How to Kill a Greek God: A Meta-Analysis and Critical Review of 14 years of Proteus Effect Research

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Abstract

The Proteus Effect is a phenomenon whereby a user of a virtual environment temporarily adopts attitudes and behaviours that are consistent with stereotypes associated with the appearance of their avatar.

A recent meta-analysis (Ratan et al, 2019) estimates that the strength of the Proteus Effect is "small to medium" under the de facto descriptors of Cohen (1992). Ratan et al also suggest some meta-analytic regressors which may moderate the overall effect.

In this replication and extension of Ratan et al's review, the conditions under which an effect should be observed are made explicit, and a number of potential issues with the previous review are highlighted and addressed. These include conflation of a number of different theories (Virtual Self Modelling, perspective taking), the erroneous inclusion and omission of studies, errors in effect size calculation, and the possible motivated selection of effects.

Results reveal that although the Proteus Effect may be a robust effect with several demonstrative studies, the omnibus effect size of the Proteus Effect is smaller than previously indicated, is sensitive to the inclusion of negative results, and that the moderators suggested in the original meta-analysis do not significantly contribute to the prediction of the effect sizes.

It is ultimately argued that the Proteus Effect ought not be embraced as an intervention and is more useful as an indicator of stereotype activations. Suggestions are made for a progressive research line which aims to unpack the Proteus Effect and increase the consistency and variety of predictions it can make, including ways to reduce the effect and allow controllers the freedom to be who they want to be in virtual environments.

Keywords: Proteus Effect, Avatars, Meta-analysis, Stereotypes, Attitudes

Word count: 12245

Introduction

In the first decade of the 21st Century, researchers at Stanford University claimed to have "broken reality" using immersive virtual environments and avatars (Yee, 2014, p.

p142). The Proteus Effect refers to the tendency for people navigating a virtual environment to adopt attitudes and behaviours that are congruent with the appearance of their virtual-self (avatar), rather than their *real* selves (N. Yee et al., 2009). For example, a player embodying an attractive avatar may adopt attributes that are stereotypical of people perceived to be attractive, such as confidence (N. Yee et al., 2009, Study 1); or a player embodying a tall avatar may result in greater assertiveness during negotiations (N. Yee et al., 2009, Study 2). There have been a great many demonstrative studies on the Proteus Effect, recently summarised in a meta-analysis which estimated the Proteus Effect to have a small to moderate aggregated influence on attitudes and behaviours (Ratan et al., 2019).

The current review aims to present a coherent model of the Proteus Effect, explicitly stating the conditions under which the phenomenon ought to predict outcomes. It will critique the 2019 meta-analysis, arguing that there may be some methodological issues leading to some important studies and effects being erroneously included or omitted. Next, the meta-analysis conducted by Ratan et al. (2019) will be reproduced, taking these considerations into account, and an updated effect size estimate using the same methods as Ratan et al. (2019) will be presented. Next, an extended meta-analysis will be presented which will include additional effects both from studies in the original dataset, and studies that were missed the first time around. These will be synthesised using a multi-level approach, modelling each study as the generator of many effects. Finally, recommendations will be made for future research, ultimately arguing that eradicating the effect would be beneficial.

I argue that in the Ratan et al. (2019) meta-analysis, the definition of the Proteus Effect was too broad, and included studies in which the appearance of a self-representation in a virtual environment changes attitudes or behaviours. In the following section, I will argue that the Proteus Effect makes very specific predictions in very specific circumstances, and many of these studies do not meet the criteria for a Proteus Effect study.

The Proteus Effect, Explicated

The Proteus Effect was first described in 2009 by Nick Yee and Jeremy Bailenson as a behavioural assimilation phenomenon rooted in the Self Perception Theory of Daryl Bem (Bem, 1972). Under Self Perception Theory, behaviours paradoxically precede attitudes; people observe themselves behaving and make inferences about their attitudes based on what they see. For instance, compared with a person who is paid a handsome fee, a person paid a paltry sum for writing an essay on a subject that they disagree with would be more likely to infer that they in fact agree with the point of a view, whereas the former may justify the behaviour as having a financial incentive (Bem, 1967). In a similar vein, the Proteus Effect predicts that people embodying an avatar representing a stereotyped group

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make inferences about their own attitudes and typical behaviours based on the observation of their virtual self and act accordingly.

In the following paragraphs the Proteus Effect will be unpacked, and a set of necessary conditions (propositions) that are required for it to occur will be presented.

Definitions

A *controller* is a person who has control over an *avatar*. This is more appropriate than gamer/player since an avatar may be used in non-play situations, and user which may extend to agents too (you may use an agent for information).

An *avatar* is taken to be any representation of the controller in a virtual environment (expanded further below).

A *virtual environment* is taken to be a system which represents a space in which a controller may interact with objects or other users. These include social media spaces, immersive virtual reality (IVR), 3D and 2D spaces.

Avatars

First and foremost, the Proteus Effect requires the controller to be navigating a virtual environment, and that this navigation is facilitated by a representation of the self, or avatar¹. In a recent comprehensive review of the literature, Nowak and Fox (2018) argue that researchers in the field of Human-Computer Interaction have been inconsistent in their definition of an avatar; and are in many cases being too restrictive (e.g. limited to a visual 3D humanoid character). In their paper they state the following:

[...] we endorse a more open definition and argue that an avatar is a digital representation of a human user that facilitates interaction with other users, entities, or the environment. [p34]

This means that an avatar can be anything from a single ASCII character to a fully articulated 3D embodied model and beyond; may be represented in any modality (visual, audio, tactile), and need not be limited to any particular form. There have been no reported studies investigating the Proteus Effect in avatars in these alternate modalities. The first proposition is then:

¹A term taken from the Sanskrit Avatara, which is the embodiment of a deity in corporal form. The terms is generally attributed to Neal Stephenson (Stephenson, 2014), although it was used as an adjective by Norman Spinrad in 1980 (“your mind is avatared”), was coined as a playable character by creator of the *Ultima* series, Richard Garriott in 1985, and was the term given to the playable character in the early Massive Multiplayer Online Role Playing Game (MMORPG) Habitat.

P_1 : A controller must be represented by an avatar in a virtual environment for the Proteus Effect to occur.

Stereotypical Appearance

The Proteus Effect relies on the existence of stereotype-congruent behaviours that are elicited by the avatar. Haslam et al. (2002) suggest two classes of stereotypes: the first, referred to as *pictures in the head* (Haslam et al., 2002), or *in-here* stereotypes (Kowert et al., 2012), are subjectively held by an individual; when considering a larger bodied, personally held beliefs regarding the likelihood that the person is lazy are activated. The second, dubbed *collective tools* (Haslam et al., 2002), or *out-there* stereotypes (Kowert et al., 2012), are attributed to the wider population and activated when considering what beliefs *an average person* has about a group. The distinction may be made by the framing of a question: “How likely do you believe it is that this person is lazy”, versus, “How likely does an average person believe that this person is lazy” (Kowert et al., 2012).

The following quote from the N. Yee and Bailenson (2009) Proteus Effect paper presents the role that stereotypes play in the assimilation effect

...in line with self-perception theory, they conform to the behaviour that they believe others would expect them to have. p274

From this quote, we can see that the mechanism of the Proteus Effect is rooted in *out-there* stereotypes i.e. conformity comes from the expected beliefs of others and infer two more propositions²:

P_2 : In order for the Proteus Effect to occur, an avatar must have explicit attributes, for example (but not necessarily restricted to) visual features, that are accessible to the controller at the time that they are controlling it.

P_3 : There must be an *out-there* stereotype associated with the appearance or attributes of the avatar from P_1 , and this stereotype should be available and accessible to the controller.

We now have a virtual environment, an avatar, and stereotypical attributes. This is still not sufficient for the Proteus Effect to occur, since for assimilation to occur, there must be something to assimilate.

²Later I will argue that *in-here* stereotypes may be important in a different paradigm called virtual perspective taking.

Attitudes and Behaviours

The original Proteus Effect studies, (N. Yee & Bailenson, 2007) emphasises that both attitudes and behaviours are affected by the appearance of an avatar:

I hypothesized that users would conform to attitudes and behaviors expected of their avatars, a phenomenon I termed the Proteus Effect. p97

Behaviours are a useful direct measurement of the Proteus Effect, since they may be measured spontaneously and at the time of embodiment (*in-vivo*) with minimal prompting from the experimenter. However, treating attitudes and behaviours as independent may be an oversimplification of the process by which behaviours are (or are not) performed. For instance, according to the *Theory of Planned Behaviour*, the probability that a behaviour is performed may be modelled as a function of other internal constructs: Attitudes (constructed from beliefs and subjective evaluations); Subjective Norms; and Perceived Behavioural control. The pathways between these constructs and behaviour is mediated by Behavioural Intentions (Ajzen, 1991) (see figure 1).³

Figure 1

Theory of Planned Behaviour Ajzen (1991). Diagram from https://commons.wikimedia.org/wiki/File:Theory_of_planned_behavior.png

By considering these additional variables, Proteus Effect studies may be seen as attempts to manipulate one or more of the Theory of Planned Behaviour factors, whilst holding the remainder constant. For instance, in N. Yee and Bailenson (2009) Study 2, participant's attitudes towards the behaviour *unfairly splitting money* were manipulated by their perceived height (*"someone this height would have a favourable attitude towards this*

³Nota bene, this is not the first application of Ajzen's theory on gaming influence research; Pena et al. (2018) applied the Theory of Planned Behaviour in a study on attitudes and intentions towards immigration after playing a recent videogame called *Papers Please* in which players take the role of an immigration officer. This study is not included in the meta-analysis because two separate games were used in the manipulation.

behaviour”), leading to a greater probability that the behaviour would be performed. In this respect, the observed behaviour is actually an *indirect* observation of the change in attitude. Arguably, observing a behaviour is the *purest* form of Proteus Effect, since performance is spontaneous and does not require self-report measures which are arguably more likely to succumb to experimenter effects or scupper any attempts at blinding the participant. From this, *Proposition4* is divided into sub-propositions.

$P_{4.1}$: For attitude assimilation to occur, a stereotype-congruent attitude must be associated with the stereotype from P_2 .

$P_{4.2}$: Behavioural assimilation is an indicator of attitude assimilation, and so the attitude should be predictive of a unique behaviour.

