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HEALTH PSYCHOLOGY | RESEARCH ARTICLE

Exploring users and non-users views of the Digital Twin on a mHealth app: a Thematic, qualitative approach

Lauren Taylor^{1*} and Bridget Dibb¹

Abstract: The aim of the present study was to explore perceptions of the Digital Twin (a three-dimensional digital representation of an anatomical body) on a mobile health application, and the potential mechanisms that are important for behaviour change, with a focus on health and weight management. An explorative and participant-led approach was taken using semi-structured online interviews to explore the experiences of people, in this case non-users and users wanting to independently manage their health. An opportunity sample of forty participants from the United Kingdom (20 who had not used digitally assistive technology and 20 who had) were recruited from social media platforms (22 females and 18 males; mean age was 30). The interviews were transcribed verbatim and analysed using Thematic Analysis. Two main themes were elicited: *Initiators of behaviour change* (i.e., autonomous choices, social influences, and personalisation) and *Barriers to behaviour change* (i.e., adverse reactions, weight management norms and negative

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PUBLIC INTEREST STATEMENT

Many mHealth apps have been used as a platform for changing behaviours through presenting virtual representations that aim to support this and engaging people to thinking about their bodies. There is a large body of evidence of the use of representations such as avatars in virtual environments, there is, however, a relative paucity of in-depth qualitative research that has explored using virtual representations in mHealth app settings, and what their perceptions, attitudes and experiences mean for the overall effectiveness of using virtual representations for behaviour change. This qualitative study sought to address this gap using semi-structured interviews with users and non-users of the Babylon app to explore their experiences and perceptions of a realistic, tailored representation of an anatomical body (the Digital Twin). The findings revealed that personalisation, self-monitoring, rewards, goal setting and positive social comparison were considered by participants in both groups to motivate behaviour change. Overall, it was suggested that the Digital Twin could be beneficial in facilitating health and weight management, instead of standard face-to-face programs, but its use should be interpreted with caution to potential adverse effects.

attitudes). Overall, it was suggested that the Digital Twin should be representative of a user's personalised health information and BMI. These results can inform an intervention designed to use the Digital Twin to initiate and maintain lifestyle behaviour change. It can also develop our understanding of how such technology can be applied as a tool for health management.

Subjects: Artificial Intelligence; Technology; Health Psychology; Risk Communication; Health Communication

Keywords: Weight management; mHealth; apps; qualitative study; smartphone; digital twin

1. Introduction

1.1. Problem formulation

Leading an unhealthy lifestyle has been associated with increasing risk in developing chronic diseases, and weight gain (Haththotuwa et al., 2020; World Health Organization, 2018). There is overwhelming evidence to suggest that this is associated with poor lifestyle choices, such as, physical inactivity and inappropriate diet consumption (Islam et al., 2020). Yet conventional face-to-face weight control programs are not effective in promoting successful weight or lifestyle management (Kim et al., 2017; Solbrig et al., 2017). These programs can be labour intensive often requiring multiple visits to the program or group location (Hurkmans et al., 2018). These shortcomings can be overcome by mobile and wireless technologies and wearable devices for improving health (mHealth apps). mHealth apps offer convenience, easy access, and automatic and ongoing progress monitoring and other data collection from the app user. mHealth applications are an example of the new avenue in the delivery of digital healthcare and behaviour change that aim to address obesity by promoting healthy lifestyle behaviours, such as healthy eating (McCarroll et al., 2017), physical activity (Martin et al., 2015), and weight management (Vlahu-Gjorgievska et al., 2018). However, their effectiveness is limited, and there is still a need for mHealth apps that achieve the desired behavioural outcomes (Marcolino et al., 2018).

Research has also demonstrated a link between a virtual representation or “digital replication” of the self in engaging people to thinking about their bodies (Behm-Morawitz, 2013; Fox & Bailenson, 2009; Fox et al., 2013; Wrzesien et al., 2015). Virtual representations have been shown to positively influencing real world behaviour change, such as weight loss, and can be presented on mobile devices (Horne et al., 2020; Kim & Sundar, 2012; Peña, 2020). It is essential to explore the perceptions and attitudes toward virtual representations that include detailed and realistic depiction of body. This may prove useful in optimising these apps and improving their efficacy in health and weight management.

1.2. Purpose

This study aims to add to previous literature by exploring the perceptions and attitudes towards a virtual representation embedded in an mHealth app aimed at weight management. For example, previous research has focused on virtual reality settings or evaluating the influence of the appearance of computer game play avatars on lifestyle or weight management (Horne et al., 2020; Scarpina et al., 2019). In addition, no studies have yet focused on a digital replication on an mHealth app that includes features of the internal body, such as internal organs and skeleton. Previous research has highlighted the benefits in applying a user-centred design and seeking participants perceptions and attitudes can prove useful in providing engagement strategies and feedback (Marcolino et al., 2018). This study aims to deliver an atheoretical contemporary qualitative account of the non-users' and users' attitudes and perceptions of a virtual representation known as the “Digital Twin” of an outer and inner body and its usefulness for managing weight. The Digital Twin is an example of a virtual representation of an internal human body that

displays all physiological and pathological outcomes in a highly detailed visual presented on the Babylon app (Liu et al., 2021). It aims to assist people in undertaking healthier lifestyle habits to reduce the risk of disease. It provides users with tailored information about their health status based on factors such as medical history, nutrition, physical activity, and weight (see, Figure 1). Virtual representations such as these can be applied to enable individuals to conceptualise their condition by being able to “see” or actively visualise what is going on inside (Jones & Petrie, 2017; Miller & Polson, 2019). As a result, visual information may also result in increased motivation for positive health behaviours in comparison to standard forms of information and transforms previously intangible concepts into concrete representations of health threats (Jones & Petrie, 2017).

