental health services has been a priority for governments around the world. Health, including mental health, can be considered to be a human right, with international treaties including the Constitution of WHO, European Convention on Human Rights and Fundamental Freedoms, and European Union Charter of Fundamental Rights clearly supporting this concept [65,66]. Considering the costs and challenges of developing inclusive health care systems on a national level, digital solutions have often been viewed positively because of relatively high penetration rates of digital technologies, low implementation costs, and human resources' effectiveness [67]. Mobile solutions, in particular, can be helpful for improving mental health services in developing world because penetration rate of mobile phones is usually higher than internet in those countries [68,69]. In addition, in a culture which mental health problems are stigmatized, mobile solutions can be effective due to their private and personal nature of use [70].

4.1. High quality user experience

The importance of user experience is recognized by decision makers in healthcare so public organizations have started developing a set of relevant guidelines and standards. For example, the United Kingdom's National Institute for Health and Care Excellence (NICE) has developed a quality standard named *Service User Experience in Adult Mental Health Services* including 15 quality statements covering multiple dimensions of user experience [71].

However, many people tend to go online when they face a health problem [72,73] and most of online resources are not a part of, and might not be approved by public services such as NICE. This also means that they do not comply with another design requirement, integration, as they operate in isolation not as part of a system. Some other existing standards in healthcare dismiss the importance of user experience, instead focusing on a wide range of technical and clinical standards and quality measures [74].

Research on the United Kingdom's NHS Friends and Family Test programme revealed that user experience is an important qualitative attribute of the healthcare system [75]. Current evidence about the efficacy of some

apps has been gathered in the clinical settings, where it is not clear if and how users would be able to use those apps in their real life on a daily basis [76].

Jones et al. [70] recommend using design principles of successful commercial app developers in designing mMH solutions to collect evidence not only about the clinical impact of the apps but also about the experiences of users. Similarly, Stoyanov et al.[77] propose a simple tool for assessing the quality of mHealth apps which addresses engagement and aesthetics, as well as functionality and information quality [78]. Kenny et al. [79] also mention qualitative factors such as engagement, social interaction, awareness, and user control among their list of requirements for designing mMH apps for young people.

Users should not be passive actors or consumers of a product, but instead, can act as quality detectives. Although the importance of user experience is understood in healthcare systems, studies show that there are still much to be done as the majority of patients still face problems related to user experience [80]. Some elements of user experience such as error prevention can have significant effects on functionality and performance of the system [81]. The quality standards in healthcare are mainly focused on performance and engineering, rather than the user experience, while a good design requires all named three elements [80]. Surprisingly, even applying co-design and participatory design techniques might not necessarily improve the situation because organizations that use such methods often focus on "*asking what was good and what was not*" rather than "*the details of what the experience was or should be like*" [78]. To address this, User Centred Design (UCD) should be addressed on strategic and organizational levels, rather than the operational front end [82].

In mental health services, user experience could be viewed as a part of the therapy itself and can directly affect the therapy dropout rate, future treatment-seeking behaviour, and quality of life after treatment [83]. Bate and Robert [78] idea for embedding UCD on an organizational level can be particularly effective for mental health services. Redesigning Care Programme Approach (CPA) in the UK is a good example of improving user experience on an organizational level [84]. This broader understanding of user experience is similar to sociotechnical design approach that suggests a holistic understanding of the interrelated systems and contexts for designing things that can participate in complex systems with both social and technical aspects [85]. Applying a sociotechnical approach to system development can potentially result in higher user acceptance, as well as better value delivery to stakeholders [86]

4.2. Demonstrating efficacy

As mentioned, mHealth could contribute to the biggest healthcare technology breakthrough in recent years. However, it seems that academic research has been more focused on mobile technologies and their potential for mHealth, rather than their efficacy [35]. The efficacy can be defined as "*the extent to which a specific intervention, procedure, regimen, or service produces a beneficial result under ideal conditions; the benefit or utility to the individual or the population of the service, treatment regimen, or intervention" [87]*.

The same is true for mMH solutions as well. Reviews of research on smartphone apps for mental health shows that there have not been many rigorous and evidence based scientific studies in this field, and there are only few evidence-based mobile mental health apps available in the market [88–93]. There is evidence that some commercial apps could be even potentially harmful [94,95].

To design apps with a good level of efficacy, designers should first consider that a mobile app is not always the best solution for an intervention, and second, they need to realize that apps may not be effective without proper integration with other attributes of the mental health service. For example, Arean et al.'s [96] study on apps for depression shows that existing apps are mainly effective for mild-to-moderate levels of depression. They also found out that without proper user experience and communication with mental health practitioners, users may not use the apps as instructed, or they may not use them continuously [97]. These findings suggest that there are strong links between user experience quality and efficacy.

Bakker et al. [89] suggest that existing evidence for the efficacy of mental health apps is heterogeneous: while in areas like cognitive behavioural therapy, mobile apps are demonstrably effective, for some problems such as anxiety the idea of using mobile apps is mainly supported by theory rather than evidence. They view mobile apps as a part of the system rather than independent solutions. Users also need external triggers for engagement or possibility to seek help from others. Another influential factor which should not be overlooked is users' perceptions of mobile interventions' effectiveness [88].

