How might avatar appearance influence health-related outcomes? A systematic review and narrative meta-review

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Abstract

Research has suggested that positive health behaviour change may be achieved using representations of the self in virtual environments (avatars) to alter self-perception, and model behaviours. This systematic review aimed to assess studies exploring the role that avatar appearance plays in influencing health-related outcomes.

Journal databases, authored books and websites, and grey literature sources were searched for experimental studies in which avatar appearance was used to manipulate physical health-related outcomes in healthy populations. A total of 16 articles (17 studies, 39 effect sizes) addressing primary (e.g. exercise, diet, and smoking), and secondary (e.g. body satisfaction) health related attitudes and behaviours were included.

Eight studies reported significant main effects of avatar manipulation, which included avatar body type (varied by adiposity or muscularity), and Self Discrepancy Theory-based (SDT; e.g. actual, ideal, ought selves) customisation.

The review indicates a dearth of research on avatar appearance and health-related outcomes. The assignment of avatars with varying body types appeared to consistently affect immediate physical activity during exercise game play. The assignment of ‘obese’ avatars appeared to reduce positive behavioural outcomes; however the absence of control conditions make it unclear whether performance was improved in the ‘thinner’ condition, or reduced in the ‘obese’ condition. Results from this review indicate a need for a grounded, theory-driven approach to future avatar appearance-based studies.

Keywords: Avatars; health; computer game-play; systematic review

Introduction

Videogames that aim to promote positive attitudes and behaviours are called *serious games* (Orji et al., 2013), and are often applied to health settings. For example, exercise (Matallaoui et al., 2017), distribution of medical information (Behm-Morawitz et al., 2016), and health-related negotiation and decision making training (Christensen et al., 2013) may all be gamified to some extent using videogames (McCallum, 2012). Invariably, serious videogames require a virtual environment for users to navigate, and therefore require a form of representation, or avatar, in this environment. Avatars have been succinctly defined by Nowak and Fox (2018) as follows:

an avatar is a digital representation of a human user that facilitates interaction with other users, entities, or the environment [p34].

An avatar is therefore distinct from *agents* which are controlled by a computer, and *Doppelgangers* which resemble a user, but do not facilitate interaction (Ahn et al., 2014). The mere appearance of an avatar alone has been shown to elicit behaviour change in virtual environments. For example, Yee et al. (2009) found that people controlling an “unattractive” avatar in a virtual environment disclosed less personal information, and maintained a larger interpersonal distance than those controlling an attractive avatar; this phenomenon is named the *Proteus Effect*. If physical appearance during a videogame (or other digitally-mediated experiences) can alter attitudes and behaviours, then it has been suggested that digital self representation may have the potential to improve health-related outcomes. The current study aimed to review the literature on the impact of avatar appearance on health-related outcomes.

Existing Reviews

Two narrative review chapters (Ahn & Fox, 2017a , 2017b), and two systematic reviews (Horne et al., 2019; Rheu et al., 2019) describe the literature on health and avatars. The narrative reviews offer interesting insights into the possible uses of avatars and agents (computer-controlled characters) in healthcare, and suggest that there are two unique affordances that avatars and agents have over traditional communication methods: interactivity (allowing users to have agency over the media content); and time acceleration (e.g. showing immediate weight loss and weight gain in response to health-related behaviours). However,

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it is notable that none of the studies reviewed are related to avatars by the recent standard definition (Nowak & Fox, 2018); and are better described as doppelgangers (i.e. object representations, rather than subject representations).

Horne et al. (2019) specifically addressed the use of avatars in a weight management context, and identified six studies that used avatar-based interventions. They conclude that avatars may have the potential to improve weight loss, but naturally more studies are needed to judge clinical efficacy [named the Oliver Twist argument by Valentine et al. (2010)]. Missing from this review is a discussion of the mechanisms behind avatar use, with avatars seemingly regarded as mere alternative mediators for more traditional interventions (e.g. education, motivational interviewing). However the attempts made to assess the quality of evidence using an established tool were beneficial (Sirriyeh et al., n.d.). The avatar studies reviewed in the Horne et al. (2019) article were arguably closer to efficacy studies for digitally-mediated interventions than studies investigating the unique contribution of avatars to health persuasion. Two studies created tailored or personalised avatars for participants, however one of these would not count as an avatar under the definition from Nowak and Fox (2018), since the model was a time-accelerated image of the participant under different weight conditions based on their current intake; this is more akin to appearance-related interventions such as facial morphing (e.g. Persson, Grogan, et al., 2018; Grogan et al., 2011).

Rheu et al. (2019) systematically reviewed health-related interventions using avatars, identifying 18 studies in which avatars were applied to health-related behaviours. The authors summarise the field, and highlight six characteristics that may be manipulated in avatar-based interventions, concluding that using an avatar that is physically active, fit, and similar looking to the participant is effective at promoting health-related behaviours. They also address potential risk of bias, using (an uncited version of) the Cochrane Tool for Assessing Risk of Bias (Higgins et al., 2011). The review by Rheu et al. (2019) is concise, wide in scope, and provides some interesting insights. However, we argue that the current the review uses more robust methodology, is more focused in its aims, covers a broader range of outcomes, and considers the effect sizes and confidence intervals generated by the studies.

There are also some potential shortcomings in the Rheu et al. (2019) paper. Their definition of an avatar included doppelgangers, which is perhaps too broad. Moreover, their definition of health behaviour was limited to diet and exercise, which in turn was perhaps too narrow. Further, the authors conflate the two key theories of digital behaviour change, the Proteus Effect (Yee et al., 2009) and Virtual Self Modelling (Fox & Bailenson, 2009); these have very different theoretical roots and implications.

Neither systematic review considered effect size, with the weight of evidence being determined by significant p -values. This is problematic for a variety of reasons. P values may be artificially inflated at low sample sizes, and when sample sizes are overly large, negligible effects may be observed as significant. Moreover, the effects of interest in some studies may not have been tested using significance testing. For instance, a 2X2 factorial design including avatar appearance and gaming task as factors may only be presented as a single significant F value, but actually contains two treatments (avatar and task), one of

which might have a small effect size, and the other a large effect size, meaning that the confidence in the effect of avatars is inflated, when it is in fact the task that is driving the difference.

Current Review

A pre-registered, transparent approach was adopted, and we followed preferred reporting guidelines (PRISMA, Moher et al., 2015). We also consulted a wider range of sources than Rheu et al. (2019) and Horne et al. (2019), including grey literature searches by contacting authors and searching thesis repositories. We queried more academic databases, ran hereditary and ancestry searches, and used a continuous searching method to identify papers that were published after the initial searches were conducted.

Since visual avatars are very common, and as such their appearance is the most salient feature, this review specifically addresses avatar appearance. The definition of health-related behaviours is wider, including smoking, UV protection, and safe sexual practices as outcomes in the literature search. A wider outcome net allows inferences to be made about heterogeneity of effects across dependent variables, and the generalisability of the approach. Since body satisfaction and health-related behaviours are broadly related (Grogan, 2017), and research suggests that exposure to idealised media may have negative consequences in some circumstances (e.g. Wasilenko et al., 2007), body image was included as a secondary outcome in the current review.

Finally, we base our conclusions on effect size estimates and confidence intervals and deconstruct factorial designs to isolate the contribution of avatar appearance on health outcomes.

Objectives

There were three main objectives of this review:

1. To determine the efficacy of avatar-appearance in improving health-related behaviour outcomes including direct observable behaviours, and direct (e.g. intentions), and indirect (e.g. related to body dissatisfaction) self reported measures.
2. To address the quality of the methodology within the studies using existing tools (e.g. the Cochrane tool for assessing bias, Statcheck, etc).
3. To use meta-analytical techniques to estimate the overall effect size for avatar health-related persuasion.

Method

The guidelines from the PRISMA statement were adhered to in the undertaking of this systematic review (Moher et al., 2015). The following is an abbreviated method section¹.

¹Full details can be found in the digital appendix <https://osf.io/k7jrn/>.

Search strategy

The studies for this review were located using electronic database searches of Medline, PsyArticles, PsychInfo, Pubmed, Web of Science, and Web of Knowledge. Unpublished papers were sought using the electronic thesis repository Proquest, and by contacting prominent authors in the field. The search strategy was developed with the assistance of an academic librarian and the terms included *avatar, digital self, videogame, virtual reality, health, exercise, behaviour, change, attitude, or intention*². Searches were not restricted to English journals, although only languages that could be translated using Google Translate were considered. Reference lists, chapters, and author websites were also consulted.

Continuous Searching

Alerts were set for NCBI and Scopus. An email was received by the author whenever a study meeting the criteria of the search terms was released. Each paper was checked using the same three point method as described below (title, abstract, full text screening).

Eligibility Criteria

Types of Studies.

All quantitative studies looking at effects of avatar appearance on health-related outcomes, using either comparative or within-group methods were considered. This included conference papers, peer-reviewed articles, and unpublished dissertations.

Types of participants.

Only studies investigating non-clinical populations were eligible for inclusion. Studies on children and adults were included.

Types of intervention.