2. Methods

Standards for conducting and reporting qualitative research were followed (O'Brien et al., 2014).

2.1. Qualitative approach and research paradigm

This study is a qualitative design utilising online, semi-structured, in-depth interviews in understanding the attitudes and perceptions of mHealth applications and the Digital Twin were elicited from users (Group 1) and non-users (Group 2) of the Babylon app.

2.2. Researcher characteristics and reflexivity

In terms of personal values and assumptions of the researcher, there were no competing interests, although participants elicitation of emotionally charged stories of weight loss and stereotypical discrimination may have resulted in an empathetic response to the data, especially when considering concerns relating to eating disorders. However, this was acknowledged, and great consideration was taken to set aside any assumptions for the integrity of the study.

Figure 1. Generic and anthropomorphic digital Twins.



2.3. Setting and recruitment

Recruitment took place between November 2020 to December 2020 using opportunity sampling and snowballing methods. Participants were recruited by means of an online advertisement using both the researcher's and the University of Surrey's email and social media pages (i.e. Facebook, Twitter and LinkedIn), and was promoted using shares. A £10 gift card was offered as an incentive to take part in the study.

2.4. Sampling strategy

This study recruited a convenience sample of a total of forty participants who were recruited using convenience sampling. Group One consisted of twenty participants who had not used any mHealth apps that incorporated virtual representations. Group Two consisted of another twenty participants that had used Babylon app which included the Digital Twin (an example of a virtual representation). Adults aged 18 and over interested in managing their health, who were able to converse in English, and owned a smartphone were recruited and invited to interview following completion of the screening questions. As the Digital Twin is a new concept on a mHealth app, it was thought to be beneficial to include participants with any BMI as the Digital Twin provides information on health and weight management.

2.5. Ethical approval

The study was approved by the University of Surrey Ethics Committee (FHMS 19–20 071 EGA).

2.6. Data collection methods

The Digital Twin is the first example of its kind to be included on an mHealth app that is publicly available to both Android and Apple smartphone users, it was essential to qualitatively investigate this further. Data collection took place between November 2020 and June 2021. Quantitative demographic data was firstly collected using an online questionnaire (Qualtrics) before qualitative data was collected via online interviews using Microsoft Teams. The data was analysed between July 2021 to December 2021.

2.7. Data collection instruments

After providing consent, each participant first completed an online questionnaire on Qualtrics (www.qualtrics.co.uk) about demographics, anthropometrics (i.e., height and weight), and preferred health outcomes that they would like to improve, for example, weight, fitness, etc. Then participants were invited to take part in an online semi-structured interview (see Supplement 1 for interview guide). Before conducting the interviews, five pilot semi-structured interviews with five participants from both groups—users and non-users—lasting between 22 to 38 minutes were undertaken with an aim to refine the interview question and assess and improve its suitability. This feedback was applied in refining the interview schedule and the revisions were considered suitable as participants were able to understand and answer the questions in depth (see Supplements).

During the interview, non-users were provided a brief description of the Digital Twin, and that it was a feature on the Babylon mobile app. Both groups were asked if they perceive that the Digital Twin could be used for health and weight management. The interview questions were centred around their perceptions of two Digital Twin images and whether they thought that any of these could be used to manage health and/or weight loss. Participants in the non-user group were asked about their experiences of mHealth apps in general. While participants in the user group were asked about why they downloaded the mHealth app which included the Digital Twin, with questions focusing on their experiences of using it, such as the features, whether they found it helpful in managing their health, and whether they identified with it. Participants were also asked to share their interpretations of the term “digital body”, the meaning it conveyed to them, and the functions it should provide. Following this, participants were shown two versions of the Digital Twin. One version was generic and androgynous and the second, larger Digital Twin represented an anthropomorphic overweight female (Figure 1). Participants were asked about the degree of

relatedness of each Digital twin version, and its' usefulness and suitability for managing their health. The interviews were recorded using a digital voice recording device.

2.8. Data processing

The interviews were audio-recorded, transcribed verbatim, and coded into main themes, with the participants' consent. The audio recordings and the transcripts were pseudonymised by assigning a participant identification number to each interview.