And finally, since there is little point in preparing an avatar that evokes athleticism, and not providing the controller an opportunity to perform exercise (if that is the relevant behaviour), I propose the following corollary:

C_1 : There must be an opportunity to perform the behaviour from $P_{4.2}$.

I suggest that these four propositions (and one corollary) form the necessary conditions under which behavioural change through the Proteus Effect should occur, ergo if one is absent then any observed changes would be attributable to some other effect.

Proteus Effect Notation

To make communicating the predictions from a particular Proteus Effect study clearer, I propose a notation, borrowed from probability theory, that makes these expectations explicit. The notation uses the | (bar) operator such that *Attitude|Attribute* means “a stereotypical attitude given the presence of an out-group attribute”; this is connected to the probability of a behaviour being performed, so $P(B) \sim X|Y$ means the probability of seeing behaviour B performed is predicted by the degree of stereotypical Attitude X, invoked by perceiving Attribute Y. For example, in the original study by N. Yee and Bailenson (2009), the stereotype was that attractive people are more sociable and confident. These attributes were measured through interpersonal distance and self-disclosure; we can therefore use the notation to provide $P(IPD, Disclosure) \sim Sociability|Attractiveness$.

If P_{1-4} & C_1 are met then it should be simple to code a study design using the above notation. I predict that if a study design does not meet the requirements of P_{1-4} & C_1 , then coding these studies using the above notation will make little sense⁴.

Rationale

The current review initially aims to reproduce meta-analysis conducted by Ratan et al. (2019). Next, Using expanded search terms and inclusion criterion based upon the postulates above, the meta-analysis will be replicated and extended. The structure of the paper is as follows:

1. The existing dataset from Ratan et al. (2019) will be re-analysed, with and without the studies that do not conform to the postulates above.
2. A new review and meta-analysis will be presented using studies found using a new search and selection procedure, with expanded search terms provided.
3. All relevant effects will be coded, whether these are significant or non-significant, and the meta-analysis will be re-run using a multi-level approach.
4. A pseudo-multiverse analysis will be run on the new set of papers to estimate the robustness of the meta-analytic effect size.

Reproduction and Sensitivity Analysis of Ratan et al. (2019)

In their 2019 meta-analysis of 46 effects, Ratan et al. (2019) estimated the effect of avatar characteristics on controller attitudes and behaviours to be between $r = 0.22$ and $r = 0.26$. Using the arbitrary descriptors from Cohen (Cohen, n.d.), this may be described as a “small to medium” effect. In the following, the analysis will be reproduced using the published dataset.

Method

Study Evaluation

Each study from Ratan et al. (2019) was accessed and coded for whether it met the necessary conditions for the Proteus Effect. Seven studies did not meet the minimum requirements for inclusion as a Proteus Effect study, four were omitted because they were perspective taking studies, and one was omitted for having questionable results. These decisions are detailed further in the discussion.

⁴For instance, in one of the studies included in the Ratan et al. (2019) meta-analysis, the manipulation was avatar gender, and the outcome was perceived self-similarity. This gives $P(\text{SelfSimilarRating}) \sim \text{Closeness}|\text{Gender}$ which reads as “the belief that an avatar is rated as self-similar is predicted by the stereotype that relational closeness is held more by one gender than another”. To the best of my knowledge, this isn’t a common stereotype, and is more likely the tautology that women will more likely identify with a female avatar because they are female.

Data preparation and analysis

In order to reproduce the results from Ratan et al. (2019), I estimated variances for the r values using the reported r value and sample size using the `escalc` function from `metafor` (Viechtbauer, 2010).

I followed the same method implied by Ratan et al (2019), who cite using “generally established procedures” (Rosenthal & DiMatteo, 2002). This involves weighting the Fisher Z transformations of the raw correlations coefficients by sample size using the formula:

$$n_i - 3 \times (k / \sum n_i - 3)$$

Or the sample size of each study minus three, multiplied by the number of studies (k) divided by the sum of all of the sample sizes minus 3. After weighting, the z values are transformed back into correlation coefficients, and added, with their estimated variances, to a meta-analytic regression equation.

To do this, I used the `metafor` package (Viechtbauer, 2010), and the `psych` package (Revelle, 2018) in the R programming environment (script available on the Open Science Framework).

I make the assumption that Ratan et al used raw correlation coefficients, rather than transformed Z scores in calculating the summary effect size estimate, since running the meta-analysis on both raw correlation coefficients and Fisher Z scores yields a rounded weighted r of 0.24, but the latter to three decimal places is 0.244 and the former is 0.240. Since Z correlations are normally distributed, they can be used in general linear models. As such, in the moderation analysis below I use the transformed values.

I then ran a set of hierarchical random effects meta-analyses on the weighted r values (weighted by sample size, as per Ratan et al. (2019)) using the `rma()` function from the `metafor` package. The set included an intercept only model, followed by the inclusion of two of the proposed moderators from Ratan et al. (2019), and a Platform moderator which had two levels (Desktop and VR):

$$y \sim 1 + (1|Study)$$

$$y \sim 1 + Behaviour + (1|Study)$$

$$y \sim 1 + Behaviour + Within + (1|Study)$$

$$y \sim 1 + Behaviour + Within + (1|Study)$$

The main effect moderator was excluded because effect sizes were coded using marginal means for two groups, where an interaction would require several factors. This would not make sense from a point biserial effect size perspective. In cases where a moderator was included using ANCOVA, was unclear whether the reported means were covariate adjusted, so coding for more complicated effects was not feasible.

These model were repeated on both full and reduced datasets. Finally, funnel plots were created to assess the extent of publication bias in the dataset

Table 1

k	n	r weighted	95% CI Lower	95% CI Upper	Variance	Expected Variance	Unexplained variance
46	3,867	0.24	0.20	0.28	0.02	0.01	0.01
40	3,359	0.22	0.19	0.26	0.01	0.01	0.00
33	2,579	0.22	0.18	0.26	0.01	0.01	0.00

Note. Three effect size estimates, total sample sizes, and variance estimates. The table shows the reproduced effect size from the full dataset of Ratan et al (2019) ($k=46$), an effect size estimate when the studies by Bian et al, Fox et al and Yoon & Vargas were removed ($k = 40$), and an effect size estimate when virtual perspective takings studies were removed also ($k = 33$)

Results

Table 1 provides the reproduced values from Ratan et al. (2019), followed by the same models run on reduced datasets (see below). In Figure 2 the effect sizes, errors, and aggregated effect are presented as a forest plot.

In addition to reproducing the results of Ratan et al. (2019), the moderation analysis that was implied by the original paper was also run, using main effects and the measurement of behaviour as categorical predictors. The results are presented in Table 2.

Although Ratan et al. (2019) hedge their claim that their proposed moderators affect the overall, stating that it should be seen as ‘qualitative evidence’ (p13), once confidence in

Table 2

	Weighted r	SE	p value	Lower 95%CI	Upper 95% CI
Full Dataset					
Intercept	0.23	0.04	0	0.16	0.3
Main vs Int	-0.01	0.07	0.69	-0.15	0.12
Behaviour vs Attitude	0.02	0.05	0.61	-0.08	0.12
Five Articles Removed					
Intercept (k-5)	0.2	0.04	0	0.13	0.27
Main vs Int (k-5)	0	0.07	0.74	-0.14	0.15
Behaviour vs Attitude (k-5)	0.05	0.06	0.38	-0.06	0.15
Perspective Taking Removed					
Intercept (k-5-PT)	0.2	0.04	0	0.12	0.28
Main vs Int (k-5-PT)	0	0.09	0.75	-0.16	0.17
Behaviour vs Attitude (k-5-PT)	0.04	0.07	0.48	-0.09	0.17

Note. Meta-regression with whether the effect was based on a main effect or an interaction, and whether the study measured attitudes or behaviours as moderators. Analysis is repeated for each of the three datasets ($K = 46$, $K = 40$, $K = 33$).

the difference between the scores is accounted for, the influence of the effects of the inclusion of interaction terms and behaviour are vanishingly small.

Sensitivity Analysis

After confirming that the meta-analysis was reproducible, the sensitivity of the findings was checked by repeating the analyses upon removing questionable and potentially non-Proteus Effect related studies. The first round of re-analyses was conducted after removing the Fox and Bailenson Doppelganger Effect studies (Fox, Bailenson, et al., 2009; Fox, 2010a; Fox & Bailenson, 2009); Yoon and Vargas (2014a) which has been scrutinised for being potentially fabricated (Hilgard, 2019); and the studies from Yulong Bian et al. (2015) in which participants did not even use an avatar; and two studies from Ratan's laboratory which did not use obvious stereotypes in the study design (Ratan & Dawson, 2016; Y. J. Sah et al., 2017a)

In the second round of reanalyses, perspective taking studies were removed, since these were conceptually distinct from Proteus Effect research, and if anything, make the opposite predictions to those that PE make.

Removing the questionable studies had a negligible effect on the overall estimate, with the meta-analytic r value being reduced by 0.02 with the Doppelganger Effect studies and Yoon & Vargas' studies removed, and 0.02 with the additional removal of strictly perspective taking studies.

Publication Bias

Ratan et al. (2019) account for publication bias in their paper, although they use outdated methods (failsafe N) which have been shown to be inadequate (Lakens et al., 2016). Indeed, one criticism of the Fail-safe N method is that effect size inflation may be due to selective reporting, rather than omission of whole studies, which may have been the case in Ratan et al. (2019) as will be discussed below.

Presented in Figures 3 & 4 are a funnel plots of the effects reported by Ratan et al. (2019). A funnel plot provides an estimate of the expected variation in an observed effect size, given a particular study configuration (e.g. sample size). Studies with larger standard errors should scatter from the 'true' effect size to a greater degree than those with smaller standard errors. That is, when studies have a small sample sizes (and therefore large standard errors), it should be less likely that an observation close to the true effect size should be observed. Under conditions of no publication bias, this would mean that there is a symmetrical distribution of observed effect sizes across both sides of estimated population effect, with studies with larger standard errors yielding a wider range of effect sizes. Under conditions of publication bias, a funnel plot will be asymmetrical, with studies with smaller and non-significant effects being omitted from the publication literature. Although the Ratan dataset is symmetrical when centred on the estimated effect size, when the plot is centred on zero the plot is asymmetrical and there are several effects falling on the funnel plot line, indicating that the p -values for these effects is on the cusp of the 0.05 significance level 'required' for publication. Again, as will be discussed, there is reason to believe that

Figure 2

*Forest plot of studies from Ratan et al's meta-analysis. Studies marked with an * did not meet the necessary conditions for the Proteus Effect; Studies marked with a ± were classified as perspective taking experiments; studies marked with a § were omitted based on questionable results. Scores and intervals are transformed from r to Fisher z scores.*

some studies were excluded on account of being non-significant, and so in the replication of the meta-analysis, non-significant effects will be included too.