Only studies manipulating some element of avatar appearance were included in the review. Participants also had to have some control over the avatar. As such, studies in which the only manipulation was customisation (e.g. Waddell et al., 2015), and those that used avatars but did not manipulate the appearance between (or within) conditions (e.g. Morgan et al., 2014) were excluded. Manipulations included variation induced through instructions given to participants during customisation, and studies in which different avatars were assigned to a participant. When reviewing studies for inclusion, the definition of ‘avatar’ was identified as a major source of variation. The research question was consulted again, and the research team decided to define an avatar as a representation of the self in a virtual environment. Excluded from this definition were studies on virtual self modelling, which rely on the participant seeing the model as different from themselves, or as a ‘doppelgänger’. In these studies, participants typically observe the model, and have no control or influence over it. This was fundamentally different from the majority of studies selected for inclusion. VSM studies may warrant a separate systematic review. Similarly, virtual pet studies were

²Full search terms with boolean operators may be found in the appendix.

also excluded on a similar basis, in that the avatar was not intended to represent the participant, but to act as a model that reflected their behavioural decisions such as eating breakfast (Ahn et al., 2015).

Types of outcome measures.

Primary outcome measures included behaviours such as exercise and dieting, and observed and self reported changes in health-related attitudes, beliefs, and intentions. Secondary outcome measures pertaining to body image and body dissatisfaction were also of interest.

Study selection

Studies from all sources were aggregated into a master RIS (Research Information Systems) file and screened for title and abstract using Rayyan (Elmagarmid et al., 2014; Khabsa et al., 2015). Initial screening was conducted by the author. The second and third authors blind-reviewed 10% of the judgements made by the author. Conflicts were discussed at research meetings and were attributed to misunderstandings of the operational definitions, and were subsequently resolved. The studies that were included after initial screening were subjected to full-text screening. Eligibility of ambiguous papers was discussed and resolved at research meetings.

Data Extraction

Data were extracted following the method of a previous literature review (Freijy & Kothe, 2013), and involved extracting the country, health outcome, sample characteristics, comparison group manipulations and relevant results. Inferential statistics for the relevant results were also extracted. Unless otherwise justified in a pre-registration, the highest acceptable error rate to represent a meaningful effect for this review was 0.05, and so any studies reporting ‘marginal’, or ‘trends towards significance’ were interpreted as not significant. In addition to p-values, Cohen’s D Effect sizes and variances were calculated, either from reported means and standard deviations (where available), or through transformation using degrees of freedom and F statistics using the `fes()` function from the `compute.es` package in R (Del Re, 2013). Where factorial designs were adopted, marginal effect sizes isolating the avatar appearance-related treatment were calculated by hand (formulae can be found in the supplemental data). “No avatar” or “no play” control conditions were excluded as effects sizes [8,9], as were cases in which the task varied but not the avatar. For example, in study [10], participants either had a customised or assigned avatar during a jogging game, or a customised avatar during a bowling game. The latter was excluded. Since these designs were not anticipated, the decision to exclude individual effects was made during the review process. The process for this can be found in the supplementary materials. In four cases [0,8,9,12], means and standard deviations were obtained from information provided from corresponding authors.

Assessment of Risk of Bias

Risk of bias was assessed using the Cochrane Collaboration tool (Higgins et al., 2011). Each study was assessed for selection bias (randomised assignment of participants, and concealment of allocation from personnel), performance bias (blinding participants to the intervention), detection bias (blinding of assessors and other personnel, attrition bias (loss of participants), and reporting bias (selective reporting of outcomes). One study [0] was conducted by the research team, and so this study was reviewed for risk of bias by a third party. In Figure 4, effect sizes were categorised by risk of bias by coding each + in Table 7 as coded as 1, each . as 0, and each – as –1 and then summing the codes. Any study that scored below 0 was categorised as unknown, with positive and negative scores indicating high and low bias respectively.

Data Synthesis

Due to the small number of studies, and degree of heterogeneity in outcomes and methods, a full meta-analysis is not appropriate for making inferences about the literature. Although a fair number of effect sizes is presented (39), these are firstly not independent and should not be synthesised outside of a multi-level model (this is not being conducted due to sample size and heterogeneity); secondly an aggregated effect size of intentions, attitudes, beliefs, body satisfaction, and behaviour is less a case of comparing apples and oranges, with the amount of heterogeneity between studies making such an evaluation more akin to comparing the individual items of a high-end pre-packaged fruit salad. As can be seen in Figures ?? and 3, once this fair number has been divided into similar categories, there are very few effects per cell. Instead of the planned multi-level meta-regression that was pre-registered, a qualitative, narrative approach to the synthesis of the data was adopted in which effect sizes and confidence intervals of similar studies are be presented together, and the variation in these are discussed in terms of risk of bias (Valentine et al., 2010). Random effect estimates will be presented for the subgroups using the `rma()` function from the `metafor` package (Viechtbauer, 2010), since despite the small number of studies, this information may still be useful (Valentine et al., 2010), however these must not be interpreted as meta-analytic effect size since the effects from which they are calculated are not independent. Multiple effect sizes are presented from each study, meaning that the effect sizes will be correlated within studies, and the aggregated estimate will be a vastly inaccurate estimate of the population effect.

Results

Searches yielded 17 studies from 16 articles to be included in the review. Figure 1 presents the PRISMA flow diagram for study selection³. In the results and discussion below, the included studies are referenced using the identification codes from Table 2 in square parentheses.

³Full details about the yields from each source can be found in the supplemental materials.

Figure 1*Prisma Flow chart*

Study Categorisation

The clearest difference in studies was whether participants customised, or were assigned an avatar. The majority of studies had an assigned avatar condition [N = 11], although some studies also included customisation as a factor in the design matrix [1,5]. A second factor was the type of manipulation employed, of which there were four:

1. Ideal: Participants were assigned, or customised and avatar that reflected either their Ideal, Actual, or Ought selves, in line with the self models and concepts from Self-Discrepancy Theory (Higgins, 1987)
2. Idealised: Participants were assigned an avatar that reflected idealised media norms such as muscularity or extreme thinness.
3. Obese: Participants were assigned to either “slim” or “obese” avatar conditions.
4. Self: Participants were assigned an avatar that resembled themselves, or a stranger.

Although this categorisation was not pre-registered, effect sizes will be clustered by these distinctive designs for ease of interpretation.

Study Characteristics

Table 2 provides the study characteristics and identification numbers for the dataset. All but one of the studies were peer reviewed journal articles published in a range of journals including: 10 from human computer interaction journals [1,5,7,8,9,11,12,14,15,16]; four from psychology [2,4,6,12]; one from a health and environment journal [10]; and one from a games and health journal [3]. One study had previously contributed towards a doctoral thesis [5], and one study was unpublished at the time of the review [0].

Primary target health-related behaviours included smoking [13], exercise/physical activity [0,3,4,7,10,11,12], diet [2,3,6,13,16], “maintaining a general healthy lifestyle” [5], and Human Papillomavirus vaccination [1].

Regarding the populations that were sampled from, one study was conducted only with overweight children from Singapore [7], and one study was conducted only with overweight Spanish women [10]. The remainder of the studies were sampled mostly from undergraduate populations, with four studies selecting only males [1,9,12,15], and three selecting only females [8,10,12]. No studies reported sample size calculations based on statistical power analysis, although one reported an *a posteriori* power analysis [2].

Table 1

ID	Reference, country, and study design	Health-related outcome	
0	Clark et al (2019); UK; Randomised Trial	Physical activity	N = 54
1	Darville et al (2018) USA Randomised trial	HPV vaccination	N = 16
2	Jin (2012) USA Randomised trial	Diet	N = 15
3	Joo and Kim (2017) Korea Randomised trial	Exercise and eating	N = 12
4	Kastenmüller et al (2013) UK	Physical activity	N = 42
5	Kim and Sundar (2012) USA Randomised Trial	Healthy Lifestyle	N = 95
6	Kuo et al (2016) Taiwan Randomised Trial	Diet	N = 76
7	Li et al (2013) Singapore Factorial Randomised trial	Exercise	N = 14
8	Matthews et al (2016a) USA Randomised trial	Body satisfaction	N = 14
9	Matthews et al (2016b) USA Randomised trial	Body satisfaction	N = 19
10	Navarro et al (2020) Spain Randomised Trial	Physical Activity Self efficacy Anxiety	N = 42
11	Peña and Kim (2014) USA Randomised trial	Exercise	N = 96
12	Peña et al (2016) USA Randomised trial	Exercise	N = 96
13	Sah et al (2016) USA Randomised trial	Eating	N = 13
14	Song et al (2013) USA Randomised trial	Smoking	N = 62
15	Sylvia et al (2014) USA Randomised trial	Body satisfaction	N = 51
16	Velhurst et al (2018) Japan Randomised trial	Health food shopping	N = 23
17	Waddell et al (2015) USA Randomised trial	Exercise and nutrition	N = 13