4.3. Empathic design process

One of the factors that can improve mMH efficacy is users' attachments and dedication to the treatments. This relationship cannot be built upon pure rationality. Without emotional bonds, most users may give up in the middle of the way. The adaptive nature of mobile interventions and their interactivity do not fit into conventional one-way informational output models [98]. Donald Norman [99], the author of *Emotional Design: Why We Love (or Hate) Everyday Things*, believes that emotion is linked to value judgment, while cognition is about understanding. Although both play important roles in design, tools like usability and user research mainly rely on cognitive psychology and might not give designers a good grasp of emotions in human activities [100]. Similarly, processes such as UCD may neglect the designers' inspirations, and the fact that they are also being affected by their emotions. The empathic design approach aims to address the above constraints by focusing on empathy with users as a tool for design inspiration, rather than seeing users just as sources of data in different steps of the design process. To do so, designers often need to immerse in the use context, and experience the situation as ordinary users. Like UCD, empathic design research employs anthropology and ethnography research methodologies [101].

The open-end character of mobile solutions is a challenge for designers and they are often unable to predict all possible scenarios of use [102]. Unlike conventional usability design and evaluation techniques which rely on predefined tasks and use cases, empathic design gives designers opportunities to experience the whole journey from the lens of the user [100]. Therefore, empathic design is a promising method for designing mobile solutions, particularly those in complex collaborative care.

However, applying empathic design in healthcare projects has some limitations because designers are not always able to have the same experience as patients, and for some problems like dementia, patients often cannot describe their experiences in detail. To overcome these limitations, designers may need to combine various techniques, so each technique can reveal a different aspect of the patients' experience. A graduate facilitation approach is needed to enable patients to participate efficiently. The first step is typically individual harvest meetings. In the second step participants can join collective handover workshops as appropriate. Finally, the third step in the process is holding an ideation workshop with participants [103]. Another solution is to consider the process of making and designing as a tool for understanding the context and finding problems, rather than having separate research and design phases [104].

Finally, designers and developers of the mMH apps should be aware of the literature on persuasive technology, which highlights possible resistance against new technologies such as mobile users' concern about privacy [55,69]. Research on approved apps in the former NHS health apps library shows that majority of them suffered from systematic gaps in compliance with data protection principles [105].

In general, empathic design seems to be a relevant approach for designing mobile solutions while finding real world cases of its application is difficult.

4.4. Open

One of the most common uses of the term "open design" is to describe open source software development in which a software is distributed while its source code is easily available to everyone [106]. Although some designers of physical products tried to develop open product designs, the software industry is still the main beneficiary of open source design [107].

Open design, however, can describe the product of an open innovation process as the antithesis of the conventional innovation paradigms where innovation is a result of internal activities in organizations. In contrast, open innovation relies on intended inflows and outflows of knowledge to accelerate internal innovation, and also diffusion of innovation externally [56].

Looking at the main attributes of any design activity an open design has following characteristics [108]:

- The input: Voluntary participants do not need any permission to engage in the process and use resources. Resources are copyright free and therefore can be freely improved or modified. New resources can be

generated collaboratively.

- The process: The process consists of modular tasks that give flexibility to the participants to freely complete the tasks of their own interest. Quality control is also being done based on communal validation.
- The output: The final designs will be commons. Their licenses guarantee that all people can benefit from those designs without any permission. Designs can be used as a resource for further improvements and the next iterations of the design process.

Open design is a broader concept in comparison with open source software design. In open source software design, the openness is limited to people who are skilled in certain programming languages, while open design may allow a wider range of participants, including users, to contribute regardless of their skills and knowledge.

Looking at existing research and practice in mental health, it can be concluded that open source design is the dominant approach to existing solutions. Examples include:

- Open mHealth platforms for facilitating developing mobile applications [109].
- Promoting open source apps to facilitate security and integrity assessment [77].
- Promoting open source apps to facilitate implementation [110].
- Adopting open source platforms for healthcare such as maps, statistical and data management tools [111].
- Collecting data and analysing mental health related data on a global scale [112,113].
- Building tailored interactive SMS communication system for managing health workers without coding skills and for free [114–116].

The idea of open design can be also viewed as a solution for improving the healthcare ecosystem. Looking at mobile health, existing solutions represent a *patchwork* of tools with limited scope. A more coordinated development in form of an open architecture for the whole system would synergize the activities of all involved stakeholders and help to integrate these solutions into care systems [88].

4.5. Integrated

According to Berg [41] the sociotechnical approach towards designing healthcare systems views these systems as heterogeneous networks, which means that while different players in the system are connected and interrelated, they have different objectives, behaviours, and priorities. Every Patient, as a critical player within the heterogeneous network, often has trajectories which ought to be managed and guided properly by the network in a collective and cooperative manner. This means that, the nature of health care work is pragmatic and fluid and requires dealing with sudden and unpredictable events. It is almost impossible for such systems to run by predefined and concrete clinical workflows and processes, and there is always need for case-specific interventions based on empirical and qualitative evidences. Accordingly, the main objective of sociotechnical design is to integrate the social and technical subsystems [117]. That is why, a combination of soft and hard management skills are necessary for both design and use of sociotechnical systems to ensure problem solving on social, technical and individual levels [118].