2.9. Data analysis

The verbatim transcripts from both studies were analysed according to Braun and Clarke's (2006) six-step Thematic Analysis approach, which was utilised to capture the non-users' attitudes and perceptions of mHealth applications and the Digital Twin. Firstly, the researcher familiarised herself with data by listening to the interview audiotapes and re-reading the transcripts. This was followed by generating codes which are features of the data that appear meaningful, searching for any emerging themes, then reviewing and defining them (Figure 2). Finally, the analysed data was transformed into overarching themes using specific examples from the transcribed interviews. The themes were also mapped to existing behaviour change theories to determine the behavioural change components of the Digital Twin.

2.10. Validity and reliability of analysis

As recommended, both researchers performed the analysis to triangulate the data, and to ensure the validity of the results and their interpretations (Malterud, 2001). If a new code was introduced, all the narratives were read again to ensure that the data extraction was complete and to verify that the initial classifications were accurate.

3. Results

Participants' characteristics are reported in Table 1. The sample included 40 participants of a mean age of 30 (SD = 8.7), 22 of whom were women, and 18 were men. The mean BMI was 24.7 (SD = 5.1). Overall, the total interview duration was between 32 minutes to 1.5 hours (mean time: 50 minutes).

3.1. Synthesis and interpretation

Overall, two overarching themes emerged from the combined datasets of users and non-users and were named using participant data: "*Facilitators of behaviour change*" and "*Barriers to behaviour change*". All participant accounts made strong references to the barriers and facilitators to initiating behaviour change, including the adoption of mHealth applications and the Digital Twin, maintaining continued app use as well as behaviour change in general. Potential mechanisms (factors initiating behaviour change) were identified (see, Figure 2).

Figure 2. Overarching themes and sub-themes.

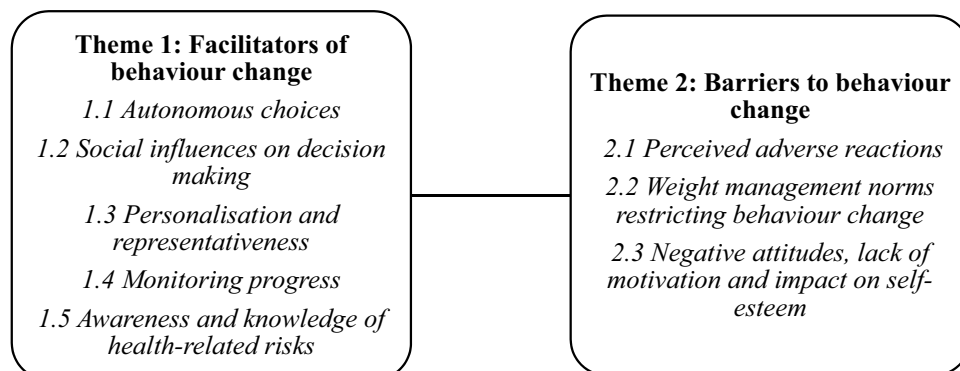


Table 1. Descriptive statistics of demographics, and BMI for users and non-users

Characteristic	Subcategory	Non-users	Users	Total
Gender	Female	13	9	22
	Male	7	11	18
Age	18–25	9	6	15
	26–35	8	10	18
	36–45	1	4	5
	>55	2	0	2
BMI	<18.5	0	1	1
	18.5–24.9	2	13	25
	25–29.9	12	5	17
	30–39.9	6	1	7
Interview Duration (minutes)	Mean interview time	54 (SD = 13.10)	44 (SD = 7.62)	98
	Shortest Interview	40	32	72
	Longest Interview	89	62	151
Ethnicity	White British	10	8	18
	White Other	2	5	7
	Mixed	1	1	3
	Mixed Other	1	1	2
	Black African	2	1	2
	Black Caribbean	1	0	1
	Asian African	0	1	1
	Asian Pakistani	0	1	1
	Asian Indian	0	1	1
	Asian Chinese	0	1	1
	Asian Other	1	0	1
	Other	2	0	2
Preferred area of health management	Weight	16	9	25
	Fitness	18	17	35
	Chronic Illness	1	9	10
	Alcohol Consumption	2	5	7
	Smoking	3	1	4

3.2. Theme 1. *facilitators of behaviour change*

Participants highlighted five factors as facilitators that could motivate behaviour change when considering both mHealth apps and the Digital Twin images. This was related to autonomous choices, social influences on decision making, personalisation, self-monitoring behaviours, and awareness of health-related risks.

3.3. *Autonomous choices*

Participants consistently referred to the responsibility in managing their own health through the process of self-care and would use an app to initiate the process of behaviour change, thus facilitating the autonomous decision-making process:

At the end of the day, your health is down to you, and you need to take the first steps to look after yourself by signing up to a mobile app such as this.” (P10, Non-user).

Participants suggested that their desire to maintain current physical health was related to age as an internal initiator and how this could impact their long-term health. The key to being and looking healthy was also linked to future identities, as highlighted by P20:

It is essential to be able to lead your life for the next 10 years in reasonable health and fitness ... I think it is important to think of the future ... I want to live as long as possible and look as healthy as I can ... and using an app with a digital version of me can really put things into perspective.” (P20, User).