Table 2

Summary of study characteristics

ID	Reference, country, and study design	Health-related outcome	Sample	Comparison group manipulations	Relevant results
0	Clark et al (2019) UK Randomised trial	Exercise	N = 51 Full time students between the ages of 18 and 40	Participants played a bespoke running exergame either as a 3D humanoid larger or an athletic bodied avatar. They controlled the avatar by running on the spot.	No main effect of avatar type on time taken to complete the track.
1	Darville et al (2018) USA Randomised trial	HPV vaccination	N = 168 (108 completed) Full time students between 18-26 years	Participants either selected or created an idea or actual self-avatar and played a serious game (Vax!) in which they had to stop the spread of a disease using vaccinations. Avatars were 2D images that remained on screen throughout the game.	No main effect of avatar type for perception of risk of HPV. No main effects of avatar condition for self efficacy. No main effect of avatar type on behavioural intentions. Intervention itself was effective.
2	Jin (2012) USA Randomised trial	Diet	N = 156 Undergraduate students (103 women, 53 men), mean age 19.89 (SD 1.12)	Participants created a Nintendo Mii to represent their actual or ideal self, and played a Wii Fit exercise game (ski slalom, running and Hula-hoop).	No main effect of avatar appearance on low calorie dieting intentions.
3	Joo and Kim (2017) Korea Randomised trial	Exercise and eating	N = 124 Undergraduate students, Males = 45, females = 79, aged 20-29 years	Participants played 'The Sims' with either an Obese or a "normal" avatar.	No main effect of avatar body shape on number of steps taken on a stepper. No main effect for avatar body shape on number of high sugar cookies consumed.
4	Kastenmüller et al (2013) UK Randomised trial	Physical activity	N = 42 (41 included) Students, 17 women, 24 men, Mean age 20.88, SD 2.05.	Participants played a Nintendo Wii jogging game using either a generic avatar, or one that they had created to resemble themselves. A control group played the Wii bowling game with the generic character. They provided self report responses for exhaustion, motivation to exercise, and perceived similarity with the avatar. Participants returned to the laboratory a week later to complete a follow-up survey about their physical activity levels over the week.	No difference between avatar conditions for running exhaustion. Participants who jogged with their own character reported higher motivation to perform physical activity than those in the generic running or bowling conditions. Participants who jogged with their own character performed more exercise the following week than those who jogged or bowled with a generic character.
5	Kim and Sundar (2012) USA Randomised Trial	Healthy Lifestyle	N = 95 Undergraduate students (69 women, 26 men), aged 18-34 years	Participants either created an avatar to resemble their desired or actual self; or were assigned an attractive or unattractive avatar. They used the avatar in a virtual Centre for Disease Control in second life and interacted with an agent that explained the mission of the CDC, and demonstrated posters that included information about sleep disorders OR obesity.	Participants who created actual avatars had a higher 'general perceived risk to the physical body' than those who created desired avatars. Participants who customised their avatars said they would devote more time to maintaining good health than assigned avatars. People who customised their avatars selected a higher number of unhealthy product coupons than those who were assigned avatars.
6	Kuo et al (2016) Taiwan Randomised Trial	Diet	N = 76 Undergraduate students Females = 48, males = 28 Mean age = 21.2	Participants were immersed in a 3D virtual environment and presented with a fitting room. They were instructed to look in a virtual mirror and saw either their actual self or a weight reduced version. The ideal-weight self was tailored to the participants self-reported ideal size. They completed measures on temporal discounting and various filler measures before being asked to complete an ice-cream taste test and indicate the amount of sugar they would like in a reward Bubble Tea drink.	Participants in the weight-reduced self condition ate less ice-cream during the taste test (once the last meal was controlled for) than those in the current self condition. Participants in the weight reduced condition chose smaller amounts of sugar for the reward drink than those in the current-self condition. Participants in the weight reduced self condition were more likely to choose a sugar free version of the drink than those in the current self condition.

7	Li et al (2013) Singapore Factorial Randomised trial	Exercise	N = 140 Overweight students aged 9-12 years	Participants played a Wii exercise game with an avatar. Avatar had large or "normal" body size Stereotype threat induction or not	Main effects of avatar body size. Those embodying larger avatars had lower exercise attitudes, exercise motivation, exergame motivation, and game performance.
8	Matthews et al (2016a) USA Randomised trial	Body satisfaction	N = 149 Female undergraduate students aged 18-24 years.	Participants played video games either as an ideal (Beyond Good and Evil, Beijing Olympics 2008), or a hyper-ideal avatar (Mortal Kombat, Dead or Alive Beach Volleyball). There was a no-game control condition.	No difference in sexual Attractiveness, Higher (more favourable) scores on weight concern in hyper idealised condition than idealised condition; No difference Physical Condition; No difference in Body Discrepancy; No difference in Contour Bust Size Scale; Lower scores on Body Dissatisfaction sub-scale for participants in hyper idealised condition.
9	Matthews et al (2016b) USA Randomised trial	Body satisfaction	N = 197 Male undergraduate students, aged 18-30	Participants played video games either as an ideal (Alan Wake, Fight Night), or a hyper-ideal (UFC Undisputed, Street Fighter 4) avatar. There was also a no-game control condition.	No differences in physical attractiveness, No differences in upper body strength, No main effect on physical condition, No main effect on body discrepancy, No main effect on muscle Discrepancy, No main effect on positive attitudes towards muscularity.
10	Navarro et al (2020). Spain, Randomised Trial	Physical Activity, Self efficacy, Anxiety, Motivation	N = 42, Overweight women with body dissatisfaction, aged 19-61	Participants played a bespoke running game with Microsoft Kinect either as an avatar designed to represent their actual self, their ideal self, or with no avatar. Participants were given a recording of their performance that could be rewatched on their phone. They also participated in an online goal setting intervention.	No Main Effects of Avatar reported, only interactions with time point. Physical Activity the previous week: No interaction between time and avatar condition. Goal Choice: No difference in type of goal chosen (walking vs running) between conditions. Motivation: No significant interactions between time and avatar condition on any measure of motivation. Anxiety: Significant interaction between time and condition. Participants in IAC and NAC showed lower anxiety levels during PA after the intervention. Self-Efficacy : No significant interaction between time and condition.
11	Peña and Kim (2014) USA Randomised trial	Exercise	N = 96 Female undergraduate students, aged 19-25 years	Participants played a Virtua-Tennis game on the Wii. Avatar had "normal" or "obese" body.	Main effect of avatar body size. Women in normal body condition made more wrist movements than those in the obese condition. No effect on wrist movement.
12	Peña et al (2016) USA Randomised trial	Exercise	N = 96 Male undergraduates, aged 18-32 years	Participants played a Virtua-Tennis game on the Wii. Avatar had "normal" or "obese" body.	Main effect of avatar body size. Men in normal body condition made more wrist movements than those in the obese avatar condition. No effect of waist movement.
13	Sah et al (2016) USA Randomised trial	Eating	N = 133 Female undergraduate students Mean age 20.26 (SD = 1.34)	Participants created either an actual, ideal, or ought self in the bespoke virtual environment YooNot. They selected food items for the avatar in YooNot and made the avatar perform in-game exercise activities such as dancing and jumping traffic cones.	No difference between the actual and ideal group in the number of healthy food items selected by participants after the game. Fewer items selected by participants in the ought than the actual avatar condition.
14	Song et al (2013) USA Randomised trial	Smoking	N = 62 Undergraduate students, 38 males, 24 females, mean age 22.05 (SD 3.28)	Participants played a social smoking related serious videogame with an avatar that had their photo as a face, or another person photograph as a face. The face either had age related artefacts or not in the second level.	Multivariate differences between future face and not future face conditions, but not self and other avatar condition. No difference between future face groups on perceived risk, but sub group analysis showed there was a difference in the self-avatar condition; Participants in the future face group had stronger attitudes against social smoking than those in the no-future face group; participants in the future face group had stronger intentions to quit smoking. Participants in self condition reported stronger perceived susceptibility to smoking than those in the other condition. No differences between self and other avatars on any dependent variable.

15	Sylvia et al (2014) USA Randomised trial	Body satisfaction	N = 51 Male undergraduates, aged 18-24	Participants played Skyrim for 45 minutes. Avatar had either normal or muscular physique.	Differences in body satisfaction between hyper muscular and normal group. No differences in perceptions of muscularity.
16	Velhurst et al (2018) Japan Randomised trial	Health food shop- ping	N = 23 Students (21 male, two fe- male), mean age 22.5, SD = 0.71.	Participants performed a food shopping task in an immersive virtual environment using either an obese avatar or a "normal" avatar.	Participants in the obese conditions bought nei- ther more healthy products nor less unhealthy products than those in the "normal" condition. Participants in the obese condition neither per- ceived unhealthy items as healthier than those in the 'normal condition'.

Reliability and Validity

For self-report measures, all but two studies [6,16] reported a measure of internal consistency (Cronbach's alpha, α). No study provided a justification for selecting α rather than other measures of internal consistency (e.g. Omega, ω). Internal reliability of measurement ranged from 0.7 to 0.94. Only one study discussed the validity of its measures [10]. In some cases, standardised measures were used, and such information could, in principle, be acquired by following references. Table 4 provides details of the validity and reliability measures discussed in the papers.