Designing mobile applications which can work as a part of wider healthcare system, requires sociotechnical understanding. However, only few studies recommend sociotechnical principles for designing mHealth solutions [119,120].

Chan et al. [121] recommend a framework for evaluating mMH apps in which integration is one of the three evaluation dimensions. From their point of view, an integrated mMH app should be secure for users and protect their privacy, work within user's workflow, and be able to share data with other relevant medical systems. Users need to feel that their data is safe, and they trust that they can share personal information without consequence.

Mobile solutions can be only a part of the complex mental health ecosystem and should not be considered as standalone tools [90]. This ecosystem is not limited to conventional public and private providers of mental health. Social media and internet play a very important role in encouraging individuals to use mMH apps. In fact using mobile apps for coping with mental health issues like depression is becoming a norm, and this interaction often happens without involvement of a therapist through diverse patterns of use and for various objectives [122]. At the same time, integration of mental health services into primary health care system have significant advantages [123], suggesting that mMH apps are not only a part of mental health ecosystems, but also a part of the larger primary healthcare ecosystem. Hence, designing mMH apps with an ecosystem approach

cannot only improve the efficacy of mMH apps but also can guarantee their scalability and sustainability [13].

Unlike conventional one-to-one therapy model, using mobile solutions could collect data from real world behaviours and experiences. Mobile devices can bring virtual experiences into real life and generate a mixed experience called as *interreality* [124]. This emerging type of therapy can change behaviours and thoughts indirectly, through emotions which may result in more sustainable impacts [125,126]. As effective communication tools, mobile devices may also change the mental health service model by connecting different parts of the service together [126] and changing the way that practitioners work in the following way:

- Providing them with individualized therapy assessment tools
- Facilitating analysis of real world behaviours and experiences using sensing technologies
- Enabling patients to self-track their emotional states
- Persuading patients to engage with treatment
- Helping patients to apply relevant skills in their everyday life [126]

However, according to Olff [93], existing mMH apps do not fully implement these potentials, and poor integration could be one of the reasons. Existing mental health apps often do not connect their users to conventional health care systems and therapist who can approve the quality of interventions [127]. Organizations within the healthcare system often neglect the importance of providing guidelines and standards for evaluating mobile apps, while some of them try to develop their own apps [121].

Understanding the business context can be a way for moving towards more integrated mental health services. The wide range of requirements necessary for designing an mMH app means that developers should have multidisciplinary teams consisting experts in design, user experience, software engineering, security, and mental health [91,93]. In reality, this is not feasible for start-ups and SMEs that develop majority of mMH apps. There are also solutions designed by large public organizations such as universities with a strong scientific approach that may suffer from lack of market and business understanding [128]. Open and collaborative design tools can help both large and small organizations to collaborate and design products with better integration with mental health services and social contexts of use and technological possibilities. Another barrier which should not be underestimated is incompatibility of conventional psychiatric assessment and analysis methods with the type of data that is being provided by smartphones, especially big data [129].

4.6. Inclusive

Inclusive design should be defined in its most comprehensive form when it comes to healthcare systems [65]. Using digital solutions does not always guarantee inclusiveness [130] due to challenges like digital divide, increasing power distance, patients' integrity, and lack of transparency in some digital services. Although penetration rates of smartphones are high, penetration of health related apps and health literacy among smartphone users is not necessarily high [131]. There is a common belief that UCD can be a promising approach when designers want to design inclusive systems. However, successful implementation of UCD requires a deep understanding of the approach, the context, and methods for tailoring UCD design tools for each project [62]; otherwise it is quite likely that one fails to get desirable results out of it. Designers often fall into the trap of asking users "what they want" and assume that they are able to predict the requirements of all future users [132]. User studies often cannot cover all users, so designers may unconsciously start designing for "average users"[133].

These constraints are sometimes embedded in design tools, and designers may not be even aware of them. Usability evaluation methods may dismiss the possibility of users' temporary or permanent cognitive disabilities [134]. Design approaches such as universal design usually focus on more obvious forms of disability, often associated with the body and not the mind. Although numerous mMH apps are available in the market, patients with serious mental health issues rarely can benefit from mobile solutions [135], while penetration rate of smartphones among patients and their willingness to use the apps to improve their mental health can be relatively high [136].