3.4. Social influences on decision making

Participants highlighted social support as an external initiator through competition and sharing progress with friends using their smartphones, which increased accountability of certain lifestyle behaviours. This was a means of feeling supported throughout their weight loss journey:

I've got a messaging group with my friends that I grew up with, who are also struggling with weight management and making a start ... We take screenshots of our activity daily and sort of group as a form of accountability ... This makes me feel really supported and not alone.” (P6, Non-user).

When shown the Digital Twin, participants also suggested that there are body standards, in promoting the “need for thinness” as a pressure in maintaining what is perceived to be a “healthy” weight:

There is more of a pressure to stay thin from society ... and that it is important to keep your weight down using things like an app to try and stay trim and healthy, and just fit in ... I think being overweight has always been associated to being unhealthy ... I think being presented with the twin can help me to rationalise my weight and compare myself to it and other peoples to say to stop to this pressure and accept my body and realise everyone has a different body.” (P27, User).

The perceptions that being “overweight” and “unhealthy” as not socially desirable further encouraged participants to “fit in” according to societal standards, and that signing up to an mHealth app with the Digital Twin can help achieve this.

3.5. Personalisation and Representativeness

Many participants commented on the appearance of both Digital Twin images (see, Figure 1) but found the first Digital Twin to be too generic and perceived the second Digital Twin to be more representative of an overweight user (see, Image 1). However, either Digital Twin could be used to model desired behaviours and a visual motivator or target in adhering to managing their health goal:

This Digital Twin could be used to show the type of person you are wanting to become through exercising, eating well, managing your weight ... so that you can save that image to motivate you to want to try and work harder so you reach the goal you want.” (P6, Non-user).

Participants also positively responded to having a virtual representation on an mHealth app that was inclusive of different body shapes and sizes. For example, participants suggested that they preferred the second Digital Twin as they want their own Digital Twin to be “representative” of their BMI as this was related to greater identification and association:

I want mine, my twin to represent me ... so you can see where exactly I have put on weight ... and seeing this on an app on my phone makes it all the more personal.” (P22, User).

3.6. Monitoring progress

Participants suggested that understanding the impact of their habits and behaviours on their organs through viewing their Digital Twin was essential in understanding the impacts of internal health and this reflected on the Digital Twin could be used as an incentive in changing a person's behaviour. This participant spoke about weight loss, and how the Digital Twin could be a visual motivator compared to most mHealth apps:

I think it would motivate someone to lose weight just by being able to see how healthy the organs are, how healthy the body looks in general ... Give me the information I need to change, like exercise more, or eat better and track it over time ... show me what to do instead of showing me the statistics like most apps do.” (P8, Non-user).

Participants also spoke of being able to understand health from “inside” and to remove the superficial element of judging health from appearance, for example:

I liked the Digital Twin because it allowed me to see what is going on inside of my body, which is beneficial as it is so easy to focus on the exterior of yourself ... it helped me to think about my organs and to realise it is not just about what is going on for the outside but also the inside.” (P14, User).

Participants suggested that notifications (alerts and reminders triggered by the app) encouraged them to use the app and make their interactions with the app efficient while increasing the likelihood of achieving their goals. For example, this participant suggested that the Digital Twin was motivational in helping them to stay on track with their goals as positive reinforcement, and compared this to other mHealth apps which have enabled them to do this:

Just for the Digital Twin to prompt me or make changes to each prompt as I improve my health ... it is good to have some sort of recognition I deserve for good behaviour ... some other apps that I have used in the past has allowed me to do that too and I respond really well to it.” (P21, User).

It was also suggested that the smaller Digital Twin can be used as a goal body that can be compared to the larger Digital Twin as a current representation of their body (see, Figure 1). This participant suggested that this could be used as motivation and having it on a mHealth app is “convenient” in effectively “pushing” them to work towards their desired goal:

It was just something like this goal body that I would like to achieve, the first one you showed ... Whereas, the second body, the bigger one, is a bit more like me and more suited to my body type ... I could use this to begin with to push me to work and making the right changes towards making myself look like the first body ... and it is so convenient because I can use this on my phone ... I have never seen a mobile app do this before.” (P7, Non-user).

3.7. Awareness and knowledge of health risks

This sub-theme illustrates how the Digital Twin has influenced participants’ knowledge of diseases and how their’ risk can be reduced through behaviour change. For example, one participant reduced their alcohol consumption because of the feedback provided by the Digital Twin:

... For the alcohol management, it’s more about looking at how my consumption is evolving ... the app has influenced me drinking less as it’s a good indicator of knowing the risks ... which can be useful if you don’t realise how this can damage your health and can cause diseases that could kill you ... and the twin highlighting on it the organs that could be damaged was a bit of a wakeup call.” (P22, User).

The phrases “evolving”, “influencing” and “wakeup call” suggest that the information provided by the Digital Twin has increased the participant’s awareness of the associated risks and that this knowledge could initiate possible behaviour change. This could be related to weight management, whereby a user could be provided with the associated risks of obesity, and this could be a useful trigger in behaviour change.