Figure 3

Funnel plot centred on mean effect size.

Discussion

Although the effect size reported by Ratan et al. (2019) was reproduced, a number of issues with the methods were identified in the process. These are discussed below.

Theoretical Distinctions

As highlighted above, there were a variety of theoretical approaches that are distinct from the Proteus Effect as described by N. Yee and Bailenson (2009). The Proteus Effect has a number of necessary conditions which are not strictly met by studies that fall into these different categories. For reference, the conditions were:

- An avatar is in use
- The avatar must have explicit and accessible attributes
- An *out there* stereotype associated with the attribute must be accessible and available to the controller
- The opportunity to perform a behaviour that is typical of the stereotyped group must be available

Figure 4

Funnel plot centred on 0

Below I will discuss the different categories and how they are distinct from the Proteus Effect.

Proteus Effect vs Virtual Self Modelling/Doppelganger effect.

Virtual Self Modelling (hereafter the Doppelganger Effect) refers to a phenomenon in which a person's behaviour may be influenced by displaying a digital character that has been created to resemble the user being altered somehow. The most prevalent application is promoting health-related behaviours through virtual weight-loss. Participants observe their doppelganger appearing to lose weight in reaction to a behaviour such as exercise, or abstinence from soft drinks (Ahn et al., 2014; Fox, 2010b), and adapt their behaviours, or intentions to behave as a result. Although the Doppelganger effect is an interesting observation, with potential benefits to health promotion, it does not meet the necessary conditions for the Proteus Effect. There is typically no avatar in use: the Doppelganger is seen as if a third person. Further, although the model has visible attributes, these are not associated with an *out there* stereotype⁵. Rather, the behaviour change mechanism surrounding the Doppelganger Effect grounded more in improving perceived behavioural control and perceived outcome expectancy than it is in Self Perception Theory.

Proteus Effect vs Perspective Taking.

Within the dataset, there was a clear distinction between studies using a Proteus Effect paradigm and studies using a perspective taking paradigm. The former has already

⁵Indeed, this would make little sense "The majority of people expect a version of me that loses weight when exercising to exercise more"

been discussed above and requires a stereotypical structure from which to draw inferences about the new *digital* self. The latter will be briefly discussed below.

Perspective Taking.

Perspective taking may be seen as a variation of the imagined contact method of counter-stereotyping and bias reduction. Under an imagined contact paradigm, a person is asked to imagine an interaction with an out-group member who has attributes that are contrary to the general stereotype for this group (Blair et al., 2001). For instance, when participants were asked to imagine an interaction with a “strong, confident, assertive, obese person”, they reported less fat bias than those who imagined an interaction with a “lazy... obese person”, although the authors also note that there are a large number of studies in which no effect was found (Dunaev et al., 2018).

Perspective taking involves going a step further and imagining oneself *as* the out-group member; this has been shown to reduce stereotypical attitudes on both conscious and unconscious tasks (Galinsky & Moskowitz, 2000).

Some researchers have taken this *even further* and investigated the effect of mediated perspective taking through the use of an out-group avatar on bias (Yee & Bailenson, 2006). This was the paradigm of choice in a number of studies in the Ratan et al meta-analysis, although ultimately the Proteus Effect and Virtual Perspective Taking paradigms have very different pathways. Where the Proteus Effect draws on wider societal stereotypes, VPT studies aim to influence personally held attitudes and beliefs by reducing the perceived distance between the target and the self.

For instance, where a Proteus Effect study predicts that people using a black avatar will act more aggressively based on the expected behaviours drawn from society-level negative stereotypes⁶, a VPT study would predict that *pre-existing* biases would be reduced after the experience of controlling a black avatar. That is, Virtual Perspective Taking studies aim to affect *in-here* stereotypes, whereas in Proteus Effect studies the stereotype is merely *heard*. Although it is beyond the scope of this review to explicate VPT studies, some candidates for necessary conditions for this effect might include a pre-existing *in-here* bias towards an out-group, and the opportunity to experience embodiment of an out-group member. The different conditions required for each type of study suggests that they ought to be treated separately; indeed, the Proteus Effect is not even mentioned in a recent VRPT study (Loon et al., 2018).

Body Image

A frequent occurrence in the literature search was the use of sexualised avatars to evoke constructs such as body dissatisfaction, self-objectification, and rape myth acceptance. The inclusion of this literature is debatable because the mechanism by which an avatar is expected to affect the construct may take a variety of paths, one of which is consistent with the Proteus Effect.

⁶Whether personally held beliefs affect the activation of Proteus Effect has yet to be established, although one study has provided evidence that negative bias may moderate Proteus Effect (Marine Beaudoin et al., 2020).

Self-Objectification Theory states that women are socialised to regard themselves as objects of sexual desire, which results in an internal third-person representation of the self (Fredrickson et al., 1998). It has been suggested that self-objectification may lead to the assumption that others have similar investments in themselves, resulting in the objectification of others (Beebe et al., 1996; Bevens et al., 2018) which may affect rape myth acceptance. Early Self-Objectification studies manipulated objectification using attire: for example, Fredrickson et al. (1998) found that wearing a swimsuit led to self-objectification in white women, and Hebl et al. (2004) found that this replicated in other groups too. In this respect, the swimsuit makes the body-as-object association salient and participants self-objectify; rather than inferences about the type of person who wears a swimsuit. Sexualised avatar studies may make similar predictions; when sexualised avatars are used this pathway is very different from the assimilation of perceived attitudes held by the group “Women who wear revealing outfits”.

The effect would be consistent with Proteus Effect if a common stereotype of women who wear sexualised clothing was that they self-objectify, have low self-esteem and body satisfaction, and believe in the accountability of rape victims. Then, a participant showing elevated levels of these constructs could be seen as assimilating an attitude. However, such a stereotype has yet to be established, and seem to include lower intelligence, lower ‘niceness’, and higher popularity; but not necessarily lower body satisfaction and rape myth acceptance (Stone, 2017).

The studies were included in the meta-analysis because it is feasible that sexualised clothing might lead to the assumption that the avatar self-objectifies, and the assimilation of this perceived attitude. However future studies should delineate these two pathways.

Not meeting necessary conditions

Definition of Avatars.

As noted above, the Proteus Effect requires the *use* of an avatar in order for behavioural assimilation to occur (P_1). As N. Yee and Bailenson (2009) demonstrate, simply being primed through the observation of a character that contains stereotypical attributes will not lead to behavioural assimilation. In other words, the presence of stereotypical attributes is a necessary, but not sufficient for the Proteus Effect to occur. Many of the studies included in the Ratan et al. (2019) review meet the strict ‘avatar’ definition, although some do not. For instance, two studies by Jesse Fox (Fox and Bailenson (2009), Fox, Bailenson, et al. (2009)) were included in the review, when the experimental treatment was a 3D virtual representation (doppelganger) of the self which was not controlled by the user. If the aim of the review was to assess the broader research question of ‘behaviour change through self-representation’, then it would make sense to include Fox and Bailenson (2009), but also similar studies such as those by Ahn (2016), Ruiz et al. (2012), which also used doppelgangers to manipulate behaviours⁷.

⁷A further, minor, point is that in the height version of the Proteus Effect (N. Yee & Bailenson, 2009, Study 2) participants avatars were not technically visual representations, since there was no mirror condition as there was in the Study 1. Participants in this study would have simply felt taller or shorter than the confederate’s avatar. Although this may not be a major criticism, it is worth noting, since the implications

Presence of Stereotypes.

In the original definition of the Proteus Effect, there needs to be a popularly-held belief about the probability that a certain group, represented by the appearance of the avatar, will perform a behaviour. There are some cases in the studies selected by Ratan et al. (2019) in which this is not the case. For instance, Y. J. Sah et al. (2017b) asked participants to customise an avatar to represent either their ideal, actual, or ought selves, and to play a game (YooBoot) in which various health-related behaviours were conducted. Although observed behaviours were affected in game (once health consciousness was held constant), the mechanism behind this effect is somewhat different since: 1. participants in the ought and ideal conditions presumably created their avatars to reflect behaviours that they wanted/felt compelled to perform on some level; 2. the differential between an actual and ideal/ought self does not represent an out-there stereotype; 3. Participants were conscious of the attributes that the avatar held, since they designed the avatar! This is somewhat different to a participant being unwittingly assigned an avatar that somehow triggers an unconscious assumption of how the avatar should act, and then acting in a commensurate way. As above, if the scope of the research question is to be expanded, then there are notable omissions that also used avatar customisation as a manipulation (e.g. Darville et al., 2018; Jin, 2012; Kim & Sundar, 2012).

Studies with Questionable Methods

The meta-analysis also included a number of studies that had methods that deviated significantly from the majority or contained questionable results.

Methodological Deviations.

First, in the study by Yulong Bian et al. (2015), participants did not actually control an avatar, but observed images of avatars and were asked to imagine what they would do in a similar situation and respond on a self-report survey.

In the reported study by Lee-Won et al. (2017), male participants who created more muscular avatars after having their masculinity “threatened” created more muscular avatars and spent longer on a hand-grip endurance task than those who were not threatened. It is not clear whether the hand-grip effect was due to the avatar, or whether the avatar and handgrip task had a common cause, the masculinity threat. As such, the study was omitted from the analysis.

Questionable Results.

The study by Yoon and Vargas (2014a) has been heavily criticised in a recent review by Hilgard (2019). In this study, the variances were unusually small for the task, and the effects were questionably large. This study ought to be excluded from the meta-analysis, or at the least checked for sensitivity of the overall effect size.

are different - participants would have only drawn visual cues from the confederate, so this may represent an opponent perception effect, such as the Kohler effect, (Feltz, 2011, p. @kohler1926), rather than a self-perception effect.