In order to improve the usability of digital health solutions, the influence of experts' mental models on system should design be minimized [134]. Healthcare systems can be designed for the so-called "extreme users" who

are expected to have more problems when using the systems. Users with visual, hearing, physical, cognitive, and language impairments are amongst the most vulnerable ones who should be considered according to this strategy [65]. The practicalities of including psychiatric patients with varied diagnoses in evaluating app design in clinical settings has been explored, with one study concluding that it was feasible for vulnerable participants to provide feedback [18]. Another solution is adapting existing design tools to the mMH context. For example, in Chan et al.'s [121] framework for evaluating mMH apps, usability dimensions are defined based on disability, cultural, socioeconomic, and generational accessibility. Sociotechnical approach encourages designers to apply tailored tools and processes according to the specific context of design. Therefore, when user groups with special needs are targeted, sociotechnical approach can have significant advantages. Eason et al. [137] study on using telehealth technologies for the elderly shows sociotechncial design capabilities for overcoming technology implementation and acceptance challenges.

5. Existing designs

In line with the research questions, it is necessary to look at existing research about real world design and development of mMH apps. Our initial set of references about design requirements were quite diverse, but only a small group of those represents cases in which an operational mMH was designed, developed or evaluated by real users. We reviewed these references to identify the links between existing designs and the core design requirements used for this review. Through the review we observed a tendency towards using UCD and Human Centred Design (HCD) approaches, as well as interesting examples of identifying sociotechnical relationships between the design of the app, context of use and the healthcare system.

5.1. Presence of some design requirements

Majority of applications designed through the studies were not accessible online. However, the methodology, research objectives, and design features mentioned in each study helped us to understand the extent each design requirement has considered in the resultant app:

- *High quality user experience:* Quite a few studies appreciate the importance of system usability. Improving usability is an important step towards delivering user experience excellence. However, usability evaluation alone does not guarantee high quality user experience. Understanding various scenarios of use, users' emotional attachment to the app and the treatment, and overall service design should be also taken into account [80].
- *Demonstrating efficacy:* Proving technical and clinical reliability of designs was the most common objective of the reviewed studies. However, more complicated aspects of efficacy in real world settings were not much discussed.
- *Empathic design process:* Although having an empathic approach towards design was not directly mentioned, few studies addressed similar strategies, mainly mixed with participatory design practices.
- *Open:* We did not find any relevant case among the reviewed studies in this section.
- *Integrated:* Multiple aspects of integration have been highlighted, including systemic relationships between stakeholders during design and use, concerns about ethics and privacy, cultural specifications, and cost-effectiveness.
- *Inclusive:* Few studies explain how mobile solutions can help certain demographic groups or individuals who suffer from a particular mental health illness who may not be able to benefit from conventional service models.

5.2. Different definitions of UCD

A common pattern in the reviewed research studies is to focus on the technology of the app and the clinical evidence of its impact. Such studies often miss the fact that the same intervention and the same technology can be translated into an app in different ways, just because of different design approaches and processes; and consequently, each design may have a different impact on users. Among the studies which mentioned a certain design approach, UCD and HCD were the most common approaches. With the exception of the Patient-Clinician-Designer Framework [138], there was no other particular design approach specifically adapted for mMH.

In the reviewed literature, the term UCD was more common than HCD. Even in design literature, there is an ambiguity about UCD and HCD [139]. While some references differentiate these two, some other ones may use either term for describing the same concept [140]. The term UCD itself also can be defined in different ways including:

- A philosophy towards design thinking which affirms human dignity in varied social, economic, political, and cultural circumstances [139].
- A strategic design approach (rather than a step by step process) in which users' needs, wants, and abilities should be the main design priority. This approach insists that technologists and developers "do not know better" [141].
- An iterative process, similar to what is described in ISO (International Organization for Standardization) 9241-210 [142] standard, in which users are being considered in understanding the problem, identifying the requirements of the system, and also evaluating the designed system [140,143].

In the context of mMH, current use of UCD is often limited to the iterative process. In some studies, UCD and associated terms such as participatory design just reflect the fact that users have been asked about their views on system requirements, without considering all other characteristics of the UCD process.

5.3. Lack of sociotechnical understanding

One of the limitations of defining UCD as a step by step process in this context is neglecting sociotechnical dimensions of healthcare systems. As mentioned, sociotechnical design often rejects highly structured processes, and prefers case-specific interventions, based on qualitative and empirical evidences [41]. Although UCD as an iterative process addresses some of those evidences, it does not provide designers with a comprehensive understanding of complex sociotechnical systems [144], as a requirement for designing integrated mMH solutions [121].

Unlike UCD, sociotechnical design was not directly mentioned by any of the studies including a real-world design case. However, findings of some studies including those with a technocentric and/or a clinical approach highlighted sociotechnical aspects of design, such as impact of ethics, trust, privacy and engagement on treatment, importance of understanding multiple stakeholders and user groups including carers and clinicians, and flexibility of user interfaces for various users' trajectories.

Of course, there are relatively few retrospective case studies, practical tools, and frameworks available for learning and applying sociotechnical design [145,146]. There is also a need for wider conceptualization of what constitute a system [146]. Due to such limitations, sociotechnical design is relatively unknown in mobile industry despite its advantages. Hence, improving awareness of sociotechncial design and including its principles in decision making is necessary [147].