This is supported by another participant in the non-user group, in suggesting that the Digital Twin needs to provide tailored advice for the user to be able to “relate” and act on the information, in comparison to other mHealth apps:

I need advice and to be told that I need to do something ... And then it might make this image more relatable and different to the other health apps because then you are physically seeing the impacts of your actions on the twin about your health alongside information for what these changes are going to be better for.” (P3, Non-user).

Many participants found viewing the risk perception bar displayed next to the Digital Twin to be beneficial in understanding the differences between their risks of disease and normative information compared to the average of the rest of the population (Image 1). However, P21 suggested that they wanted to be able to compare their Digital Twin to other users to encourage behaviour change and monitor their progress:

I think that would make me want to do something if my twin looked worse compared to my friend ... It would make me really think that I do not want to be unhealthier than them and I need to do something about it.” (P21, User).

3.8. Theme 2. barriers to behaviour change

The themes identified thus far have been testament to the positive experiences of the Digital Twin, and reaction to the two images presented. However, towards the latter stages of the interviews, many participants from both groups raised concerns after being presented with the larger Digital Twin (see Image One), relating to body dysmorphia, eating disorders and how these negative attitudes could impact a user’s self-esteem. Participants from both groups mostly focused on the Digital Twin in itself, and made suggestions for the overall development of the app.

3.9. Perceived adverse reactions

This sub-theme highlights the concerns raised by participants from both groups when shown the second Digital Twin image (see, Figure 1) could encourage adverse, obsessive weight loss behaviours, leading to body image distortion and eating disorders:

... Like I can see that looking at this bigger body [larger Digital Twin] can become a bit obsessive ... and needs to be regulated by the app develops as a person needs to be aware of the dangers of obsessing over a body and how to manage those bad thoughts so that they don’t become too thin.” (P18, Non-user).

This suggests that the physical presentation of the Digital Twin could promote body dysmorphia whereby a user compares their physical appearance to their idealised body weight. Another participant suggested that if the Digital Twin were to reflect a person’s BMI, it could be off-putting for participants who have negative thoughts or beliefs about their body:

If someone’s very obese or very anorexic, they may not actually want to see their body on this app because they feel bad about it ... So, for them to confront it is quite hard. If there’s someone’s quite obese, they may not feel like seeing it is helping them and might stop using it.” (P24, User).

Many participants continued to express discomfort when shown the larger Digital Twin as they felt it could negatively impact self-esteem and mental health, for example:

It [larger Digital Twin] makes me feel which is uncomfortable ... psychologically low. I believe if I wasn’t super healthy with a six pack it would impact my mental health because it would be constantly saying I need to be better and achieve something that is not achievable for me.” (P4, Non-user).

3.10. Weight management norms restricting behaviour change

A commonly identified barrier was related to societal expectations and perceptions related to weight loss and body types. For example, many participants expressed the difficulty that they may experience in using the larger Digital Twin by feeling confronted by a realistic image that is not accepted by societal standards, or usually presented on mHealth apps in general:

I think we're not really used to seeing plus sized people on apps ... Especially not really like fitness or health apps, because we deem that size as unhealthy ... it is not an image that fits in to what society wants. This could make it difficult for someone to see this and not have negative perceptions about themselves." (P13, Non-user).

This was supported by users, in suggesting that who also attributed their personal insecurities related to weight gain as a further barrier to encouraging or reinforcing behaviour change, for example:

I don't know if I am ready to be shown an accurate image of myself in a digital format such as this ... I have gained weight recently and to see it shown on an app, where I don't even like looking in a mirror at the moment ... it would probably put me off using it to make any new lifestyle changes for myself because I don't like how I look because I have a higher BMI than most." (P22, User).

3.11. Negative attitudes, lack of motivation and impact on self-esteem

The final sub-theme explores how the Digital Twin could reduce a user's self-esteem, and this was associated to having a negative mindset on motivation to continue to use the app and to pursue health behaviours.

I think certainly for some people who just could be really negatively impacted from having that information shown to them on that body [larger Digital Twin] and on the app itself because they're not mentally strong enough to still take the information that is being presented to push themselves to hit that target ... I think it is down to the individual and whether they are ready to accept a representative and honest image like this ... it could stop people from using the app." (P9, Non-user).

In addition to discussions about mindset and motivations, many participants also attributed their personal insecurities related to weight gain as a further barrier to encouraging or reinforcing behaviour change. For example, one participant described negative associations when receiving feedback presented on the Digital Twin to poor health and therefore how they feel about themselves:

I find it to be depressing ... I find where I'm not the most healthiest of people, I kind of feel bad seeing this negative feedback and I think it makes me feel not so good about myself as like a person ... I think I will need some positive feedback and reward too otherwise it will be too negative to motivate me further, even if it is a small improvement ... even if that includes positive notifications or recommendations that pop up on the twin or the rest of the app." (P29, User).

The need for "positive feedback" and "rewards" highlights the importance in the Digital Twin providing reinforcement to all positive behavioural changes within an app, or on a virtual representation.