There is also a high risk of bias in the Yulong Bian et al. (2015) study, since the two reported studies were in fact conducted on the same sample, but with different questionnaires, which yielded conflicting results. Rather than reporting this as such, the authors reported the conflicting results not just as a different hypothesis, but as a totally different study.

In conclusion, the weaknesses discussed warrant an updated meta-analysis in which these issues are addressed.

Replication & Extension

In the reproduction of Ratan et al. (2019), I demonstrated that the estimated effect size was reproducible from the data, and that this effect size was not overly sensitive to the removal of studies with questionable and deviate methods. I also demonstrated that the proposed moderators from Ratan et al. (2019) were not statistically robust.

Following the reproduction, I revisited the studies reported by Ratan et al. (2019) and noted certain methodological issues within the review. These issues are broadly related to the selection of studies, and the choice of effect sizes from each study. Based on these issues, I concluded that a replication and extension of the meta-analysis was warranted.

Operational Issues

Search Terms

The search strategy used by Ratan et al. (2019) was a limitation of the study. In the methods section they state that they queried a variety of databases with the search term “Proteus Effect”, completed ancestry searches, contacted authors for grey literature, and looked for papers that “did not necessarily use the term Proteus Effect” yielding 83 potential papers for inclusion. Ideally, the initial search terms would be more comprehensive, or if multiple searches were run, each set of search terms would be reported. Since the first published use of the term ‘Proteus Effect’ in the Human-Computer Interaction field was in 2007, wider searches would have made the strategy more accurate and reproducible, since various studies using avatars to effect changes attitudes and behaviours were published prior to this date; including at least one by the team that coined the name (Yee & Bailenson, 2006). This may have resulted in a number of important early studies being omitted from the meta-analysis

Omission of Non-significant effects

The effects within the Ratan et al. (2019) meta-analysis appear to have been selected based on the statistical significance of the results. This represents a source of bias, and ideally both non-significant and significant effects would have been included in the random effects model.

For example, in one study (N. Yee & Bailenson, 2009 study 2), the predicted effect was that participants in the *tall* avatar condition would negotiate more aggressively in the

first cut of an ultimatum game than those in the *short* avatar condition. What was found was that participants were more aggressive in the second cut, and this was explained *ad hoc* as participants “testing the waters” of the game before getting assertive (p 285). Ideally, the hypothesised effect would have been included in the meta-analysis, rather than the significant one. However, it’s understandable that this early study could be regarded as exploratory in nature, and future hypotheses be updated to reflect this. However, there was an attempted replication of this study in N. Yee and Bailenson (2009) in which the original hypothesised ‘first cut’ effect was observed, rather than the second cut effect found in the original. This effect was included in the meta-analysis, rather than the updated expectation of the second cut, which was non-significant. Amazingly, in a third replication (N. Yee & Bailenson, 2007, dissertation study 2), the observed effect reverted back to the second cut, in line with the original study - which was the effect Ratan et al included in their meta-analysis. A way around this would be to either aggregate multiple effects from each study into one estimate (Quintana, 2015) , or to conduct a multi-level meta-analysis in which all effects contribute towards the final effect size (Voorre, 2016).

Study Coding

In the majority of studies, the effect sizes reported by Ratan et al. (2019) were reproducible. Notable exceptions were Aviles (2017), DeRoij (2017), Sah (2017), Via (2016) in which different effect sizes were found. In some cases, the reported r values in the meta-analysis did not match the reported d values in the corresponding papers.

Ratan et al converted F scores to point biserial correlation coefficients; however, many of the studies used ANCOVA rather than ANOVA, for example controlling for T1 attitudes. The calculation to convert an ANCOVA F requires the number of covariates and the multiple correlation coefficient between predictors and outcome; details which are seldom reported. If these are not included in the conversions, the effect size will be inflated. For instance, the value reported by Ratan for McCaine et al (2018) was $r = 0.21$ ($d = 0.42$), when McCain et al reported an effect size of $r = 0.15$ ($d = 0.3$). It is entirely possible that this effect size inflation is the reason behind the larger effect sizes observed for studies that included moderators.

A second issue was with the calculation of effect sizes using ANOVAs when there were more than two groups. The use of standardised effect sizes such as Cohen’s d or Pearson’s r as effect sizes in meta-analyses is reliant on there being two comparable groups. This is because d is the standardised mean difference between two groups, and r in this case is the point-biserial correlation which requires two separate conditions that are non-dichotomised (i.e. have no underlying continuity). Not meeting these assumptions when converting F to a standardised effect size will result in inaccurate estimates. In my replication of the meta-analysis, where there were more than three levels of an independent variable, effect sizes were calculated from means and standard deviations (all calculations are available in the supplemental R code).

Ratan et al. (2019) also seem to have an aversion to negative effect sizes. There were a number of studies in which the effect was actually opposed to the hypothesised direction. For instance, Ash (2016) predicted that people playing a boxing game as a black avatar

would be more aggressive than those using a white avatar, as measured by the number of punches thrown by participants in game. In fact, the reverse was found, and people using white avatars threw more punches. Instead of including this behavioural measure in the meta-analysis, Ratan et al. (2019) opted for the number of stereotype-related words used in a writing task after the game, rather than including a negative effect size which would presumably have reduced the overall effect size. A similar finding in which people using white avatars were more aggressive than those using black avatars was reported by Via (2016)⁸. In the replication, effect sizes will have a sign that indicates the corroboration with direction of the hypothesis.

Rationale

To address the issues with definitions that were discussed above, I acquired the papers from the Ratan et al. (2019) study, summarised the hypotheses, and re-coded the effects. This time all relevant reported effects were calculated and included. To address the possible sensitivity of the analysis to the effects chosen for inclusion, I ran a combinatorial multiverse meta-analysis on the new dataset to explore the number of *paths* that arrive at the value reported by Ratan et al. (2019). In addition, I re-ran the database searches using more inclusive terms, and papers that were either missed by the original meta-analysis or had not been published were included.

Methods

Study Selection

Ratan et al dataset.

All papers from the Ratan et al. (2019) meta-analysis were accessed and screened for inclusion with the exception of Gomes (2013) which was not available. The studies that were excluded in the reproduction were also excluded from the replication.

Database searches and screening.

The 2019 meta-analysis only queried the databased with the term “Proteus Effect”, which as mentioned above may have missed studies conducted prior to 2007 when the names was coined. In the replication and extension of the meta-analysis, search terms from a previous systematic review on the effects of avatar appearance on health-related behaviours were adapted for all behaviours (O. Clark et al., 2019). These included terms for avatars, virtual reality, as well as the Proteus Effect, and exclusionary terms for the various biological factors with the same name.

RIS acquired from the databases were uploaded to Rayyan.qcri for filtering and selection (Ouzzani et al., 2016). Rayyan is a free, machine learning based systematic review

⁸This was not discussed as an instance of the Proteus Effect - presumably because there is an assumption that white people are not stereotypically aggressive, despite a bloody history of colonisation, genocide and world domination attempts. In fact, white violence is a common, but undiscussed theme in Proteus Effect research: in Pena (2009), participants operated avatars that were wearing Ku Klux Klan robes - a group that were notoriously both violent and white.

assistant that allows sorting by inclusionary and exclusionary keywords, and ranks entries based on their relevance. The review has been made available for interested readers to access [<https://rayyan.qcri.org/reviews/178339>].

Breadcrumb Trail.

A variety of different databases were queried, additional terms were added in later searches to narrow down the number of retrieved articles. The terms used to query each database are reported below:

- Web Of Science > (“Proteus effect”) OR (avatar OR “Virtual self” OR “digital self”) 4124
- Scopus > (“Proteus Effect” OR ((avatar OR “virtual self”) AND stereotyp)) *AND NOT (cancer OR "stem cell")* 167
- Microsoft > (“Proteus Effect” OR (avatar OR “virtual self” AND stereotyp)) *AND NOT (cancer OR "stem cell")* 38

((“Video games” or games) AND (Character OR Avatar)) AND (Stereotype OR stereotyping OR stereotypes OR identification OR influence OR behavior* OR appearance)

- PsyArticles > “Proteus Effect” OR ((avatar OR (‘video game’ AND character) AND (behaviour* OR stereotyp* OR attitud*)) 55
- PsychInfo > “Proteus Effect” OR ((avatar OR (‘video game’ AND character) AND (behaviour* OR stereotyp* OR attitud*)) NOT (schizophrenia or psychosis or psychoses or psychotic disorder or schizophrenic disorder) > Empirical and Quantitative only = 1015

The first search on WebOfScience yielded 4124 entries. These were manually screened by title to remove any studies that were clearly irrelevant. This was achieved by filtering the entries by exclusionary; the three most common of these were ‘patient*’, ‘therapy’, and ‘agents’⁹.

After filtering on the first RIS file had been completed, searches were run on the additional databases Scopus, Microsoft Academic, PsychArticles, and PsychInfo. The unique entries were then uploaded to Rayyan and ranked for relevance before selection.

After selection, a total of 80 studies, and 168 effects were included in the meta-analysis.

Figure 5 presents a flow diagram of the selection procedure.

⁹The term Agent is Usually indicative of the use of computer, rather than human controlled virtual models - although the terms agent and avatar were frequently used interchangeably to mean computer controlled, which complicated selection (Fox, Ahn, et al., 2015).

Figure 5*Prisma Flow chart*

Coding

All effect sizes were calculated using the `compute.es()` package in R (Del Re, 2013). Where possible, the `mes()` function was used to calculate effect sizes from means, standard deviations and cell sizes. If data were presented visually, rather than in text, the software WebPlot Digitiser was used to extract the values from graphs and error bars (Rohatgi, 2017). It was quite common for cell sizes to not be reported which made calculating sample sizes difficult. In these cases, the sample size, inferred from the degrees of freedom reported with the inferential statistics were split in half. This is not ideal and may result in an overestimation of the effect size, meaning that the final value represents the *largest possible* effect size. In cases where means and standard deviations from multiple groups were presented, marginal means and standard deviations were calculated to isolate avatar manipulation. Where means and standard deviations were not available, inferential statistics were converted to standardised effect sizes, provided that these were available for two groups. The procedure for calculating the effects sizes and reproducing Table 3 is provided on <https://osf.io/9b5fm/>.