5.4. Few wellbeing and prevention apps

Within the few studies that addressed design and development of mMH apps, adolescents and older adults were the most mentioned target users. The most common mental health issues were serious mental illnesses such as dementia, schizophrenia, post-traumatic stress, and bipolar disorder. Other issues addressed include data collection and management (such as mood tracking), weight loss, alcohol consumption, and workplace stress. There was little information about designing mMH solutions for prevention and wellbeing purposes, although such apps are dominant in market and being used by many users [148]. Table 2 exhibits a summary of reviewed design studies.

Table 2. *Summary of reviewed design studies*

Author	Issues and users addressed	Design requirements addressed	Design approach/ process	Are sociotechnical aspects of system or intervention addressed?
Matthews et al. [149]	Adolescents' mental health (generic)	User experience and efficacy	UCD as an iterative user research design and evaluation process Usability evaluation	Research addresses some contextual issues such as ethics and data privacy, but its overall recommendations are mainly based on usability principles such as understandability and error prevention, and does not suggest solutions for facing unexpected and case-specific issues that may happen through a patient's unique trajectory
Mathews et al. [150]	Adolescents' mood monitoring	Efficacy, only from the technical point of view	No focus on the design process Engineering/ techno centric approach	No
Zhang et al. [151]	Elders with dementia who stay at home	User experience and efficacy	UCD as an iterative user research design and evaluation process	Little attention to integration with healthcare system. The design process was focused on end-users and carers.
Depp et al. [97]	Severe Mental Illness (bipolar disorder, schizophrenia)	Efficacy and integration	No focus on the design process Clinical and Engineering/ techno centric approach	As research was highly dependent on quantitative data, it did not aim to identify problems associated with sociotechnical design. However, it found some potential sociotechnical links, such as relationships between feasibility of using mobile interventions and privacy issues, as well as cost-effectiveness.
Mulvenna et al.[152]	Support patients with dementia	Empathic design process and inclusiveness	Participatory design as a process in which users participate in identifying the requirements of the system	Little attention to integration with healthcare system. The design process was focused on end-users and carers.

Burns et al. [153]	Depression	Efficacy, only from the technical point of view	No focus on the design process Engineering/ techno centric approach	No
Marcu et al. [138]	Bipolar disorder	User experience , efficacy, and integration	UCD as an iterative user research design and evaluation process Patient-Clinician-Designer (PCD) Framework.	Few elements of an integrated approach can be seen, including looking at both patient and clinician through the design process, as well as benefits of using persuasive technology in cultural contexts in which mental illness is a sensitive and less understood issue.
Matthews and Doherty [154]	Adolescents' mood monitoring	Efficacy and integration	No focus on the design process Engineering/ techno centric approach	Although the research methodology is mainly technocentric, the outcomes of the user trial shows some aspects of sociotechnical design, including impact of adherence and engagement on treatment, importance of privacy and security, and more importantly need for flexible tools for data capturing that can address various patients' trajectories.
Bardram et al. [155]	Bipolar disorder	User experience , efficacy, and integration	UCD as a process in which end users are involved Patient-Clinician-Designer (PCD) Framework	Few elements of an integrated approach can be seen, including looking at both patient and clinician through the design process, as well as benefits of using persuasive technology in cultural contexts in which mental illness is a sensitive and less understood issue.
Bright and Coventry [156]	Assistive technology for older adults	User experience , efficacy, and empathic design	UCD as an iterative user research design and evaluation process Socio-emotional design	No

Das and Svanæs [157]	Supporting weight loss treatment	User experience, efficacy, integration, and inclusiveness	HCD (UCD) as an iterative user research design and evaluation process An adopted HCD(UCD) process suggested in which four different roles are defined: informants, design partners, testers and users. Other stakeholders also may take part in parallel design processes.	The research highlights the importance of designing and evaluating the system with multiple stakeholders, including those who are a part of the healthcare system.
Heber et al. [158]	Workplace stress-management	Efficacy	No focus on the design process Clinical approach	No
Gaggioli et al. [159]	Collecting users' psychological, physiological, and activity information for mental health research	Efficacy, and to some extent user experience	Requirements of the system were defined by interviewing researchers and clinicians but no major focus on the design process Mainly clinical and Engineering/ techno centric approach	No
Good et al. [160]	Using reminiscent therapy to support people with borderline personality disorder	User experience and inclusiveness	UCD as a process in which end users are involved	No
Pelletier et al. [18]	Collecting and managing data of psychiatric patients	User experience, efficacy and inclusiveness	Participatory research for identifying the requirements of the system	No
Reid et al. [161]	Assessing and managing youth mental health problems in primary care	Efficacy, integration, and to some extent inclusiveness	No focus on the design process Clinical approach	The controlled trial looked at three aspects of use, including using the app as a clinical assistance tool, doctor-patient rapport, and pathways to care.
Watts et al. [162]	Major depression	Efficacy	No focus on the design process Clinical approach	No
Ben-Zeev et al. [163]	Schizophrenia	User experience and integration	Minimizing the effect of developers and healthcare professionals mental model in system design	Collaborative design of mMH service by multiple stakeholders.