4. Discussion

The interviews provided a detailed account of the non-users' perceptions and attitudes towards the Digital Twin and mHealth apps and users' attitudes and experiences of the Digital Twin, therefore addressing both of our overall aims. In addition, suggestions for the improvement of health apps and the Digital Twin are provided. In addition to the perceived barriers and facilitators, the findings provide an uncharted new insight into the experiences, attitudes, and perceptions towards the Digital Twin on an mHealth application, in addition to exploring the perceived initiators and facilitators of behaviour change and the barriers to mHealth app use, and the perceptions of non-users as to its applicability and acceptability for lifestyle and weight management. Overall, two superordinate themes emerged from the analysis which relate to various concepts documented by previous research, as per the following discussion.

The first superordinate theme highlights the perceived responsibility and health-related control that participants from both groups suggested were important factors in initiating behaviour change.

For example, if participants held autonomous beliefs that they are solely responsible for their health, they suggested that they would be more likely to be motivated to use the Digital Twin to improve and control their overall health. This was linked to participants highlighting the importance of setting themselves as their personal role model to build knowledge from the Digital Twin to and are motivated by a desire to be healthy. For example, previous research has highlighted the benefits of mHealth apps in promoting self-management skills by increase users' awareness and motivation for healthier lifestyle choices (König et al., 2021; Yuan et al., 2015). Participants suggestions to use the Digital Twin to monitor progress over time was also related to accountability and performing healthier behaviours. This was supported by previous research highlighting the link between a virtual representation of self and real-world behaviours (Behm-Morawitz, 2013; Fox & Bailenson, 2009; Fox et al., 2013; Wrzesien et al., 2015) because of individuals identifying with their avatar and increasing health-related autonomy (Schultze & Leahy, 2009). As a result, the Digital Twin could be used to increased motivation relating to performing weight management behaviours.

A thread through the discussions was the importance of setting a personal goal that could be worked towards, and that the Digital Twin could be used as a goal image in presenting users with their ideal body. Participants also suggested that the Digital Twin should include a feature highlighting weight loss in real time as a motivational reward in pursuing positive behaviours. This is because many participants viewed weight loss as an independent journey and would like to be encouraged where necessary to continue pursuing this goal long-term. Furthermore, many participants suggested that they wanted to use the Digital Twin as a tool to reflect progress and to use the visual information to independently lose weight if goal setting could be incorporated as an additional feature to the application. This is supported by previous research which has suggested that apps and virtual representations should be customizable and tailored to individual needs and goals (Attig & Franke, 2020; Flaherty et al., 2019; Perski et al., 2019). This also supports the classification of self-concept proposed by Higgins's (1987), which distinguishes the ideal self (also known as a self-concept representing hopes and aspiration) and the ought self (self-concept representing duties and responsibilities) from the actual self (self-concept representing actual attributes). Therefore, individuals who have a goal of being healthy may behave in a healthy way if the goal is prompted by a virtual representation reflecting these self-concepts (Javornik et al., 2021). For example, participants perceived a representation with a lower BMI (generic Digital Twin) to be more socially desirable than a representation with a higher BMI (anthropomorphic) and therefore would use this association as a motivator in weight loss. Therefore, the prospect of a more appealing physical appearance may be a powerful motivator for behaviour change.

This was supported by participants who wanted the Digital Twin to appear "human-like" and more "representative" of the individual user. This can be related to the concept of anthropomorphism, which is the projection of human traits, such as cognitions, intentions, and behaviour onto virtual representations (Banks & Bowman, 2016). Previous research has highlighted that human-like representations are judged more favourably, and are perceived to be highly realistic (Westerman et al., 2015). This is linked to the Uncanny Valley Hypothesis (Mori et al., 2012), which indicates that there is a trend for humans to positively respond to representations that demonstrate human features. This is highlighted by Lyles et al. (2017), in suggesting that visually rich representations that accurately portray how bodies appear may have a greater impact on behaviour than can a number on a scale or BMI percentage. This was demonstrated in the results where participants with a higher found the second Digital Twin to be more representative of their body shape and preferred it because it could be used as a snapshot image in addition to being able to use the Digital Twin to see how their bodies change over time. Furthermore, this suggests that personalisation of a virtual representation is an important factor for engagement and motivating behaviour change as highlighted for participants need for the Digital Twin to resemble them as individuals and to increase identification with it. This could be achieved by manipulating the Digital Twin to reflect a user's features, such as sex, age, race, weight, and body distribution of fat.

However, many participants suggested that using the Digital Twin as a visual motivator was not enough on its own, and therefore required additional features such as cues to action (e.g., notification, targets to be achieved), feedback and social support, for long term use. Interacting with other users

and sharing information has been associated to positive experiences in increasing awareness, sharing progress and competitiveness in initiating behaviours (Dennison et al., 2013; Hosseinpour & Terlutter, 2019). However, many participants suggested that they wanted these cues to action to be personalised, which relates to the tailoring subtheme. Although many of the health apps attempt to provide personalized and tailored information, currently these apps do not have adequate input from users with their personal information to provide tailored feedback. This supports previous research as the participants did not just want generic information from the apps; they expected to obtain individualized information from the health apps (Chan et al., 2017; Conroy et al., 2019; Peng et al., 2016).