Categorisation

Next, each study was coded for whether or not it strictly followed the postulates of the Proteus Effect. The dataset contains studies that fall under two categories: Proteus Effect, in which all three postulates are met; and Virtual Perspective Taking, in which users controlled an avatar that had stereotypical attributes, but the goal was to reduce prejudice rather than assimilate behaviours. Initial analyses were run only on the Proteus Effect studies, but an additional analysis includes perspective taking studies too. Perspective taking studies were defined as studies in which the outcome was an attitude towards a group, rather than an attitude or behaviour consistent with a stereotype of a group (e.g. Implicit Association Task (Greenwald et al., 1998)). Studies that met the criteria for Virtual Self Modelling were omitted from the dataset.

Additional methods of coding included the platform that the study was conducted on (Desktop or Virtual Reality), and whether the behaviour or attitude was measured during (peri) the virtual experience, or afterwards (post). Little work has been conducted on the longer term effects of avatar exposure, and the evidence that does exist is not very convincing.

Multiverse Analysis

As discussed above, some of the choices for selecting the effect to include in the meta-analysis were not made explicit by Ratan et al. (2019). It is possible that some of the effects were selected because they yielded a larger meta-analytic effect than others. Although there is no reason to believe that these decisions were premeditated, there is a variety of ways in which the analysis could have been conducted, simply by including some effects instead of others. These decisions may be seen as representing forks in a path that one may choose, with each fork resulting in an alternate outcome (Gelman & Loken, 2013, p. @orben2019association). In approaching this potential source of bias, a form of Multiverse

analysis called Combinatorial Meta-Analysis was conducted (see Voracek et al., 2019). In its purest form, Combinatorial MA would involve analysing all possible combinations of studies, which would result in 2^{k-1} (i.e. 2^{45}) possible combinations of studies, ignoring that there are multiple effects per study! Since this is an unfeasible number of meta-analyses to conduct, a Monte Carlo method was employed in which a single effect, chosen at random, was selected from 46 of the studies included in the replication of Ratan et al. (2019). This was assumed to represent the range of possible meta-analyses that could have been run if effects and studies were arbitrarily selected from the range of possible studies. Here then, of the 80 studies, and 168 effects included in the analysis, 46 were selected 1e4 times, the resultant datasets were analysed using the `rma()` function in `metafor`, and the summary statistics reported and plotted.

Of course, the Ratan et al. (2019) meta-analysis did not include negative effects, which may have led to the overall effect size being diminished substantially, so the analysis was re-run on the absolute effect size estimates.

To estimate whether the year in which the meta-analysis was conducted may have affected the outcome, the above combinatorial meta-analysis was repeated a further six times, capping the year in which a study was conducted between 2015 and 2020.

Multi-Level Modelling

Using a Bayesian multi-level framework, a random effects estimate was calculated for each study, with each relevant reported effect being included in the estimation. Relevance was defined as any measured attribute that would be expected to change if the Proteus Effect occurred. For instance, if a study randomly assigned the avatar's gender and measured maths ability and self-presence, only maths ability would be relevant.

Weakly informative priors were placed on the intercepts and beta coefficients of the models. By default, `brms` sets a half-t prior on all parameters, however this omits negative values. Instead a normal prior centred on 0 with a standard deviation of 0.5 was placed on all parameters. This is very wide, given that the measure is a transformed correlation coefficient, but allows it assigns the majority of the probability density to feasible values (i.e. ± 1).

The models were built up from intercept only to a full model with all moderators included:

$$y_{ij} \sim 1 + (1|study)$$

$$y_{ij} \sim 1 + Behaviour_{0,1} + (1|study)$$

$$y_{ij} \sim 1 + Behaviour_{0,1} + Between_{0,1} + (1|study)$$

$$y_{ij} \sim 1 + Behaviour_{0,1} + Between_{0,1} + (1|study)$$

$$y_{ij} \sim 1 + Behaviour_{0,1} + Between_{0,1} + Platform_{VR,DT} + (1|study)$$

Results

Table 3 presents the effects identified in the selected papers. The results are separated into two sections, multi-level Bayesian modelling, and multiverse analysis.

Manipulations and Outcomes

Unsurprisingly, groups with visually salient features were the most common Proteus Effectors over all studies. Common manipulations included gender, race, age, and body shape. Figure 6 presents the frequencies of each by study (not by effect).

Figure 6
Frequencies of Stereotyped groups used as Proteus Effectors.

The most common stereotypes that were conjoined with these effectors were the stereotype that women are inferior at maths, that black people are aggressive, that old people are slow, and that fat people are lazy or lack control.

Outcomes were broadly divided into attitudes and behaviours, and included aggression, perceptual tasks (e.g. size estimation), creativity, cognitive ability, decision making, pro and anti-social behaviour, and health related outcomes such as exercise intensity and food consumption. Behaviours were measured using interpersonal distance with a confederate, quantity of hot sauce dispensed to another participant, decisions made during and

after avatar use (e.g. ultimatum game splits), in game behaviour such as number of items collected, or number of punches thrown in a boxing game. Health-related measures included intensity of exercise and unhealthy food consumption. Attitude measures were predictably self-report measures, including displaced aggression, rape myth acceptance, and self-objectification. Behavioural measures of attitudes included Implicit Association Tasks, but these were used in perspective taking studies rather than strict Proteus Effect studies.

The notation describing each manipulation-outcome pairing can be found in the full dataset (<https://osf.io/9b5fm/>).

Platforms, Games, and Environments

Most studies were conducted using desktop or console systems, rather than fully immersive VR, and over half of the treatments were bespoke environments made specifically for the research. Second Life was the most common consumer product to be used, which make sense because it has a flexible avatar creation system. Three Dimensional avatars were used most frequently outside of immersive virtual reality.