Table 3

Health-related outcome	ID	Behaviour	Attitude	Intention	Manipulation	Michie Tax
Physical activity	0	NS	.	.	OB	NA
HPV vaccination	1	.	NS	NS	SDT	13.1
Diet	2	.	.	NS	SDT	13.1
Exercise and eating	3	NS	.	.	OB	6.1; 6.2
Physical activity	4	+	+	.	CUST	6.2
Healthy Lifestyle	5	.	+	$\pm$	SDT	13.1
Diet	6	+	.	-	ID	13.1; 16.3
Exercise	7	+	+	+	OB	6.2; 13.5
Body satisfaction	8	.	$\pm$	.	ID	6.2
Body satisfaction	9	.	NS	.	ID	6.2
Physical Activity Self efficacy Anxiety	10	NS	NA	NS	SDT	NA
Exercise	11	+	.	.	OB	6.2; 13.5
Exercise	12	+	.	.	OB	6.2; 13.5
Eating	13	-	.	.	SDT	13.1
Smoking	14	.	+	+	SELF	16.3; 9.3
Body satisfaction	15	.	-	.	ID	6.2
Health food shopping	16	NS	NS	.	OB	13.5
Exercise and nutrition	17	NS	.	NS	SOT	NA

Table 4

Summary of validity and reliability of measures

Reference	ID	Measure	Reliability	Validity
Clark et al (2019)	0	NA	NA	NA
Darville et al (2018)	1	Adapted measures from previous HPV research.	Self Efficacy: $\alpha = 0.812$ Intention: $\alpha = 0.836$ Perceived Risk: $\alpha = 0.910$	Validity of behavioural intentions in predicting behaviour mentioned. Validity of measurement not discussed.
Jin (2012)	2	Novel measure: Development not described (Unsure if they used Ajzen's framework)	Low calorie dieting intention: $\alpha = 0.8$	NA
Joo and Kim (2017)	3	Behaviour	NA	Validity not discussed
Kastenmüller et al	4	Novel and adapted measures	Similarity with avatar ($\alpha = 0.96$) Exhaustion (One item) Physical activity motivations [attitudes towards running] ($\alpha = 0.73$) Physical Activity Questionnaire (NR)	Validity not discussed
Kim and Sundar (2012)	5	Novel measures and borrowed items	perceived Risk: $\alpha = 0.93$ Attitudes towards social smoking: $\alpha = .83$ Perceived susceptibility: $\alpha = .78$ Perceived Risk to Physical Appearance: $\alpha = 0.8$ Perceived Risk of general physical body: $\alpha = 0.7$ Self perseveration: NR	Validity not discussed
Kuo et al (2016)	6	Observed quantity of ice-cream eaten and intended quantity of sugar consumed in the future.	No reliability reported.	Validity not discussed
Li et al (2013)	7	Novel measures	Exercise Attitude: $\alpha = 0.84$ Exercise Motivation: $\alpha = 0.9$ Exergame Motivation: $\alpha = 0.91$	Validity not discussed
Matthews et al (2016a)	8	Standardised and novel measures	Body Esteem Scale: SA $\alpha = .86$; WC $\alpha = .92$; PC $\alpha = .89$ Body Discrepancy: NR Contour Bust: NR Eating Disorder Inventory: BD $\alpha = .85$	Validity not discussed
Matthews et al (2016b)	9	Standardised and novel measures	Body Esteem Scale: PA $\alpha = .87$; UBS $\alpha = .91$; PC $\alpha = .87$ Swansea Muscularity Attitudes Questionnaire: PAM, $\alpha = 0.93$	Not clear whether accelerometer is a valid measure of exergame movement.
Peña and Kim (2014)	10	NA	NA	Validity of behavioural measure not discussed.
Peña et al (2016)	11	NA	NA	Validity of behavioural measure not discussed.
Sah et al (2016)	12	Novel measure	Health consciousness: $\alpha = 0.76$	Validity not discussed
Song et al (2013)	13	One modified measure, two novel measures	Perceived Risk: $\alpha = 0.93$ Attitudes towards social smoking: $\alpha = .83$ Perceived susceptibility: $\alpha = .78$	Validity not discussed
Sylvia et al (2014)	14	Standardised and modified measures	Swansea-Muscularity Scale: $\alpha = .916$ Body Esteem Scale: $\alpha = .955$	Standardised methods used - validity not discussed.

Velhurst et al (2018)	15	Translated 'inspired' by peer reviewed research	NR	Validity of measures not discussed
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Experimental Paradigms

Although there was a visual appearance element to the avatar manipulations in all of the studies, the task, type of variation, and type of avatar varied considerably both between and within studies. A between subject design was employed in studies where avatars varied by body size [0,3,6,7,11,12,16], and muscularity [8,9,15]. Within subject factors were employed in two studies in which change in outcomes over time was of interest [1,10], but avatar treatments were always between subject factors.

In general, the studies in which participants customised their avatars were more complex, with both assignment and customisation being used as manipulations in some cases [e.g. 1, 5], and only customisation used in others [e.g. 10]. Moreover, the customisation paradigms were far more varied between studies. There were 10 separate manipulations, including different combinations of the self-models and self concepts described by Self-Discrepancy Theory (Higgins, 1987). These were used as instructions during avatar customisation (e.g. “create an avatar that reflects your ideal self”). Participants were instructed to create an avatar that reflected their actual, ideal, or ought selves in one study [13], and actual or ideal selves in four studies [1,2,5,10]. For the purposes of synthesis, these have all been categorised as ‘ideal self’ paradigms. .

Evidence for effectiveness

Figures 2 and 3 provide forest plots of the effect sizes calculated and confidence intervals from the results sections of the papers⁴. Figure ?? presents the effect sizes and confidence intervals for assigned and customised avatar studies separately, whereas Figure 3 presents each outcome (Behaviour, Intentions, Attitudes) separately, and categorised by treatment. Regarding statistical significance, seven of the assigned and two of the customised avatar effect size confidence intervals did not include zero.

The majority of studies [$N = 13$] reported direct effects (rather than/in addition to interactions) of avatar appearance on health related attitudes and behaviours, with eight reporting positive changes (an increase in health related attitudes, beliefs, intentions or behaviours) [4,5,6,7,11,12,13,14], and five reporting negative effects [6,8,14,15]. For manipulations involving obese avatars (i.e. an assumed ‘non-ideal’, or ‘feared’ self avatar), performance during an exergame was reduced in three studies [7,11,12], whereas manipulations involving idealised avatars (i.e. an assumed ideal avatar) sometimes reduced positive attitudes towards the self [15]. Studies reporting negative effects were predominantly those manipulating avatar body type, with participants using larger (‘obese’) bodied avatars reporting lower self-report outcomes or demonstrating a lower performance (conflated with physical activity) in game compared with those in the smaller (“normal”) body type conditions. However, it is important to note that none of the studies reporting negative effects had an adequate control condition. Only one study [7] measured attitudes, intentions, and behaviours.

⁴Note that the effect size for study [13] was taken from a meta-analysis published by one of the original paper’s authors, we were unable to reproduce this effect size

Table 5

Summary of effects. ID = participants were presented with normative ideal avatars; SDT = participants were primed with Self Discrepancy Theory self-concepts when designing their avatars; OB = participants were assigned either an 'average' or 'obese' avatar; SELF = participants were presented with either a self resembling or a stranger-resembling avatar; CUST = participants customised their avatar.

Health-related outcome	ID	Behaviour	Attitude	Intention	Manipulation	Michie Taxonomy Code
Physical activity	0	NS	.	.	OB	NA
HPV vaccination	1	.	NS	NS	SDT	13.1
Diet	2	.	.	NS	SDT	13.1
Exercise and eating	3	NS	.	.	OB	6.1; 6.2
Physical activity	4	+	+	.	CUST	6.2
Healthy Lifestyle	5	.	+	±	SDT	13.1
Diet	6	+	.	-	ID	13.1; 16.3
Exercise	7	+	+	+	OB	6.2; 13.5
Body satisfaction	8	.	±	.	ID	6.2
Body satisfaction	9	.	NS	.	ID	6.2
Physical Activity Self efficacy Anxiety	10	NS	NA	NS	SDT	NA
Exercise	11	+	.	.	OB	6.2; 13.5
Exercise	12	+	.	.	OB	6.2; 13.5
Eating	13	-	.	.	SDT	13.1
Smoking	14	.	+	+	SELF	16.3; 9.3
Body satisfaction	15	.	-	.	ID	6.2
Health food shopping	16	NS	NS	.	OB	13.5
Exercise and nutrition	17	NS	.	NS	SOT	NA

(a) *Assigned* (b) *Customised* **Figure 2**

Forest plots of effect sizes for the effect of avatar appearance. Categorized by assignment and customisation

Behaviour.

Behavioural outcomes included both in-game and post-game measures, and were manipulated using 'Obese' avatars and subjective ideal avatars. In-game dependent variables included the number of healthy *virtual* food items selected by participants [12,16], and performance of participants in an exergame [0,7,11,12]. The aim in study [13] was for participants to practice selecting healthy food with the expectation that this carry-over into real-world food ordering; whereas in [16] there was no apparent real world application - the study merely aimed to demonstrate the Proteus Effect in food selection behaviours.