The second superordinate theme suggested that virtual representations such as the Digital Twin can also highlight the potential stereotypes relating to weight loss. For example, participants with a higher BMI said they felt there was a stigma related to weight and perceived judgment when attempting to lose weight. This is consistent with the literature in suggesting that overweight people are the targets of greater prejudice and discrimination than healthy-weight people (Johnstone & Grant, 2019). As a result, it was emphasized that many mHealth apps fail to represent a diversity of users. This was linked to the suggestions that mHealth apps are catered to users that are physically fit and from a younger generation (Chan et al., 2017). As a result, this study is beneficial in introducing new information and the benefits of applying alternative virtual representations to the literature that comparatively focuses on studies that include pro-thin images for managing health (Porrás-García et al., 2020).

In addition, participants consistently associated the second Digital Twin to obesity and suggested that this is a person who that is less likely to lead a healthy lifestyle and has bad behavioural habits (Haynes et al., 2018; Kim & Sundar, 2012). This is related to the concept known as Priming, which suggests that an individual is observing an external party, focusing on external cues, associating them with stereotypes, and being influenced by them (Peña, 2020). Therefore, the negative reactions towards the second Digital Twin could be attributed to participants of a lower BMI comparing themselves to an image with a higher BMI and applying negative interpretations when considering its effectiveness. This was particularly prevalent in both groups, whereby the concerns relating to body dysmorphia when shown the second Digital Twin was more likely to be highlighted by females than males.

This study also has unique implications regarding the application of Digital Twin as useful app for users to monitor and assess weight loss goals with realistic visuals. This supports previous literature that has highlighted perceptions of body image discrepancy, body satisfaction, and weight regulation intention related to viewing a virtual representation (Mölbart et al., 2018; Park, 2018). However, there were also adverse reactions to app and Digital Twin usage in obsessively counting calories, which could also influence body image perceptions. This is supported by previous research where participants have reported excessive food or calorie counting and being overly engaged with one's states and behaviours (Cordeiro et al., 2015; Perski et al., 2017). The negative app-generated information including feedback based on the information provided by the Digital Twin was also associated with guilty and anxiety, which supports previous research highlighting negative emotional reactions if users fall short of reaching a predetermined goal when using an application, or users feeling neurotic about their body image (König et al., 2021).

4.1. Mapping themes to theories

It was also found that many of the themes could be mapped to existing behaviour change theories. The most commonly emerging theories were the Theory of Planned Behaviour (Ajzen, 1991), the Stages of Change Model (Leventhal et al., 1980), Implementation Intentions (Gollwitzer, 1999), and the Health Belief Model (Janz & Becker, 1984). For example, participants need for personalised information and the Digital Twin to be tailored to their health requirements is related to the perceived behavioural control construct in the Theory of Planned Behaviour (Ajzen, 1991). In addition, the requirement of reminders, rewards or other means of positive reinforcement is

related to the cues to action construct in the Health Belief Model (Janz & Becker, 1984). Furthermore, Table 2 presents an overview of how some of the identified themes and sub-themes can be applied to different theoretical constructs (additional theories can potentially be mapped to identified themes). We do acknowledge that this list by no means is exhaustive, and additional theories can potentially be mapped to identified themes.

5. Limitations

This study is limited as it only provides a snapshot of the user's experiences and attitudes and non-users perceptions of and towards using the Digital Twin, when typically, users able to visit this on the app for multiple occasions over time. Most participants were recruited via social media which limits the representativeness of those potential participants to whom the study was advertised. This study did not screen for eating disorders or underlying health issues which could have influenced participant responses. However, this study was able to recruit participants with varied age ranges with different experiences relating to mobile phone and application use, resulting in different levels of knowledge of the technology in this area. It was beneficial to compare the findings from both groups to aid in the design of an intervention study that will utilize the Digital Twin and recruit non-users of the app. However, a large proportion of the sample had a normal BMI, which could have influenced participants answers, and may have had biased attitudes and perceptions towards the Digital Twin. In addition, participants were offered incentive for participating, which may have influenced participants responses to have been more positively predisposed towards the Digital Twin.

A notable disadvantage is that all participants were shown a female Digital Twin as the second image, despite the sample including males. As a result, in comparison to the users who had full access to the 3D Digital Twin, the non-users were only shown the two different 2D images of the Digital Twin, leaving their interpretations to be subjective and pragmatic (Jason & Glenwick, 2016). Thus, this presents difficulties in enabling the participants to envision how this may be applicable to an app setting in changing behaviours.

6. Future directions

Researchers should continue to investigate the various ways that virtual representations can resemble humans, whilst considering the features of the representation and individual differences that influence perceived anthropomorphism (Blut et al., 2021). However, as the Digital Twin is a unique example of both anthropomorphic and non-anthropomorphic images, future research is needed to understand how people process and interpret androgynous avatars and how this could influence behaviours.