Table 3

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
1	Ash2016	-0.20	82.00	Aggression	Aggression	Fight	DT	TPS	Peri	0	0	0
1	Ash2016	0.07	82.00	Aggressive Cogni- tion	Aggression Black Black	Fight Night 4 Night 4	DT	3D	Post	1	0	0
1	Ash2016	-0.02	82.00	Aggressive Affect	Aggression Black	Fight Night 4	DT	3D	Post	1	0	0
2	Aviles2017	0.10	130.00	BlackIAT	Bias Race	Sims 4	DT	TPS	Post	0	1	0
2	Aviles2017	0.08	130.00	BlackExplicit	Bias Race	Sims 4	DT	TPS	Post	0	1	0
3	Aymerich-Franch (2014) study 1	0.15	54.00	Anxiety	Anxious Self	Bespoke	VR	Embodied	Peri	0	1	0
4	Aymerich-Franch (2014) study 2	0.11	105.00	Anxiety	Anxious Self	Bespoke	VR	Embodied	Post	0	1	0
5	Banakou 2013	0.53	29.00	Size esti- mation	Perception Age	Bespoke	VR	Embodied	Peri	0	1	1
5	Banakou 2013	0.60	29.00	Size esti- mation	Perception Age	Bespoke	VR	Embodied	Peri	0	1	1
5	Banakou 2013	0.47	29.00	Size esti- mation	Perception Age	Bespoke	VR	Embodied	Peri	0	1	1
6	Banakou 2016	0.37	59.00	Black IAT	Bias Race	Bespoke	VR	Embodied	Post	0	1	0
7	Banakou 2018	0.37	30.00	Tower of London perfor- mance change	Intelligence Scientist	Bespoke	VR	Embodied	Post	0	1	0
7	Banakou 2018	0.49	30.00	Age IAT change	Bias Age	Bespoke	VR	Embodied	Post	0	1	0
8	Beaudoin2020	0.11	104.00	Mental imagery walking speed	Speed Age	Bespoke	VR	Embodied	Peri	0	1	1
9	BehmMorrowitz2009	0.09	218.67	Attitudes to women cog capes	Objectification Sexualisation	Tomb Raider	DT	3D	Post	1	1	0
9	BehmMorrowitz2009	0.13	218.67	Attitudes to women physical capabili- ties	Objectification Sexualisation	Tomb Raider	DT	3D	Post	1	1	0
9	BehmMorrowitz2009	-0.01	218.67	Attitudes to ap- pearance	Objectification Sexualisation	Tomb Raider	DT	3D	Post	1	1	0
9	BehmMorrowitz2009	-0.04	218.67	Attitudes to gen- der roles be-	Objectification Sexualisation	Tomb Raider	DT	3D	Post	1	1	0
10	Bian2015	0.35	90.00	Typical behaviour	Social Attractive	Sims 3	DT	3D	Post	0	1	0
11	Bian2015 study 2	0.18	90.00	Typical behaviour	Social Attractive	Sims 3	DT	3D	Post	0	1	0
12	Buisine2016	0.76	12.00	User needs	Userfocus Archetype	Second Life	DT	3D	Peri	0	0	0
12	Buisine2016	0.32	12.00	Technical uses	Creativity Inventor	Second Life	DT	3D	Peri	0	0	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
12	Buisine2016	0.26	12.00	Product functions	<i>Creativity Inventor</i>	Second Life	DT	3D	Peri	0	0	0
13	Buisine2020	0.29	68.00	Fluency	<i>Creativity Inventor</i>	Second Life	DT	3D	Peri	0	0	0
13	Buisine2020	0.34	68.00	Perceived Creativity	<i>Creativity Inventor</i>	Second Life	DT	3D	Peri	0	0	0
13	Buisine2020	0.39	20.00	Uniqueness	<i>Creativity Inventor</i>	Second Life	DT	3D	Peri	0	0	0
14	Chang2019	0.01	76.00	Amount learned (maths)	<i>Learning gender</i>	Bespoke	VR	Embodied	Post	0	1	0
14	Chang2019	0.00	76.00	Maths	<i>Math Gender</i>	Bespoke	VR	Embodied	Post	0	1	0
15	Chen2015	0.39	28.00	Displaced aggression	<i>Aggression Gender</i>	Quake 3	DT	FPS	Post	0	1	0
16	Christou2014	0.11	96.00	Body blows	<i>Aggression</i>	Bespoke	VR	Embodied	Peri	0	0	1
16	Christou2014	0.17	96.00	Velocity	<i>Species Aggression</i>	Bespoke	VR	Embodied	Peri	0	0	1
17	Cicchirillo2015	0.04	175.00	Affective Aggression	<i>Species Aggression Race</i>	GTA	DT	3D	Post	0	1	0
18	Clark2019	-0.14	52.00	Time around an exergame track	<i>Laziness Fat</i>	Bespoke	DT	3D	Peri	0	0	0
19	Driesmans2015	0.31	57.00	RMA	<i>Serism Sexualisation</i>	Story of Arado	DT	Static	Post	0	1	0
19	Driesmans2015	0.29	57.00	Tolerance of harassment	<i>Serism Sexualisation</i>	Story of Arado	DT	Static	Post	0	1	0
20	Eastin2006	-0.44	71.00	Aggressive thoughts	<i>Aggressive Male</i>	Unreal Tournament	DT	FPS	Post	0	1	0
21	Eastin2006b	-0.24	72.00	Aggressive thoughts	<i>Aggressive Male</i>	Unreal Tournament	DT	FPS	Post	0	1	0
22	Eastin2009	-0.16	168.00	Aggressive thoughts	<i>Aggression Race</i>	Unreal Tournament	DT	FPS	Post	0	0	0
23	FerreraGarcia2018	-0.03	40.00	Body Distortion	<i>Objectification Sexualisation</i>	Bespoke	VR	Embodied	Post	0	1	0
23	FerreraGarcia2018	-0.07	40.00	Body Dissatisfaction	<i>Objectification Sexualisation</i>	Bespoke	VR	Embodied	Post	0	1	0
24	Fox2013	0.29	82.00	Body thoughts	<i>Objectification Sexualisation</i>	Bespoke	VR	Embodied	Post	0	1	0
24	Fox2013	0.00	86.00	RMA	<i>Objectification Sexualisation</i>	Bespoke	VR	Embodied	Post	0	1	0
25	Fox2015	0.28	83.00	Self Objectification	<i>Objectification Sexualisation</i>	Second Life	DT	3D	Post	0	1	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
25	Fox2015	0.19	83.00	RMA	<i>Objectification Sexualisation Delinquency Age</i>	Second Life	DT	3D	Post	0	1	0
26	VanGelder2013	0.25	67.00	Test Cheating		Bespoke	VR	Embodied	Post	0	0	0
27	Goris2019	-0.11	68.00	Spheres dodged Robot	<i>Competence Robot</i>	Bespoke	VR	Embodied	Peri	0	0	1
27	Goris2019	0.08	68.00	vs Dplgr Spheres Dodged SuitVs-	<i>Competence SciFiSuit</i>	Bespoke	VR	Embodied	Peri	0	0	1
27	Goris2019	0.10	68.00	Dplgr Perceived vulnerability, rbtvsd-	<i>Vulnerability Robot</i>	Bespoke	VR	Embodied	Post	0	1	1
27	Goris2019	-0.11	68.00	plg Perceived vulnerability, rbtvsd-	<i>Vulnerability Sfsuit</i>	Bespoke	VR	Embodied	Post	0	1	1
27	Goris2019	0.09	68.00	plg Perceived integrity rbtvsd-	<i>Integrity Robot</i>	Bespoke	VR	Embodied	Post	0	1	1
27	Goris2019	-0.01	68.00	plg Perceived integrity rbtvsd-	<i>Integrity SFSuit</i>	Bespoke	VR	Embodied	Post	0	1	1
28	Groom2009	-0.25	49.00	plg Black IAT	<i>Bias Race</i>	Bespoke	VR	Embodied	Post	0	1	0
29	Guegan2016	0.40	54.00	Fluency	<i>Fluency Inventor</i>	Second Life	DT	3D	Peri	0	1	0
29	Guegan2016	0.64	54.00	Uniqueness	<i>Uniqueness Inventor</i>	Second Life	DT	3D	Peri	0	1	0
30	Happ2013	0.27	60.00	Hostile perception bias	<i>Aggression Hero</i>	MK_Vs_DCOT	3D	3D	Post	0	1	0
30	Happ2013	-0.14	60.00	Judgement of violence	<i>Aggression Hero</i>	MK_Vs_DCOT	3D	3D	Post	0	1	0
30	Happ2013	0.27	60.00	Probability of letters being picked up	<i>Prosocial Hero</i>	MC_Vs_DCOT	3D	3D	Post	0	0	0
31	Hasler2016	0.02	32.00	IAT change	<i>Bias Race</i>	Bespoke	VR	Embodied	Post	0	1	0
32	Heng2017 study 1	0.34	75.00	HOT SAUCE	<i>Aggression Hero</i>	Warcraft3	DT	3D	0	0	0	0
33	Heng2017 study 2	0.45	78.00	HOT SAUCE	<i>Aggression Hero</i>	Warcraft3	DT	3D	0	0	0	0
34	Hershfield2011	0.26	50.00	HypotheticalSaving money saved	<i>Saving Older</i>	Bespoke	VR	Embodied	Post	0	1	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
35	Hershfield2011 Study 2	0.35	21.00	Short term dis- counting	<i>STD</i> <i>Older</i>	Bespoke	VR	Embodied	Post	0	1	0
35	Hershfield2011 Study 2	0.27	21.00	Long term dis- counting	<i>LTD</i> <i>Older</i>	Bespoke	VR	Embodied	Post	0	1	0
35	Hershfield2011 Study 2	0.27	21.00	Retirement Spend- ing	<i>RS</i> <i>Older</i>	Bespoke	VR	Embodied	Post	0	1	0
36	JooKim2017	-0.04	124.00	Steps Taken	<i>Laziness</i> <i>Fat</i>	Sims 4	DT	3D	Post	0	0	0
36	JooKim2017	-0.07	124.00	Food eaten	<i>Diet</i> <i>Fat</i>	Sims 4	DT	3D	Post	0	0	0
37	Junetal2015	0.13	40.00	Steppability	<i>Stride</i>	Bespoke	VR	Embodied	Peri	0	0	1
37	Junetal2015	0.84	40.00	Gap width judge- ment	<i>Stride</i> <i>Footsize</i>	Bespoke	VR	Embodied	Peri	0	0	1
38	Kaye 2018	-0.01	113.00	Total Score	<i>Gameability</i> <i>Gender</i>	Kima Kumba High	DT	Platform	Peri	0	0	0
38	Kaye 2018	0.03	113.00	PDR	<i>Gameability</i> <i>Gender</i>	Jump Kima Kumba High	DT	Platform	Peri	0	0	0
38	Kaye 2018	0.07	113.00	Task Compe- tence	<i>Competence</i> <i>Gender</i>	Jump Kima Kumba High	DT	Platform	Post	0	0	0
38	Kaye 2018	0.08	113.00	Self- esteem	<i>Esteem</i> <i>Gender</i>	Jump Kima Kumba High	DT	Platform	Post	0	0	0
38	Kaye 2018	-0.05	113.00	Self Effi- cacy	<i>Efficacy</i> <i>Gender</i>	Jump Kima Kumba High	DT	Platform	Post	0	0	0
39	Kilteni 2013	0.41	36.00	Groove	<i>Rhythmic</i> <i>Black</i> <i>Arhythmic</i> <i>White</i>	Jump Bespoke	VR	Embodied	Peri	0	0	0
40	Lee 2014	0.21	120.00	Maths ability	<i>Maths</i> <i>Gender</i>	Bespoke	DT	Static	Peri	1	0	0
41	Lee 2018	0.09	95.00	Self dis- closure	<i>Selfdisclosure</i> <i>Age</i>	Bespoke	DT	2D	Peri	0	0	0
42	Li2014	0.20	140.00	Exergame perfor- mance	<i>Laziness</i> <i>Fat</i>	EA Ac- tive	DT	3D	Peri	0	0	0
42	Li2014	0.28	140.00	Exergame Attit- tudes	<i>Laziness</i> <i>Fat</i>	EA Ac- tive	DT	3D	Post	0	1	0
43	Lindner2019	0.24	89.00	Self Objecti- fication	<i>Serism</i> <i>Serualisation</i>	Tomb Raider	DT	3D	Post	0	0	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
43	Lindner2019	0.24	89.00	Shame	<i>Sexism</i>	Tomb Raider	DT	3D	Post	0	0	0
43	Lindner2019	0.24	89.00	Body satisfaction	<i>Sexualisation</i>	Tomb Raider	DT	3D	Post	0	0	0
43	Lindner2019	-0.13	86.00	Aggression	<i>Sexism</i>	Tomb Raider	DT	3D	Post	0	1	0
43	Lindner2019	-0.13	89.00	Other-objectification	<i>Sexualisation</i>	Tomb Raider	DT	3D	Post	0	0	0
44	Martens2018	0.76	87.00	empathising objects	<i>Sexualisation</i>	Second Life	DT	3D	Peri	0	0	0
44	Martens2018	0.76	87.00	Systematising objects	<i>Empathising Gender</i>	Second Life	DT	3D	Peri	0	0	0
45	McCaine2018	-0.15	133.00	Narcissism	<i>Systematising Gender</i>	Bespoke	VR	Embodied	Post	0	1	0
45	McCaine2018	0.02	133.00	Luxury purchasing	<i>Narcissism</i>	Bespoke	VR	Embodied	Peri	0	0	0
45	McCaine2018	0.07	133.00	Attitude towards KK	<i>Kardashian</i>	Bespoke	VR	Embodied	Post	0	1	0
46	Palomares2009	-0.03	157.00	Emotional language	<i>Narcissism</i>	Bespoke	DT	Static	Peri	1	0	0
46	Palomares2009	0.00	157.00	Apologetic language	<i>Emotion Gender</i>	Bespoke	DT	Static	Peri	1	0	0
46	Palomares2009	-0.03	157.00	Tentative language	<i>Apologetic Gender</i>	Bespoke	DT	Static	Peri	1	0	0
47	Peck2013	0.45	30.00	Racial IAT	<i>Tentative Gender</i>	Bespoke	VR	Embodied	Post	0	1	0
48	Peck2018	-0.02	63.00	Difference in congruency	<i>Bias Race</i>	Bespoke	VR	Embodied	Peri	0	0	0
48	Peck2018	0.14	63.00	Saccade accuracy	<i>Maths Gender</i>	Bespoke	VR	Embodied	Peri	0	0	0
49	Peck2020F	0.07	62.00	Difference Saccade	<i>Maths Gender</i>	Bespoke	VR	Embodied	Peri	0	0	0
49	Peck2020F	0.19	63.00	NBaccuracy	<i>Maths Gender</i>	Bespoke	VR	Embodied	Peri	0	0	0
49	Peck2020F	-0.01	63.00	Maths confidence	<i>Maths Gender</i>	Bespoke	VR	Embodied	Post	0	1	0
50	Peck2020M	0.07	63.00	Difference Saccade	<i>Maths Gender</i>	Bespoke	VR	Embodied	Peri	0	0	0
50	Peck2020M	0.04	46.00	NBaccuracy	<i>Maths Gender</i>	Bespoke	VR	Embodied	Peri	0	0	0
50	Peck2020M	-0.01	46.00	Maths confidence	<i>Maths Gender</i>	Bespoke	VR	Embodied	Post	0	1	0
51	Pena2009	0.43	52.00	Behavioural intentions	<i>Aggression Clothing</i>	Jedi Knight II	DT	3D	Post	0	1	0
51	Pena2009	0.36	52.00	Attitudes to violence	<i>Aggression Clothing</i>	Jedi Knight II	DT	3D	Post	0	1	0
51	Pena2009	0.10	52.00	Subjective norms	<i>Aggression Clothing</i>	Jedi Knight II	DT	3D	Post	0	1	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
52	Pena2009b	0.37	94.00	TAT Af- filiation	<i>Affiliation</i> <i>KKK</i>	Jedi Knight II	DT	3D	Post	0	1	0
52	Pena2009b	0.18	94.00	TAT Ag- gression	<i>Aggression</i> <i>KKK</i>	Jedi Knight II	DT	3D	Post	0	1	0
52	Pena2009b	0.10	94.00	TAT Achie- vement	<i>Achievement</i> <i>Doctor</i>	Jedi Knight II	DT	3D	Post	0	1	0
53	Pena2014	0.08	94.00	Wrist move- ments	<i>Laziness</i> <i>Fat</i>	Virtua Tennis	DT	3D	Peri	0	0	0
53	Pena2014	0.20	32.00	Waist move- ments	<i>Laziness</i> <i>Fat</i>	Virtua Tennis	DT	3D	Peri	0	0	0
54	Pena2016	0.30	76.00	Wrist move- ments	<i>Laziness</i> <i>Fat</i>	Virtua Tennis	DT	3D	Peri	0	0	0
54	Pena2016	-0.08	72.00	Waist	<i>Laziness</i> <i>Fat</i>	Virtua Tennis	DT	3D	Peri	0	0	0
55	Ratan2016	0.44	72.00	Identification??		Wii Sports Resort	DT	3D	Post	0	1	0
56	Ratan2015	0.00	144.00	Maths ability	<i>Maths</i> <i>Gender</i>	Wii Sports Resort	DT	3D	Post	1	0	0
57	Ratan2016b	0.02	144.00	Helping be- haviour	<i>Benevolence</i> <i>Superhero</i>	Bespoke	DT	Static	Peri	0	0	1
57	Ratan2016b	-0.07	144.00	Unrelated helping	<i>Benevolence</i> <i>Superhero</i>	Bespoke	DT	Static	Peri	0	0	1
58	Reinheart2020	0.44	45.00	Walk first half	<i>Speed</i> <i>Age</i>	Bespoke	VR	Embodied	Post	0	0	0
58	Reinheart2020	-0.01	45.00	Walk first half	<i>Speed</i> <i>Age</i>	Bespoke	VR	Embodied	Post	0	0	0
59	DeRooij 2017	0.21	40.00	Creativity	<i>Creativity</i> <i>Artist</i>	Bespoke	VR	Embodied	Peri	0	1	0
60	Rosenberg2013	0.26	60.00	Pens picked up	<i>Prosocial</i> <i>Hero</i>	Bespoke	VR	Embodied	Post	0	0	0
60	Rosenberg2013	0.34	60.00	Time to help	<i>Prosocial</i> <i>Hero</i>	Bespoke	VR	Embodied	Post	0	0	0
61	Sherrick2014	0.15	106.00	Feminine be- haviours	<i>FeminineTraits</i> <i>Gender</i>	Bespoke	DT	2D	Peri	0	0	0
61	Sherrick2014	-0.17	141.00	Masculine be- haviours	<i>MasculineTraits</i> <i>Gender</i>	Bespoke	DT	2D	Peri	0	0	0
62	Siebelink2016	0.00	29.00	Attribute Framing	<i>Decision</i> <i>Scientist</i>	Skyrim	DT	3D	Peri	0	0	0
62	Siebelink2016	0.30	29.00	Risk framing	<i>Decision</i> <i>Scientist</i>	Skyrim	DT	3D	Peri	0	0	0
63	Sylvia2014	-0.34	50.00	Body Esteem	<i>MuscAtt</i> <i>Muscularity</i>	Skyrim	DT	3D	Post	0	1	0
63	Sylvia2014	-0.02	50.00	Percep- tion	<i>MuscAtt</i> <i>Muscularity</i>	Skyrim	DT	3D	Post	0	1	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
64	Vandenbosch2017	0.18	115.00	Self objectification rated similarity	<i>Objectification Sexualisation</i>	Runescape	DT	3D	Post	0	0	0
65	VanDerHeide2012	-0.23	48.00	Dyad rated similarity	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
65	VanDerHeide2012	-0.21	48.00	Dyad rated intimacy	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
65	VanDerHeide2012	-0.01	48.00	Dyad rated Receptivity	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
65	VanDerHeide2012	-0.28	48.00	Observer rated similarity	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
65	VanDerHeide2012	-0.35	48.00	Observer rated Intimacy	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
65	VanDerHeide2012	-0.23	48.00	Observer rated Receptivity	<i>RelationalAffinity Attractiveness</i>	Second Life	DT	Static	Peri	0	0	0
66	Verhulst2018	-0.13	23.00	Unhealthy items selected	<i>Unhealthyfood Fat</i>	Bespoke	VR	Embodied	Peri	0	0	0
66	Verhulst2018	0.16	23.00	Healthy items selected	<i>Healthyfood Fat</i>	Bespoke	VR	Embodied	Peri	0	0	0
67	Via2016	0.15	90.00	Crimes against people	<i>Crime Race</i>	GTAV	DT	3D	Peri	0	0	0
67	Via2016	-0.17	90.00	Crimes against property	<i>Crime Race</i>	GTAV	DT	3D	Peri	0	0	0
68	Won2015	0.06	64.00	Block sorting ability	<i>Competence Robot</i>	Bespoke	VR	Embodied	Peri	0	0	0
69	Yang2014 study 1	0.12	58.00	Explicit racist attitudes - Non-violent videogame	<i>Bias Race</i>	Saints Row	DT	3D	Post	1	1	0
69	Yang2014 study 1	0.25	66.00	Explicit racist attitudes - violent videogame	<i>Bias Race</i>	Saints Row	DT	3D	Post	1	1	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
69	Yang2014 study 1	-0.01	58.00	Implicit racist attitudes - Non-violent videogame	<i>Bias Race</i>	Saints Row	DT	3D	Post	1	1	0
69	Yang2014 study 1	-0.22	53.00	Implicit racist attitudes - violent videogame	<i>Bias Race</i>	Saints Row	DT	3D	Post	1	1	0
70	Yang2014 study 2	0.24	139.00	Implicit racist attitudes - violent videogame	<i>Bias Race</i>	Fight Night 4/WWE	DT	3D	Post	1	1	0
70	Yang2014 study 2	0.47	139.00	HOT SAUCE	<i>Aggression Black</i>	Fight Night 4/WWE	DT	3D	Post	1	1	0
71	Yang2014b	0.34	236.00	HOT SAUCE	<i>Aggression Gender</i>	Virtua Fighter	DT	2D	Post	0	0	0
72	Yee2006	0.55	44.00	Word association with elderly Quiz question bias	<i>Bias Age</i>	Bespoke	VR	Embodied	Post	0	1	0
72	Yee2006	-0.01	46.00	Ambiguous story score	<i>Bias Age</i>	Bespoke	VR	Embodied	Post	0	1	0
72	Yee2006	0.14	32.00	Ultimatum split 2	<i>Bias Age</i>	Bespoke	VR	Embodied	Post	0	1	0
73	Yee2007	0.09	30.00	IPD	<i>Aggression Height</i>	Bespoke	VR	Embodied	Post	0	0	0
73	Yee2007	0.41	32.00	Self closure	<i>Prosociality Attractiveness</i>	Bespoke	VR	Embodied	Peri	0	0	0
73	Yee2007	0.38	32.00	First Split	<i>Prosociality Attractiveness</i>	Bespoke	VR	Embodied	Peri	0	0	0
74	Yee2007 Study 2	-0.06	32.00	Split 2	<i>Aggression Height</i>	Bespoke	VR	Embodied	Peri	0	0	0
74	Yee2007 Study 2	0.36	32.00	Partner choice	<i>Aggression Height</i>	Bespoke	VR	Embodied	Peri	0	0	0
75	Yee2007 Study 3	0.41	35.00	Reported Height difference	<i>Prosociality Attractiveness</i>	Bespoke	VR	Embodied	Post	0	0	0
75	Yee2007 Study 3	0.46	35.00	IPD	<i>Prosociality Attractiveness</i>	Bespoke	VR	Embodied	Post	0	0	0
75	Yee2007 Study 3	0.27	35.00	Split 1	<i>Prosociality Aggression Height</i>	Bespoke	VR	Embodied	Peri	0	0	0
76	Yee2009	-0.36	40.00	Split 2	<i>Prosociality Aggression Height</i>	Bespoke	VR	Embodied	Peri	0	0	0
76	Yee2009	-0.09	40.00			Bespoke	VR	Embodied	Peri	0	0	0