(a) *Behaviour* (b) *Intentions* (c) *Attitudes and Beliefs* **Figure 3**

Forest plots of effect sizes for the effect of avatar appearance. Categorized by manipulation: Categorized by manipulation: Ideal = ideal vs actual self activation, Customised = Customised vs assigned avatar, Obese = larger bodied vs slimmer avatar.

The degree of in-game performance was the dependent variable in four studies and was measured using accelerometers on the wrist and waist [11,12], and through exergame completion times [0,7], which were used as proxies for exertion. Some studies assessed post-play behaviours, which have different implications. Rather than directly affecting behaviours, the implication is that there is a more complex psycho-social process, such as that predicted by the Theory of Planned Behaviour (Ajzen, 1991), in which the avatar increases self efficacy or behavioural intentions, leading to a greater probability that they will perform a behaviour. Post-test outcomes included number of days a physical activity goal was met in the week between intervention and follow-up [10], the number of steps taken on a stepping machine [3], the quantity of high-sugar food consumed [3,6], and the number of healthy snacks selected by participants [12]. No studies measured long term behaviour change (i.e. > 1 week).

Effect sizes for slim versus obese avatars on behaviours were mostly positive, meaning that people with slimmer avatars exerted themselves more or made healthier food choices. There were three non-significant exceptions [0a, 3a, 12b] in which participants in the obese avatar condition were more active than those in the slim condition. Two studies demonstrated that health-related behaviours were more likely to be performed when an ideal-self avatar was presented, compared with an actual-self avatar⁵.

Intentions.

Intentions were measured using self-report methods that were either developed for the study or adapted from previous research. The development of these self-report measures was not discussed in detail, nor was a framework referenced for their development (e.g. Ajzen, 2002). Motivation to exercise was measured in study [10], and a standardised, theory driven framework was used to measure this. Two studies [5,6] attempted direct measures of behavioural intentions using either a coupon selection analogy [5] in which participants were invited to select vouchers for products or services that were either healthy or unhealthy; or through the amount of sugar to be included in a bubble tea reward drink [6]. Study [5] reports the outcome as ‘perceived risk to self’, however the items appeared to be asking participants the extent to which they intend to perform health-related and risk reducing activities (jogging, visits to a doctor, p1360), and so this was categorised as an intention measure. The development and standardisation of these methods was not discussed within the papers, and so the extent of their validity cannot be determined.

Effect sizes for avatar appearance on avatar appearance were mostly positive across all manipulations, although only four 95% confidence intervals excluded zero [5a, 5b, 6b, 7c]. However, study [5] reported that people who customised their avatars selected more unhealthy coupons than those who were assigned avatars. This effect was calculated from the scores reported in the authors thesis (Kim, 2010, p. p57).

Attitudes and Beliefs.

Attitudes and Beliefs were collapsed into one category since the outcomes are conceptualised as proportional to one another (Equation 1 Ajzen, 1991, p. p191), and few

⁵NB study [6] utilised a weight-reduction paradigm, however participants were selected based on their intention to lose weight, and so the assumption that a weight reduced avatar represents a subjective ideal is justified.

studies measured either. Attitudes were measured using a mixture of novel and standardised methods. Although study [4] reported measuring motivation to be physically active, upon inspection the measure seemed lacked face validity and appeared to actually measure attitudes towards jogging. One other study measured attitudes towards health behaviours using questions about participants opinions of exercise [7]. Study [10] included measures of Anxiety towards exercise, Demotivation, and Enjoyment of exercise. Participants' self-reported attitudes towards their bodies were measured in three studies [8,9,15], and included standardised measures such as the Swansea Muscularity Attitudes Questionnaire, Body Esteem Scale and Body Perceptions Scale. Three studies measured perceptions of risk or susceptibility [1,5,14], each of which used novel or adapted measures, and may be interpreted as a belief about the probability that an event (e.g. contracting HPV) may occur.

Overall, the effect of avatar appearance on Attitudes and Beliefs was the weakest of the three outcomes. The majority of the effects were close to zero, or included zero in the 95% confidence interval. The studies involving idealised avatars appeared to have the largest effect on attitudes, although this seemed dependent on gender, since in studies involving men, attitudes towards their body were reduced, whereas they were increased (albeit non-significantly) in women. Five effect sizes were negative [1e,1f,10b,15a,15b], suggesting that provision of some avatars may reduce positive attitudes or beliefs about health-related behaviours or the body, however the 95% confidence intervals of only two effect did not contain zero.

Use of Health Psychological Theory.

Table 5 also includes a column indicating which (if any, or the closest match) of the interventions catalogued in the Behaviour Change Technique Taxonomy (BCT) were used in each study (Michie et al., 2013)⁶. This taxonomy was the result of a review of 124 behaviour change techniques followed by several rounds of delphic discussions. These BCTs were reduced down to 93, clustered into 16 groups, each of which have an index number (e.g. 4.3 is the third BCT in cluster 4. The most common 'type' of BCT was Social Comparison (6.2), featuring in seven of the studies (although in some cases attitudes rather than behaviour were the measured outcome). This is to be expected, since avatars provide a visual stimulus for the player, and various theories predict that players will compare the avatar with themselves. Alternative approaches included 'Identifying the Self as a Role Model' (13.1, N = 4) and 'Identity Associated with Changed Behaviour' (13.5, N = 4), both of which were approached from a Self Discrepancy Theory perspective. The supplemental materials from Michie et al. (2009; "Supplemental Material for Effective Techniques in Healthy Eating and Physical Activity Interventions," 2009) also have some relevant categories. For instance, parallels may be drawn between category T9 (Model/demonstrate behaviour) [3], T19 (provide opportunities for social comparison) [0,3,7,8,9,11,12,15,16], and T21 (Identification as rolemodel/advocate).

⁶This was not included in the pre-registration, and was added after some very useful feedback from a senior colleague.

Assessment of Methodological Risk of Bias

Assessment of the risk of bias is presented in Table 7⁷. The clearest message is that not enough steps were taken to control for (or report) bias in these studies. Two very recent studies provided details about the random allocation method and blinding of study personnel [0,10]. cursory mentions were made by other studies, but in general, there was no indication that steps were taken to blind participants or researchers to assignments or manipulations. Three studies [7,8,14] indicated that participants were allocated prior to arrival, meaning that selection bias could potentially be higher. One study described the method of randomisation as being a permuted block randomisation [5], but it was unclear whether steps were taken to ensure personnel were sufficiently blinded to the allocation. Three studies (two from the same author) included an awareness check to detect participants who had guessed the purpose of the study [5,11,12]. Attrition bias was not suitably addressed, with the majority of studies having discrepancies between the reported sample size and the degrees of freedom reported with their inferential statistics - and in two cases (from the same article) [8,9], the degrees of freedom varied between outcomes within the same study. The majority of studies used self report measures, so observer bias was not applicable. Most studies reported all outcome variables, however in two, [9,11] covariates were omitted from the analysis due to the variable not being a significant predictor, and the values were not reported.

Six statistically significant effects from four studies were categorised as *unknown* risk of bias. Although this does not mean the studies are biased *per se*, replications of these effects should be conducted with adequate experimental controls. There were five effects from two studies yielding statistically significant effects in the higher risk of bias category, again this does not mean that the effects should be discarded, but care should be taken when interpreting the results, and authors are urged to implement bias reduction techniques such as blinded assignment and randomisation, awareness checks, and adequate reporting of results, or at least improve the reporting of their use in methods sections. It may be telling that none of the low risk of bias studies yielded statistically significant effects, but the length of the confidence intervals in each case offer the alternative explanation of inadequate sampling; specifying a smallest effect size of interest, testing for equivalence, and conducting *a priori* power analyses would have allowed further exploration of the nature of these null results.

⁷Justifications for these decisions are provided in the supplementary materials

Table 6

ID	Reference	Adequate sequence generation	Allocation concealment
0	Clark et al (2019); UK; Randomised Trial	+	+
1	Darville et al (2018)	?	?
2	Jin (2012)	?	?
3	Joo and Kim (2017)	?	?
4	Kastenmüller et al	?	?
5	Kim and Sundar (2012)	?	?
6	Kuo et al (2016)	?	-
7	Li et al (2013)	?	?
8	Matthews et al (2016a)	?	?
9	Matthews et al (2016b)	?	?
10	Navarro et al (2020)	+	+
11	Peña and Kim (2014)	?	?
12	Peña et al (2016)	?	?
13	Sah et al (2016)	?	?
14	Song et al (2013)	?	?
15	Sylvia et al (2014)	?	?
16	Velhurst et al (2018)	?	?
17	Waddell et al (2015)	?	?