Dagöö et al. [164].	Social anxiety disorder	Efficacy	No focus on the design process Clinical approach	No
Dennis and O'Toole [165]	Trait anxiety in adults	User experience and empathic design	Using a mobile game to modify the attention bias, or in other words applying gamification in the design process.	No
Gajecki et al. [95]	Risky alcohol use by young people	Inclusiveness and efficacy	No focus on the design process Clinical approach	No
Kuhn, et al. [166]	Help with post-traumatic stress symptoms	Inclusiveness and efficacy	No focus on the design process Clinical approach	No
Stinson, et al. [167]	Supporting adolescents to cope with chronic pain	User experience, efficacy, integration, and inclusiveness	UCD as a process in which end users are involved	The qualitative design research covers multiple aspects of the system, including personal aspects of use, as well as broader issues of patients and healthcare system interaction.
Baharav [168]	Improving sleep	Efficacy	No focus on the design process Clinical approach	No
Possemato et al. [169]	Help with post-traumatic stress symptoms	Efficacy, inclusiveness, and integration	No focus on the design process Clinical approach	Combining clinician support and mobile self-management tools would improve the outcomes of intervention.

6. Discussion

The review was structured by looking at a number of design requirements. The outcomes of the initial requirements' workshop show that experts often addressed the requirements of the final product, while the results of the subsequent literature review suggest that in many cases, to achieve a certain characteristic in an mMH app, certain conditions should be met in the design and development process. Therefore, when design requirements are being discussed, the term design could be used for the process of design, rather than its resultant product.

Digital solutions often have a short lifespan, so their design process is a continuous and iterative activity. In comparison with the fast pace of digital technology, process of publishing academic research is slow, and therefore scientific publications about mMH apps lag behind the developments of products in the market [131]. Therefore, exploring the design process, and not the product, seems to be the best way for understanding and improving design for mMH. UCD as an iterative and sequential process has been the most common way of designing mMH apps, perhaps because of its dominance in commercial mobile industry. In contrast, sociotechnical design remains relatively unexplored in mMH while it gives designers a better idea of the complex, heterogeneous, and dynamic nature of healthcare systems, as well as a more sustainable and integrated approach towards designing effective solutions. Moreover, there is not much tendency to open design among developers of mMH, though this approach can create more synergies between organizations and businesses that face resource constraints.

The outlined design requirements in this study are interconnected and should not be seen as independent factors. For example, the poor user experience can directly affect the efficacy of an mMH app. Without usability users' motivation for the long-term use of the app cannot be established and there is less chance of a successful intervention. A similar claim can be made about the relationship between desirability and empathic design of the app. Perhaps one of the barriers in this way is the different methodological approaches in these pathways. For example, randomised controlled trials which are common tools in clinical approach, are not among the most used methods in design research. However, controlled trials are being used in some similar fields including innovation and entrepreneurship [170,171]. Another example is integrating qualitative measures in health informatics. There is an expectation that introducing new technologies bring efficiency, safety and quality of the care, while there are evidences that this is not always the case, especially due to unpredictability and complexity of human behaviour. Despite their strengths, experimental and quasi-experimental studies may not be sufficient for understanding complex social systems like healthcare services, and as a result there is a need for using qualitative methods like ethnography, as well as redefining the concept of research rigor in healthcare [172].

mMH apps are being developed by various organizations including public sector, academia, large, small, and medium-sized businesses. Due to their nature, each group of organizations may have some misconceptions about the value that their app can bring, the context of use, and the business model that can make it sustainable. The public sector and academic developers may underestimate the importance of factors like the short life span of the digital solutions, the need for a sustaining business model, and impact of the app desirability on its efficacy. Businesses may miss also the fact that mMH apps are a part of the whole mental health service ecosystem. Finally, start-ups and SMEs may not have enough resources for conducting in-depth user research studies, collaborating with mental health experts and evaluating their products in real settings. Facilitating collaborations within this heterogeneous (eco)system of organizations can be a way for overcoming the limitations of each group of organizations. In fact, a system cannot run without an agreement among its main actors [173] and this is the collaboration among the actors that defines the system's characteristics and behaviour [174]. The actors may have different reasons for agreeing on collaboration [173]. Understanding the systemic relationships within the entire healthcare ecosystem improves safety by preventing incidents and problems that may occur when different subsystems interact. The conventional approach towards safety and risk management often dismiss such issues and only concentrates on individuals' errors [175].

Prioritizing shared value can facilitate collaboration among enterprises and organizations, even in a competitive market. Shared value is a concept that focuses on links between societal and economic progress in order to guarantee long term and sustainable growth [176]. Shared value can be achieved on different levels including targeting unmet needs, better management of international operations within the organizations, and changing societal conditions outside the organization to unleash new growth and productive gains. On each level, the organization should aim to see both business and social results as interdependent measures, otherwise it may miss important opportunities for innovation, growth and sustainable social impact at scale [177]. Within the healthcare systems, it is common to see stakeholders with unclear and conflicting goals, which can lead to problems. To improve this situation, achieving high value for patients must become the main aim of all involved organizations, while the shared value can be defined as the achieved health outcomes per amount of money spent [178]. This definition indicates that reducing service costs, increasing revenue, or increasing the types of services provided are not solely sufficient for achieving the shared value. That is why, the overall efficacy of a mMH app, especially when used in everyday life scenarios matters, even if it already achieved market success or promising clinical results.