As many of the participants highlighted the benefits of the Digital Twin in promoting lifestyle and weight management behaviours, it would also be beneficial to conduct a longer follow-up study with a larger sample size to evaluate the use of mHealth app intervention that incorporates virtual representation (Biduski et al., 2020). In addition, the added value of connecting our study results to theoretical concepts with the aim of providing theoretical guidance for researchers who intend to examine or develop mobile health and virtual representation technologies and features in addition to the development of associated interventions. This could be compared with a face-to-face weight loss program to see if the app improves engagement and adherence to treatment. Several studies have indicated that body composition changes (lower BMI levels) in obese individuals is associated with a variety of health improvements, such as glucose tolerance (Clark & Brancati, 2000), and increased quality of life (Ryan & Yockey, 2017). However, this may be difficult to implement as many applications are continually updated, and therefore it may be difficult to measure the same methods, consistently over time (Short et al., 2018).

Finally, the Digital Twin could aid in the management of chronic diseases, by improving knowledge and self-care behaviours by providing visual information about their condition. This could also be applied in preventative care by highlighting patients with potential risks about their physical health and recommend new actions that promote positive health behaviours in reducing these risks.

Table 2. Summary of identified themes and sub-themes mapped to theoretical constructs

Theme/Subthemes	Construct in Theories
Facilitators of behaviour change	
Autonomous choices	Perceived behavioural control and health beliefs (Health Belief Model; Janz & Becker, 1984); intrinsic motivation (Self Determination Theory; Deci & Ryan, 2012); Response effectiveness (Protection Motivation Theory; Rogers, 1975); Contemplation (Stages of Change; Prochaska & DiClemente, 1983); perceived behavioural control (TRA; TPB;); behavioural expectations (Social Cognitive Theory; Bandura, 1991); illness beliefs and emotional response (Self Regulatory Model; Leventhal et al., 1980)
Social influences on decision making	Descriptive and subjective norms (Theory of Reasoned Action; Theory of Planned Behaviour; Ajzen, 1991); upward comparisons (Social Comparison Theory; Goethals & Darley, 1987); social messages (Self Regulatory Model; Leventhal et al., 1980)
Personalisation and representativeness	Modelling (Social Cognitive Theory; Bandura, 1991); Tailoring (Kreuter et al., 2000; Noar et al., 2007); Maintenance (Stages of Change Model; Prochaska & DiClemente, 1983); Perceived behavioural control and compatibility (Theory of planned behaviour (Ajzen, 1991); appraisal (Self-Regulatory Model; Leventhal et al., 1980)
Monitoring progress	Cues to action (Health Belief Model; Janz & Becker, 1984); self-observation, modelling and self-efficacy (Social Cognitive Theory; Bandura, 1991); planning (Implementation Intentions; Gollwitzer, 1999); appraisal (Self-Regulatory Model; Leventhal et al., 1980)
Awareness and knowledge of health-related risks	Self-observation, self-efficacy, and upward comparisons (Social Cognitive Theory; Bandura, 1991); self-regulation (Leventhal et al., 1980; Baumeister et al., 2007); Descriptive and subjective norms (Theory of Reasoned Action; Theory of Planned Behaviour; Ajzen, 1991); social messages (Self Regulatory Model; Leventhal et al., 1980)
Barriers to behaviour change	
Perceived adverse reactions	Perceived severity and perceived probability of occurrence (Protection Motivation Theory; Rogers & Prentice-Dunn, 1997); Health Belief Model; Janz & Becker, 1984); emotional response to threat (Self Regulatory Model; Leventhal et al., 1980)
Weight management norms, lack of motivation and impact on self-esteem restricting behaviour change.	Health beliefs (Health Belief Model; Janz & Becker, 1984); self-esteem (Self-Determination Theory; Deci & Ryan, 2012); downward comparisons (Social Comparison Theory; Goethals & Darley, 1987); Continuing unhealthy behaviours (Self Affirmation Theory; Steele, 1988); attitudes towards behaviour and the Digital Twin (TRA; TPB; Ajzen, 1991); emotional response to threat and social messages (Self Regulatory Model; Leventhal et al., 1980)

7. Conclusions

Overall, the findings in this study illustrate the attitudes and perceptions towards the Digital Twin, whilst suggesting the features for behaviour change (particularly weight management) when designing an mHealth intervention which incorporates a virtual representation, a previously under-studied topic. The research revealed that personalisation, self-monitoring, rewards, goal setting and positive social comparison were considered by participants in both groups to motivate behaviour change. However, viewing a more representative Digital Twin was associated to eliciting

and facilitating behaviour change, particularly for weight-loss. The results also highlighted the stereotypical labels associated with appearance, and how this could be associated to the Digital Twin in influencing positive and negative attitudes towards its use. Overall, the Digital Twin could be beneficial in facilitating weight management, instead of standard face-to-face programs, but its use should be interpreted with caution to potential adverse effects.

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Data availability statement

The data that support the findings of this study are openly available in Github at <https://github.com/laurentaylorHP/UsersandnonusersDigitalTwin.git>

Disclosure statement

This paper presents independent research that is part of a PhD funded by Babylon Health who have created a mHealth application as a support tool for health management, however, Babylon Health were not involved in any part of the design, conducting, or writing of this paper and so the authors declare that the research was conducted in the absence of any potential conflict of interest.

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