Table 7

Summary of assessment of risk of bias

ID	Reference	Adequate generation	sequence	Allocation	conceal-	Blinding of participants	partici-	Blinding of study personnel/assessors	Incomplete outcome data addressed
0	Clark et al (2019)	+		+		+		+	+
1	Darville et al (2018)	?		?		?		?	?
2	Jin (2012)	?		?		?		?	+
3	Joo and Kim (2017)	?		?		?		?	-
4	Kastenmüller et al (2013)	?		?		-		-	+
5	Kim and Sundar (2012)	?		?		?		?	-
6	Kuo et al (2016)	?		-		+		-	+
7	Li et al (2013)	?		?		?		?	-
8	Mathews et al (2016a)	?		?		?		?	-
9	Mathews et al (2016b)	?		?		?		?	-
10	Navarro et al (2020)	+		+		+		+	-
11	Peña and Kim (2014)	?		?		+		?	-
12	Peña et al (2016)	?		?		+		?	-
13	Sah et al (2016)	?		?		?		-	?
14	Song et al (2013)	?		?		+		?	-
15	Sylvia et al (2014)	?		?		+		?	+
16	Velhurst et al (2018)	?		?		?		?	-

Figure 4

Forest plots of effect sizes for the effect of avatar appearance. Categorized by risk of bias

Sources of Heterogeneity

There was considerable variation in how the studies were run, how the avatars were chosen or created, the activities that participants performed with the avatar, and the methods used to measure the outcomes. This was evident even after studies were categorised (e.g. by manipulation: ideal, obese, etc). In nine studies, the avatars were from consumer videogames [2,3,4,7,8,9,11,12,15]; in one study the 3D virtual world, SecondLife, was used for the customisation and presentation of avatars [5]; in six studies bespoke or specialist avatar creation software and environments were used [0,1,6,10,13,14,16]. In two studies, participants' photographs were used to create the avatar [6,14].

Studies using standardised measures reported fewer significant effects of avatar appearance manipulation [$N=1$] than those using modified or bespoke measures ($N = 5$) (see Figure 5).

Further, the inclusion of covariates was inconsistent throughout, with eight studies reporting their use (two were removed for not being significant). Covariates included weekly game use, gender, BMI, body discrepancy, and body shape concern, and time since last meal. There was no mention of covariates in the hypotheses of the studies, so it is not clear whether these were *a priori* decisions.

The platform of the study was a further source of heterogeneity. The majority of studies were conducted using desktop computers or consumer consoles, but two used fully immersive virtual reality equipment [6,16]. In six of the studies, participants were playing

exergames [0,2,4,7,11,12], meaning that as they moved, the avatar moved with them. In the remaining studies, participants controlled the avatars with either a console controller or keyboard and mouse.

Figure 5

Forest plots of effect sizes for the effect of avatar appearance. Categorised by risk of bias

Discussion

The purpose of this review was to assess the evidence that avatar appearance may influence health-related attitudes and behaviours. The results from this review imply a number of potential pathways for the influence of avatars on health-related outcomes, with varying degrees of efficacy. A direct route involves manipulating the appearance of an avatar and altering the user's self-perception. This results in the adoption of behaviours or attitudes that are congruent with the stereotypical traits of the avatar. This route, named the Proteus Effect (Yee et al., 2009), was adopted in five studies [0,7,11,12,16], and *weakly* adopted in one study [3]. These studies used avatars that were designed to appear either athletic or "obese"/"overweight, with the prediction that these would lead the user to feel that they were *fitter* (or more "lazy") than they currently were. According to the Proteus Effect, this would result in a temporary increase (or reduction) in exercise exertion during an exergaming session, or selection healthier (or unhealthy) items in food selection tasks. The long term effects of this pathway are understudied in the health literature, and there is only weak evidence that there are long term effects in the general cyberpsychology literature (e.g. Yee, 2007, Pilot Study 4). Study [3] of this review could be seen as an attempt to address post-play behaviour. However, the platform used was The Sims, in which users control created characters using menu instructions, and have no direct control,

which is arguably not the *embodied* experience required by the Proteus Effect (hence, weak adoption). The effect sizes for the direct effect of avatar appearance on behaviour were the strongest and most reliable of the studies in the dataset, and as such this pathway could potentially be effective for increasing exertion *during play*, rather than motivating people to start playing, or eliciting future health-related behaviours. However, the logical conclusion is to not allow people to create or have access to avatars with larger bodies, which feeds into the wider debate about the stigmatisation of weight. Instead of continuing to demonstrate that people are slower when they think they're fat, a more fruitful course may be to explore ways in which this effect may be reduced through positive depictions of larger bodied individuals (Clark et al., n.d.; Pearl et al., 2015).

An indirect route involved allowing players to customise their avatars to represent their actual or ideal selves in game (Higgins, 1996). It is assumed by the authors of these studies that the latter offers an outlet for wish-fulfilment, and that the presentation of such an avatar may reduce the perceived discrepancy between the actual-self, and ideal-self. This ideal self may be athletic and encourage the user to engage in more healthy lifestyles (Kim & Sundar, 2012). This approach was adopted in six studies [1,2,5,6,10,13] with mixed results. The majority of ideal-self activations had positive effects and a discussion of this incongruence is presented later.

A third, more passive route is related to traditional media theory through Social Comparison Theory (Festinger, 1954). In this, the mere exposure to ideal- and hyper-idealised forms may be sufficient to induce social comparisons, and reduce a person's body satisfaction, and by association exercise intentions or behaviours (Crawford & Eklund, 1994; Hall et al., 2011; Homan et al., 2012; Wasilenko et al., 2007). By this line of reasoning, using an athletic, idealised, or hyper-idealised avatar would result in upward social comparisons, and negative feelings towards the self. However, this simple interpretation has been criticised for suggesting that audiences are passive, critically unengaged with media content, and evidence in favour is limited (Ferguson, 2013; Gill, 2012). The passive approach was adopted in three studies [8,9,15]. The predicted effects were non-significant in [8,9], and effect sizes suggest that men are affected negatively by exposure to idealised avatars, whereas women are (non-significantly) positively affected. Clearly, replications are needed to confirm this. If mere exposure to idealised avatars is sufficient to induce body dissatisfaction, then dissatisfaction ought to occur in studies involving athletic-looking opponents, such as those used in the two studies by Pena et al [11,12], and future studies investigating the benefits of athletic over fat avatars might benefit from including body esteem measures.

Implications for Wider Health Behaviour Literature

There was a notable absence of health-psychology theory in many of the studies; with most favouring social psychological (e.g. SDT or the Proteus Effect) theories applied to health. The most common health-psychology theory to be cited was the Theory of Planned Behaviour (Ajzen, 1991), and this was mostly for the behavioural intention construct [1,2,4,5,6,7,14], although attitudes and beliefs also featured. Other constructs within the Theory of Planned Behaviour, such as perceived social norms, and perceived behavioural control were absent and would have been useful inclusions. One study [1] used elements

of both the Health Belief Model (Becker, 1974) and the Theory of Planned Behaviour to make predictions, and used self-efficacy (Bandura, 2001), a broad analogue for perceived behavioural control in the Theory of Planned Behaviour. No studies reported using the recommended methods for designing TPB-based tools, e.g. (Ajzen, 2002).

Although none of the studies in this review can strictly be regarded as interventions, they may be approximately positioned within the wider taxonomy of health-related behaviour interventions (Michie et al., 2009, 2013). Michie et al's *Identity associated with changed behavior* was the closest to the Proteus Effect, although this would actually predict the reverse: *Behaviour associated with changed identity*. This could represent a distinct category that could be added to a future version of the taxonomy. Only one study utilised avatars to apply a perceived *Punishment* in the form of time acceleration [14]. It might be advantageous for HCI researchers to cast a wider net around existing entries to the BCT taxonomy, and for Health Psychology researchers to consider including the contributions of HCI research in future versions of the BCT and alternatives.

Evidence of Effectiveness

In addition to table 5 which provides an indication as to whether the effect of interest was significant or not, Figures ?? and ?? provide forest plots of the effect size and confidence interval estimate for each effect in the study. The following sections discuss the effects in each of the two main categories (Assigned and Customised avatars).

Assigned Avatars.

The most consistently successful paradigm was the manipulation of avatar body size to affect in-game performance. However, performance was the outcome in only four studies, with the remainder of 'obese avatar' studies testing post-game behaviours [3] or virtual shopping decisions [16]. Two of the studies used identical methods (virtual tennis game) on college students of different genders [11,12]. The third [7] was conducted on a cohort of larger bodied children, and utilised a running game on the Nintendo Wii. Study [0] replicated the method of study [7] but on adults who were not selected based on body size, and reported (non-significantly) lower mean track completion times for participants in the larger bodied condition than the athletic condition. To say that the effect is reliable would be premature, and substantial work is required to confirm this.

In the two studies by Peña et al [11,12], people were selected based on being in the "normal" Body Mass Index (BMI) range. The intention appears to have been for the participants to perform downwards comparisons on the larger sized avatar, and lateral or upwards comparisons on the smaller avatar. Participants in study [0] were not screened for body size. In the study by Li et al [7], participants were selected based on being in the higher BMI range, and would therefore be expected to perform lateral comparisons on the larger avatars, and upwards comparisons on the smaller avatars. The absence of baseline performance in any of the studies makes it unclear whether the participants were performing or self reporting at, below, or above their *true* attribute.