Although there is a good understanding about mMH design requirements in the literature, there is not much information about the way such requirements can be applied in design practice. Therefore, research studies that give a clear picture of mMH design processes are rare. Most mMH apps do not provide information about their design process as well as evidences of their efficacy. Studies which discuss the design and development process have a technocentric or clinical approach rather than a sociotechnical one which considers users views as well as technical design. The term 'design' is used diversely, to describe the way that technology is being developed or the way that efficacy trials are planned. Among those studies which considered other aspects of design such as the process and understanding of users and stakeholders, there is a strong tendency to UCD. However, there are problems with how UCD is defined, with some authors simply labelling any user involvement through the process as UCD. Some others relied on one of the common ways of defining UCD, which is an iterative process of understanding, identifying, implementing and evaluating in which users are being considered, or being involved in all steps of the process. There was no example of defining UCD as a philosophy or as a strategic

design approach, and there was only one example of a customized design framework, the Patient-Clinician-Designer process [138]. Sociotechnical design can be a way forward, while it is relatively unexplored in mMH design. For instance, research studies on England's healthcare system including mental health trusts shows that local sociotechnical design can facilitate implementation of national electronic health systems and solve emergent problems that may occur due to human behaviour [179,180]. Flexibility and customizability of mobile apps may bring even more opportunities for local sociotechnical design in mental health services and addressing the requirements of various stakeholders.

Surprisingly, mMH apps mentioned in studies often address serious mental health issues, and there is less focus on prevention, wellbeing, and minor mental health problems that are more common among the public. Improving public mental health conditions and wellbeing can reduce the pressure on the mental health services in long term. The design of such apps may be one of the main directions of future research, especially when many commercial self-help and wellbeing apps are available in the market. Trialling and testing an approach to designing these apps to ensure they meet the principles outlined here may be beneficial.

7. Research limitations

To structure the review, an expert requirement workshop was used which identified a number of high- level design requirements of mMH apps. These design requirements were used as concepts for structuring the review. Within the review itself, the results showed that some design requirements are overlapping. Most of references suggest users' involvement in the processes that aim at designing mMH apps. Indeed, we acknowledge that the initial requirements workshop and consequently the study itself could have been improved if ordinary users were involved in identifying the main directions of the literature review and recognise that this is a limitation of the current review. In addition, we also acknowledge that having a different setting in the workshop, might result in different set of requirements. However, despite this limitation we still think that a cross disciplinary and collective approach towards structuring the review helped us to have a broader understanding of the topic prior to conducting the review, which is essential for exploratory research.
Finally, similar to other exploratory reviews, we had an open-ended approach towards data collection, which means that unlike systematic reviews the outcomes of this review cannot be generalized.

8. Conclusion and practical implications

A key motivation behind this review is that quality standards in healthcare technology, such as mMH, tend to focus on performance and engineering, rather than user experience. It is expected that designing good mMH solutions should be done with a consideration of these three elements. And this expectation underpinned the two research questions introduced at the start of this article:

RQ1: What are the key principles of the design process relevant for mMH?

RQ2: To what extent does current research align with these principles?

On the first question, it was found that there is a lack of systematic research and development of design principles and methods. From looking at the outcomes of the requirements workshop and existing literature on mMH it is possible to build a set of design principles, which are a high quality user experience, demonstrating efficacy, empathic and desirable, open, and integrated. While initial set of requirements in the workshop addressed the mMH apps as products, the literature review suggests that defining and implementing requirements for the design process is a more promising approach. One of the reasons for focusing on the process rather than the product is that evaluating all mMH apps is almost impossible due to the large number of apps available in the market and their relatively short lifespan. On the second question, we found that current research and practice on mMH does not provide many examples where these design principles can be found on a balanced basis. For instance, it was found that not all projects claiming to follow UCD are empathic and comprehensive enough to incorporate quality participation in mMH design as a product and as a process. In other words, while there is a good theoretical knowledge of the design requirements of mMH apps, empirical knowledge is underdeveloped especially when it comes to design for prevention and wellbeing.

Developing the empirical knowledge can be the main direction of future research studies on mMH design. In addition, adapting existing design tools for this specific context is another demanding research direction. For instance, the concept of usability is strongly linked to the users' cognitive abilities. Therefore, adapted usability

dimensions and evaluation methods might be needed for mental health services.

In terms of practical implications, developers of mMH solutions and mental health service providers need to follow certain strategies to overcome existing challenges, and to make the best use of mobile technology. These strategies may be applied in various stages of design and development of mMH apps and services. To represent implications, we used evolutionary framework of new product development which categorizes the design and development activities into three main phases of variety generation, selection and inheritance [181]. The framework illustrates new product development in a way that can be relevant to various types of industries and businesses. More importantly, it shows new product development evolution on different levels of industry, firm and project. Table 3 shows where our recommendations can be applied in each phase of an evolutionary product development process.