Table 3 continued

ID	Study	r	n	Outcome	Notation	Game	Platform	Avatar	Peri_Post	Main	Behaviour	Between
77	Yoon2014	0.48	112.00	Chocolate	<i>Aggression</i> <i>Villain</i>	Bespoke	DT	2D	Post	0	0	0
77	Yoon2014	0.57	112.00	Chilli	<i>Prosocial</i> <i>Hero</i>	Bespoke	DT	2D	Post	0	0	0
78	Yoon2014b	0.69	112.00	Chilli	<i>Aggression</i> <i>Villain</i>	Bespoke	DT	2D	Post	0	0	0
79	Yoo2015	0.20	112.00	Time to navigate book-store	<i>Speed</i> <i>Age</i>	Bespoke	DT	FPS	Peri	1	0	0
79	Yoo2015	0.21	112.00	Magazine selection	<i>Interests</i> <i>Age</i>	Bespoke	DT	FPS	Peri	1	0	0
79	Yoo2015	0.05	112.00	NPO el-derly attitudes	<i>NPOAttitudes</i> <i>Age</i>	Bespoke	DT	FPS	Post	1	1	0
79	Yoo2015	0.41	128.67	Facebook friends intentions	<i>NPOIntentions</i> <i>Age</i>	Bespoke	DT	FPS	Post	1	1	0
79	Yoo2015	0.26	128.67	NPO el-derly attitudes	<i>Donations</i> <i>Age</i>	Bespoke	DT	FPS	Post	1	1	0
79	Yoo2015	0.34	61.00	Volunteer time	<i>Volunteer</i> <i>Age</i>	Bespoke	DT	FPS	Post	1	1	0
80	Zipp2019	-0.06	152.00	Time taken to help	<i>Prosociality</i> <i>Race</i>	Bespoke	DT	3D	Peri	0	0	0
80	Zipp2019	0.01	152.00	Errors	<i>Prosociality</i> <i>Race</i>	Bespoke	DT	3D	Peri	0	0	0

Note. Table of effects, sample sizes, outcomes, notation, and moderator coding. Peri = data collecting during the virtual experience, Post = data collected after virtual experience; DT = Desktop, VR = Virtual Reality; Static = static 2D avatar, 2D = controllable 2D avatar, 3D = controllable 3D avatar, embodied = motion tracked avatar.