Only one study found significant effects of avatar body type on attitudes, intentions and behaviours [7]. In the remaining studies, these measures were either not significant

[15], or not measured [0,3,6,11,12]. Moreover, exposure to normative ideals, and hyper-ideal avatars had small, noisy, or mixed effects on body image related outcomes. For instance, muscularity had no effect on male body satisfaction in study [9], but did on one scale in study [15]; and in study [8], women self reported more favourable attitudes towards their weight, but less favourable body satisfaction. Taken as a whole, it is unclear whether merely controlling an avatar will affect psychosocial constructs, whereas the effect on behaviour during play may warrant further investigation.

Customised Avatars.

Evidence of the effect of avatar customisation on the outcomes of interest was also mixed, with the direction of effects varying both between and within studies. Three studies directly compared assignment with customisation, but only one [5] reported significant differences in a measures of self-reported intentions a behavioural analogue for intentions was not significant. This is unexpected, since if they were measuring the same construct, the direction of the effect ought to be the same. Future studies on customisation and intentions might include measures of identification (Turkay & Kinzer, 2014) and self presence (Ratan, 2010) which have been shown to influence motivation to play tradition and exercise videogames (Birk et al., 2016; Li & Lwin, 2016)

The type of instructions given to participants customising their avatars was manipulated in five studies [1,2,5,10,13]. The instructions were based on self-concepts and models described in Self Discrepancy Theory (SDT; Higgins, 1987), namely actual (perception of the self as it currently is), ideal (projection of who a person desires to be), or ought selves (projection of who a person feels they should morally be). Mere customisation based on these concepts had null [1,2,10], positive [13] and negative influences [5] on health-related outcomes. The actual self was used as an avatar creation prime in Study [5], with the hypothesis that it would lead to higher perceived risk to the body. An effect was found in one of the three scales, and the reason for choosing the significant scale appeared to be data-driven. Study [1] also used actual-self activation but found no significant differences between the actual and ideal avatars on any outcome (perceived risk, self efficacy, behavioural intentions). Other studies used actual self activation as a baseline [2,13], with ideal and ought self avatars forming the experimental condition. There were no significant differences reported between groups on any health related outcomes in studies comparing actual and ideal selves [1,2,5,10,13]. The ought self model was used in one study [13], and the authors reported that when controlling for health consciousness, participants selected fewer food items compared with those in the actual body-activation condition. What the authors did not discuss is that when not controlling for health consciousness, and when all participants were analysed together, the ought self had a stronger, and significant negative effect on the observed quantity of healthy foods eaten. Finally, none of these studies actually measured self discrepancy to see if the avatar exposure had actually worked in the intended way.

Quality of evidence

No study met the stringent reporting standards of clinical trials set out by the Cochrane Tool for Assessing Risk of Bias (Higgins et al., 2011). All significant effects were

found in studies with either high or unknown risk of bias. This is not to say the studies was biased, but there was insufficient information provided to make judgements on many of the CTAB bias domains, and ultimately this means that no firm conclusions may be made about how the studies were run. This is likely to be an issue with the field in general, which is only just starting to adopt reporting standards. However, Navarro et al. (2020, p. 10) were a notable exception, who made a substantial effort to debias their study. They implemented randomisation and blinding methods to safeguard their study. This study as also the most recent in the set, and it is hoped that future authors will follow their lead.

In three studies, participants were asked to report on the nature of the study, and those who guessed the purpose were excluded from further analysis. However, in all but two studies [0,10], no information about the blinding of conditions or allocation concealment was provided, with only a cursory mention being made to the randomisation of participants. Two studies mentioned that allocation was performed prior to the participants arriving, which could indicate a higher risk of selection bias.

No studies reported conducting an *a priori* power analysis to inform their sample size, nor was a smallest effect size of interest (SEOI) declared, with the majority of studies conflating significance with relevance. Power was only mentioned by Jin [2], who reported an *a posteriori* ‘observed power’ estimate after the sample had been collected and the effect size estimate observed. It has been convincingly argued that observed power provides little information of use by meta-scientists and statisticians, because the observed effect may be inflated due to outliers having a disproportionate influence on the overall estimate (Baguley, 2004).

The validity of measures used within the studies was not discussed in any of the articles. This is important because few of the studies directly measured behaviours, with most relying on the estimation of psychosocial constructs. Without a discussion of the construct validation of these measures it is impossible to judge whether the items are appropriate for the purpose (Cronbach & Meehl, 1955; Flake & Fried, 2019).

One area in which risk of bias was high was attrition. The degrees of freedom reported by the majority of the studies ($N = 14$) do not match the reported sample size, suggesting that the analyses were run on different samples, with no discussion of attrition. Although these differences may be due to typos, Statcheck was run on all inferential statistics and no errors were detected (Epskamp & Nuijten, 2015).

Sources of heterogeneity

There was considerable variation in the uses of avatars to affect health-related outcomes. A potential source of variation includes the level of interaction with the avatar. In nine of the experiments, participants had no control over the appearance of the avatar, and so any self similarity would be coincidental. In the remaining three studies, participants selected [1], or customised [1,2,4,12] that looked like themselves. All customisation instructions involved some level of self similarity, that is participants in these experiments were limited in their freedom to self-present.

The choice of dependent variable was also a potentially large source of heterogeneity. These ranged from self-report measures to direct observation; from post-treatment, to peri-treatment behaviours. The domain of the dependent variable did not always match the treatment. For example, in one case [2], the treatment was an exercise game and the outcome was healthy eating intentions. An argument could be made for the higher success of studies at finding an effect when there was a close, theory-driven, correspondence between the dependent variable and the treatment. For example, the Proteus Effect predicts that stereotype-relevant behaviours will be adopted when an avatar visually represents this group. If this were to follow into the muscularity studies, the Proteus Effect would predict variations of in-game behaviours, rather than post-play attitudes towards the self.

A further source of heterogeneity was the reason for conducting the study, and the implicative chain that led to the hypotheses of the studies. The Proteus Effect was the primary avatar theory in nine studies [0,2,3,5,7,11,12,13,16], whereas Virtual Self Modelling was in one study [14]. Four did not cite any of the main avatar-influence theories [1,6,8,9]. In addition to these avatar influence frameworks, there was a large variety of ancillary theories attached to the chains of many of the studies. Self Discrepancy Theory (Higgins, 1987) [1,2,5,6,13] and Social Comparison Theory (Festinger, 1954) [5,8,9,11,12] were cited in five, Social Cognitive Theory (Bandura, 2001) was cited in four studies [2,3,5,11], and Stereotype Threat (Steele & Aronson, 1995) [7] and Regulatory Fit (Higgins, 1996) [2] were used as second factors in one study.

There were more significant effects of avatar appearance on non-standardised measures than standardised measures. This is not presented as evidence of questionable research and/or measurement practices, but future authors are urged to pre-register their items, and follow the guidance provided by Flake and Fried (2019) when reporting and developing measurement items.

General Discussion

Perhaps the most consistent result from the body of work reviewed here is that playing an exercise game as an “obese” avatar makes players move less than if they were playing with smaller avatars. Three studies, conducted on different populations, reported statistically significant results on this effect. There have been no published attempts to replicate these findings, although one unpublished study [0] attempted to replicate and extend these findings. It would be possible to explore an inverted U-shaped relationship between avatar appearance and exercise behaviour, predicting optimal behavioural influence around a person’s ideal body type, and decreasing as a function of the absolute distance from that ideal. This would require a great deal of further work.

The models used in studies [0, 11, 12] were lean and muscular, and likely did not reflect an ‘average’ (i.e. non-idealised) body type. The avatars in study [7] appeared very thin. Indeed, the definition of “normal” amongst studies is ill-defined, and a baseline would need to be established prior to further work being conducted. Further, many of the studies were conducted in countries with very different cultural norms to one another. There were studies conducted in the UK, Japan, Singapore, Taiwan, and the USA. This may represent a further source of heterogeneity, since the experience of participants between these studies

may be different in relation to culturally-determined body ideals (Grogan, 2017, pp. pp31–35).

Two studies [6,14] investigated the effect of the ‘future self’. These used manipulated images as avatars, with study [6] reducing the weight of the avatar to the participants ideal, and study [14] adding smoking-related age artefacts to the face. These studies yielded fair results and there has been some compelling research on appearance related interventions for a range of health behaviours including UV protection (Persson, Grogan, et al., 2018; Persson, Benn, et al., 2018) and smoking (Grogan et al., 2011), as well as applications in non-avatar based virtual reality studies (Ahn, 2015a). As such, this may be a fruitful direction for future research.

Grounding in Theory

In moving forward with avatar-related health interventions, it is perhaps more important to ensure that what is already known is incorporated into future research than it is to continue demonstrating novel examples of the same effects. The theories that have been used to develop the studies in this review make very specific predictions, and these need to be taken into account when progressing the field.

Proteus Effect.