Table 3. *Strategies for improving mMH solutions based on the evolutionary framework of new product development*

	Variety generation		Selection		Inheritance	
	Examples of activities	Practical implications	*Examples of activities*	Practical implications	*Examples of activities*	Practical implications
Project level	*New ideas, new prototypes, new technology*	Applying an ecosystem perspective Applying sociotechnical and open design	*Technology testing, user testing, clinical trials*	Considering all dimensions of efficacy Bridging design and medical research and development	*launching a new product or service in the market*	Applying all dimensions of efficacy
Firm level	*Business models, value propositions*	Creating shared value	*Market evaluation and analysis*	Considering an ecosystem perspective	*Market feedback and reflection, documentation, making strategic decisions for future directions*	Recognizing all dimensions of efficacy Embedding sociotechnical and open design strategies
Industry level	*Emergence of new businesses and organizations, New cultures of collaboration, Knowledge exchange*	Promoting and training sociotechnical and open design Understanding and promoting shared value	*Monitoring business growth, Measuring the impact on mental health*	Recognizing all dimensions of efficacy Promoting designing for the ecosystems	*Introducing new regulations, establishing new professional bodies or communication channels*	Understanding and promoting shared value

The recommended strategies and their rationale are as follows:

- *Moving towards sociotechnical and open design strategies:* Due to the short lifespan of mMH apps, regulating the products is a challenging task. More emphasis on improving the design processes would be a better solution. To do so, there is a need for better communication and knowledge exchange among different organizations, so start-ups and SMEs with limited resources for user research can gain a better understanding of users by accessing shared or open information. It is important to note that, understanding UCD as a sequential and iterative process, might be a good starting point for smaller organizations for improving some aspects of user experience such as the app usability, but is not enough for developing integrated and tailored solutions that can work in complex healthcare ecosystems. Therefore, professional training can help designers and developers to learn principles of sociotechnical design and make them ready for facing emergent issues and trajectories as well as giving them a broad grasp of healthcare system. In that case, the quality of user experience can be improved on service level and through the whole treatment journey. Promoting and training principles of open design is another strategy which can synergize the knowledge and skills of all individuals and organizations involved in delivering or using mMH. In any case, both

sociotechnical and open design strategies will need to incorporate genuine participatory design strategies where users have not only a voice but a say in the process of design [182].

- *Understanding and creating shared value:* Designers need to understand that every mMH service or product concept requires a business model. This approach will make the solutions more sustainable and can improve the quality of mental health services in general. Since various organizations of different size need to work together for developing successful mMH solutions, a fresh perspective towards business models and their proposed values is needed. Organizations within the mental health ecosystem should acknowledge the connections between societal and economic progress, and the fact that long term business growth is not possible without creating shared value. Fortunately, the concept of share value is becoming popular in healthcare economy so there is a chance to see mMH services based on shared value business models in the future.
- *Recognizing all dimensions of efficacy:* Improving user experience is directly linked to efficacy and integration of an mMH app. Although concepts such as efficacy, integration, and desirability were first recommended by the experts as the core concepts for structuring the review, when references about efficacy, integration, and desirability were reviewed, it was found that such concepts often overlap in the importance of user experience. As mentioned, understanding users' real-world behaviours and experiences is essential to design integrated mMH solutions. Of course, authors believe that more empirical research and practice, especially with direct involvement of users is needed in this area to clarify and articulate the relationships between user experience, integration and efficacy of mMH solutions in more detail. Therefore, user experience cannot be viewed as an independent requirement. Good usability is a necessity, but not sufficient to guarantee high quality user experience. In addition to usability evaluation, developers need to find ways to observe and understand users' daily interactions with mMH apps and other touch points of the mental health service in real contexts. This deep understanding would help them to conceptualize the improved experiences. Therefore, using ethnographic user research should be a permanent part of any design process. The resultant requirements of such studies should be taken as serious as technical and medical requirements.
- *Bridging design and medical research and development:* As mentioned, there is a need for an integrated approach towards addressing multiple aspects of user experience including usability together with medical and technical efficacy. The required resources, as well as requirements and variables in the above domains are quite diverse. As a result, one solution would be developing a common language among different disciplines involved, as well as bridging methodologies for developing and evaluating mMH apps. Recent research studies on innovation controlled trials can be a good example in this regard, as it gives this opportunity to clinicians and designers to plan and run rigorous trials for concurrent evaluation of user experience and clinical variables. Another improvement is using qualitative measures in health informatics by using methods like ethnography that are well-known to the design community.
- *Ecosystem perspective:* An mMH app is just a part of a larger ecosystem. It is not possible to design it without considering the other interrelated parts, such as attributes of the conventional mental health service model. In addition, unlike most commercial apps, mMH apps cannot be designed only for one primary user. Secondary users such as mental health practitioners and caregivers should also be considered when planning user studies. Unlike most commercial mobile apps, mMH apps often have multiple direct and indirect user groups. In addition, open innovation strategies can synergize the communication and collaboration among organizations within the mental health ecosystem.

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