In general terms, the mechanisms behind behavioural assimilation from avatars are described by the Proteus Effect (Yee, 2007; Yee et al., 2009). Under this theory, embodying an avatar results in the user drawing inferences from the avatar’s appearance, and behaving in a congruent way. It is not sufficient to simply state that changing an avatar’s appearance will result in health behaviour change, since the Proteus Effect has a number of necessary conditions that must be met for behaviour to change. To wit, there must be a visually activated stereotype (positive or negative) associated with the target behaviour; the avatar must unambiguously represent this stereotype; the stereotype must be general enough that participants will have encountered it. Only four studies in the set met these conditions [0,7,11,12], and three of these found significant, and relatively strong effects results of in-game performance. There is a wide literature on weight stigma, and a persistently evident belief that larger individuals are lazy, slow, and lack control (Flint & Reale, 2018; Seacat & Mickelson, 2009). It is perhaps unsurprising then that the manipulation of avatars to have larger, stigmatised body-types would affect behaviour. However, since this effect is reliant on social constructs (stereotypes), it should not be regarded as a *medication* for larger bodied people, as suggested by Li et al. (2014) (p45), since stereotypes are subject to change and may be manipulated experimentally and sociologically. Further, the stereotype that fat people are lazy is inherently negative and stigmatic, but currently has the benefit of being deemed socially acceptable by various power structures (Gillborn et al., 2020). It is inconceivable that other stigmatised views (e.g. related to race, gender) would be prescribed in the 21st century; and instead work ought to be focused at reducing the weight-related Proteus Effect, rather than maintaining it.

As of yet there is no published literature on stereotypes related to idealised and hyper-idealised body types. An unpublished account suggests that these stereotypes may

be ambivalent, eliciting both positive (determination) and negative (arrogant, cold) activations (Clark, 2019, Chapters 6,7,& 8), both of which may influence in game behaviour. and the studies that attempted to manipulate body satisfaction using avatars relied on traditional media influence theories. Such studies have been shown to be weak, and only have an effect in very specific circumstances (e.g. women with pre-existing body image dissatisfaction, Ferguson, 2013). In the current review, it appeared that men's body satisfaction was more affected by hyper-idealised avatars than women. The absence of a literature on stereotypes, and the observation that body satisfaction might be reduced under exposure to idealised avatars suggests that the negative consequences are better established than the potential positive consequences. Absent literature on stereotypes related to muscularity, predictions cannot be made under the Proteus Effect - this step needs to be taken before broad recommendations about the avatars that people should or should not have access to are made.

Self-Discrepancy.

Similar arguments to those presented above may be directed at the avatar customisation studies. In general, the studies aimed to promote health related behaviours using self concepts from Self Discrepancy Theory. The chain of reasoning in Kim and Sundar's study [5], is that when people create an ideal avatar, they observe their distorted self perceptions from the third person perspective, which results in reflexive self perceptions, carrying over into their behaviour as per the predictions of Self Perception Theory (Bem, 1972). This chain of reasoning is not clearly supported by the literature. Higgins (1987) states that Self Discrepancy Theory also has necessary conditions for the activation of a discrepancy. A particular self concept must *a.* exist, and *b.* be accessible. At no point in any of the customisation studies was the presence of self discrepancy in participants established. Self-Discrepancy measurement typically has an ideographic and nomothetic component, that is, the participant states their ideal, ought, or feared attributes and then indicates the distance their actual self is from these attributes (Hardin & Lakin, 2009). The simple inclusion of such a measure would allow researchers to predict the effect of avatar influence on behaviour more precisely. Participants were provided with instructions to create avatars that represented their actual, ideal, or ought selves, without determining whether such discrepancies existed, or what the nature of the discrepancy was. The assumption within the studies was that participants would make a healthy version of themselves, but participants only had access to visual features. There is a body of work suggesting that the ideals of some individuals are rooted in functionality rather than appearance (Body Appreciation, Tylka & Wood-Barcalow, 2015). The ideal image of people who self-rate highly on Body Appreciation may look identical to how they currently look, but (for instance) be able to do a backflip, or hold a plank for eight hours. Without determining whether a person has health behaviour internalised, it is not possible to know what the avatar actually represents to them. In Kim and Sundar's study [5], participants were simply asked to "customise their avatar to resemble their [actual/ideal] self" - and so then if there is an underlying avatar persuasion mechanism, it is unclear what is being activated when the avatar is used, and which behaviours mapped onto the representations.

Comparison with Previous Reviews

A side-by-side comparison between the two previous systematic reviews is presented in Table 8. There are key differences in the interpretation of the results, with the two previous reviews being more positive about the effect of avatars on health-related behaviours, whereas the current review presents a more critical view of the field.

There are several similarities between the Rheu et al. (2019) review and the current review. Both attempted to synthesise evidence on the extent to which avatars may affect health-related behaviours; with a particular focus on exercise and dieting. However, this article benefits from being pre-registered, with transparent decisions and justifications throughout. Moreover, the discussion of the studies is focused on a single attribute of avatars: their appearance. The definition of an avatar-based intervention in the current review was one in which the avatar was the main manipulation. This led to the exclusion of studies such as Behm-Morawitz et al. (2016) and Christensen et al. (2013), in which the environment was the primary difference between conditions. As mentioned earlier, the findings from Rheu et al. (2019) may be inflated by the inclusion of studies that used doppelgangers rather than avatars (e.g. Fox & Bailenson, 2009; Ruiz et al., 2012), and the exclusion of unpublished, non-significant studies from doctoral theses (e.g. Fox, 2010).

Several of the studies captured by the Horne et al. (2019) review were part of the full-text review procedure of the current review, but were excluded on the basis that they did not manipulate an element of the avatar's appearance as an independent variable (e.g. Behm-Morawitz et al., 2016; Napolitano et al., 2013). The Horne review was also more restrictive in its target population, only looking at "obese" and "overweight" populations.

Unlike the current review, strength of evidence in both previous reviews was predicated solely on p values rather than an interpretation of effect sizes and confidence intervals, allowing for a more nuanced description of the effects.

Table 8

<i>Comparison of the current and two recent systematic reviews on avatar health interventions</i>				
PICO	Clark et al (2019)	Horne et al (2019)	Rheu et al (2019)	
Participants	Non-clinical			
Intervention	Avatar appearance manipulation	Obese or overweight Any weight-related intervention using avatars	Non-clinical Studies with avatar manipulations	
Comparators	Avatar assignment; customisation; platform; use of covariates	Customisation		Customisation;homophily; self do-
Outcomes	Diet, physical activity, smoking cessation, HPV vaccination, body satisfaction.	Weight loss		main; body size; behaviour. Physical activity, diet

Strengths/Limitations

Although there have been at least four qualitative reviews on avatars and health behaviour (Ahn, 2015b; Ahn & Fox, 2017a; Horne et al., 2019; Rheu et al., 2019), this study is the first to systematically collect and assess the evidence avatar appearance on health-related attitudes, beliefs, intentions, and behaviours. The previous reviews present preliminary findings on how doppelgängers, as well as avatars, can influence health behaviours, as well as how these may be integrated with social psychology theories to produce favourable health-related outcomes. The current review assessed studies investigating the use of only avatar-appearance to influence health behaviours, presented effect size estimates and confidence intervals, and addressed methodological and theoretical flaws. It is hoped that it will be used in conjunction with the existing reviews for future avatar researchers to plan their studies.

A strength of the study was the use of an established risk of bias tool. However, the Cochrane Risk of Bias tool is designed for clinical trials, and much of the information that would be provided to support low bias (e.g. randomisation protocols and measures to reduce allocation concealment) is not commonly included in psychology and human factors research. The effect sizes were also plotted against the risk of bias, suggesting that outcomes may have been influenced by biased methods.

One important finding was that there are surprisingly few studies on this topic, with a large and varied array of effect comparisons. This also meant that the estimation of a meta-analytic effect size would not have been informative.

It is important to note that, although various authors were contacted regarding file-drawer studies, and non-peer reviewed sources were searched (e.g. ProQuest thesis repository), only one unpublished study was included, and this was produced by the research team who wrote the current review. One study had previously been a Masters thesis. This is a limitation because given the near ubiquity of publication bias in Psychology (Simonsohn et al., 2014), and in videogame violence research (Ferguson, 2007), it is likely that this review does not contain all studies conducted in this field. Further, the inclusion criteria for the studies had to be adapted, since the pre-registered criteria were at once too broad and too narrow. That is, they stated that any study using an avatar would be included, and that outcomes had to be measured before and after the intervention.

Conclusion

This review reaches a different conclusion to that of Rheu et al. (2019). Where the previously published review suggests that when an avatar is “fit, customisable, and demonstrating health consequences” (p9), health-related behaviours may be improved; and that self-discrepancy related constructs could be used to benefit users health-related behaviours, we conclude that there is as yet insufficient evidence to support the use of avatar appearance as health-related interventions, although there are many opportunities to improve the area. We note that the effect sizes for customised avatars were generally weak, and many included zero in the 95% confidence interval. We also conclude that where the depiction of larger bodies may influence health-related behaviours, this should not be seen as a remedy, but as

a bias that needs to be remedied. We argue that people need to be motivated to exercise independently of body shape, and focus on function and fitness rather than shape. Further, the potential consequences of limiting avatar body sizes to athletic or “normal” ranges on body satisfaction need to be explored. More theoretical work is needed to place avatars within the wider taxonomy of health-related behaviour change; the predictions made by existing theory need to be revisited; and replication attempts are required to explicate the interaction between avatars and real world health-related behaviour.

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