Table 4

	Estimate	Est.Error	Q2.5	Q97.5
Model.1				
Intercept	0.13	0.03	0.07	0.2
Model.2				
Intercept.1	0.12	0.04	0.04	0.2
Behaviour	0.02	0.04	-0.05	0.09
Model.3				
Intercept.2	0.12	0.04	0.04	0.21
Behaviour.1	0.02	0.04	-0.05	0.09
Within	-0.02	0.12	-0.25	0.22
Model.4				
Intercept.3	0.15	0.05	0.05	0.24
Behaviour.2	0.02	0.04	-0.05	0.09
Within.1	0.01	0.13	-0.24	0.25
Platform	-0.06	0.07	-0.2	0.08

Note. Table of posterior parameter estimates for full, attitude, and behaviour only datasets.

Multi-level Modelling

The meta-analytic effect estimates, and credible intervals can be found Table 4. Presented in Figure 7 is a Bayesian forest plot of the posterior effect size estimate of each study.

From Table 4 we can see that the effect size estimated from the new dataset with all effect sizes is 0.13, 95% Credible Interval = [0.07,0.2]. The effect, when including all relevant results from a larger and more selective corpus, is considerably smaller than the value proposed by Ratan et al. (2019). Given the argument that attitudes, and behaviours ought to be correlated, I have analysed the whole corpus together and included moderators rather than running separate analyses for attitudes and behaviours.

Model Comparison.

Four nested models were compared using Leave One Out Cross Validation information criterion (Vehtari et al., 2018), starting with the intercept only, and incrementally adding dummy variables for Behaviour vs Attitude, and VR vs Desktop platforms. Table 5 provides the Expected Log Predicted Density (ELPD) estimates for each model. The intercept-only model provided the optimal fit for the data, suggesting that the contribution of the moderators to predictive accuracy was negligible.

Predictors.

Although the intercept only model provided the optimal fit for the data, posterior estimates and 95% credible intervals for the beta coefficients on the predictors are presented

Figure 7

Bayesian Forest plot of posterior effect size estimates

Table 5

	elpd_diff	se_diff	elpd_loo	se_elpd_loo	p_loo	se_p_loo	looic	se_looic
Intercept_DV	0.00	0.00	-2.66	19.08	81.23	9.94	5.32	38.15
Mod_DV.3	-1.74	1.26	-4.40	19.32	83.26	10.06	8.81	38.63
Mod_DV.2	-1.95	1.24	-4.61	19.42	83.54	10.21	9.23	38.84
Mod_DV.1	-2.03	1.16	-4.69	19.23	83.59	10.06	9.38	38.46

Note. Leave One Out Cross Validation of the three models. Including behaviour as a moderator provides the optimal model.

in Table 4. The moderators did indeed have negligible effect on the overall effect size estimate, but with such wide credible intervals, these are stronger estimates of the uncertainty surrounding the parameters than an estimate of the parameter themselves. Figures 8, 9, 10 present the conditional effects for each model.

Sensitivity Analysis.

I ran a variety of sensitivity analyses on the data. First, the intercept-only model was re-run using priors taken from Ratan et al (2019) to determine the extent to which the updated coding and additional studies changed the belief in the range of possible parameter values. There was very little deviation from parameter estimates of the model with weakly informative priors ($r = 0.14$)

Next, the intercept-only model was re-run without excluding studies that were omitted from the first analysis to allow an estimate of the degree of influence that these potentially questionable findings has on the overall parameter estimates. The estimates are presented in Table 6, with an additional forest tab showing how extraordinary the Yoon and Vargas results were compared with other studies (Figure 11).

Finally, the intercept-only model was run on absolute rather than signed effect sizes. The analysis was sensitive to this parameter, increasing the distribution of effect sizes to $r = 0.21$, 95% CI = [0.15, 0.26], which is closer to the estimate presented by Ratan et al. (2019), but still smaller. It is debatable whether negative effect sizes ought to be included in the analysis, but the calculations of the effects are consistent with the results of each paper given the expected values.

Multiverse Analysis

The average effect size across 1e4 iterations was 0.14 (SD = 0.03).

Figure 12 presents a histogram of the range of meta-analytic effect sizes. When negative effect sizes were included, the occurrence of values in the range of $r = 0.22$ - 0.26 like those reported by Ratan et al. (2019) were exceptionally rare, with a value of that or greater only being observed 0.11% of the time. The implication here is that the small to moderate effect size only emerges under very specific decision paths. The most common r values are clustered around $r = 0.14$. However, when an absolute effect size was taken

Figure 8

Conditional effects Behaviour.

Table 6

Sensitivity analysis of intercept only models.

	Estimate	Est.Error	Q2.5	Q97.5
Ratan.Prior				
Intercept	0.14	0.03	0.08	0.2
All.studies				
Intercept.1	0.16	0.03	0.1	0.22
No.negatives				
Intercept.2	0.21	0.03	0.15	0.26

Figure 9

Conditional effects Between subjects design.

($\sqrt{r^2}$), the modal effect size was 0.21, and values in the range presented by Ratan et al. (2019) were more common. In this analysis, a negative effect size was included when the observed effect was in the opposite direction to the one expected. Greater clarity in how hypotheses are framed and how reversed effects are handled may need additional discussion in meta-analyses if outcomes are this sensitive to their inclusion.

Publication Bias

When the Ratan et al. (2019) dataset was presented as a funnel plot centred on an effect size of 0 (Figure 4), a large cluster of studies fell on the line indicating a marginal ($p \approx 0.05$) significance which may be an indicator that non-significant effects were absent from the literature. This interpretation depends on the assumptions that *a.* only studies reporting significant effects are published; *b.* studies that have null findings are stuffed in a “file-draw”, meaning that they never see the light of day (Rosenthal, 1979). Arguably, if only studies with significant findings are published, only a single p-value of less than 0.05 is required to pass the publication barrier. As I discussed earlier, there was evidence that Ratan et al. (2019) selected only significant effects from studies yielding mixed findings which could also explain the pattern observed in Figure 4. This may be an issue when meta-analysts are restricted to reporting a single effect size for each study. Figure 14 presents

Figure 10

Conditional effect platform.

the current dataset as a funnel plot.

When negative effects are included in the plot, the distribution is far more symmetrical than the plot created from the Ratan et al. (2019) dataset. Figure 15 presents the same dataset with negative effects removed and also shows a more even distribution of points. Given this, it is likely that the asymmetry observed in Figure 4 was a result of motivated selection of effect sizes, rather than publication bias per se.

Discussion

Even after removing unsuitable studies from the Ratan et al. (2019) paper, 68 studies were found that met the strict inclusion criteria for Proteus Effect, and 75 when Perspective Taking studies were included. Although several of the new studies were potentially published after the Ratan et al. (2019) paper was finished (10 studies were conducted between 2019-2020), studies such as Eastin et al (2006), and Yee et al (2006) were clear examples of the effect of avatar appearance on attitudes and behaviours.

The updated estimate of the Proteus Effect was smaller than the one proposed by Ratan et al. (2019). Although their estimate was within the 95% credible interval of the current model, the pathways to an effect of a similar magnitude to that of Ratan et al.

Figure 11

Bayesian Forest plot of posterior effect size estimates, including omitted studies

Figure 12

Histogram of multiverse effect sizes. Orange = MVA with negatives; Blue = MVA with no negative effect sizes.

(2019) were particularly rare when negative values were included, as shown in the multiverse analysis suggests that the effect was sensitive to the decisions that the authors made when selecting the results to include in the analysis.

Of all 168 coded effects, 48 were negative. Negative effect sizes occurred when the mean of the group that was expected to be higher was lower than the mean of the group that was expected to be lower¹⁰. It could be argued that coding these direction reversals has biased the outcome of the meta-analysis, but I feel I have provided a fair definition of a negative (rather than a null) effect. Providing an absolute (i.e. positive) effect size for each study obviously increased the meta-analytic effect size.

As in the reproduced analysis, there were none of the observed variables moderated the prediction of effect size estimates. That platform (VR vs desktop) did not moderate the Proteus Effect was an interesting observation, since this suggests that expensive equipment is not a necessity for eliciting an attitudinal or behavioural change, meaning that the research in the field is accessible to researchers who do not have access to such facilities.

It is prudent to critique the interpretation of the 2019 meta-analysis when comparing

¹⁰The justification for each decision is provided in the study coding script, <https://osf.io/tjkxz/>.

Figure 13

Plot of possible effect sizes by hypothetical year of completion

with the current analysis. Although the reported effect of $r = 0.24$ might be “small to medium” using Cohen’s descriptors, in the same book Cohen (2013) also warns that effect sizes should be interpreted in the context of the effect sizes in similar fields. In the context of Social Psychological research, Ratan’s estimate of $r = 0.24$ is above average. In a meta-analysis of meta-analyses (a meta-meta-analysis) of 100 years of research in social psychology, Richard et al. (2003) estimated the average effect over 474 reviews to be $r = 0.21$, with a by-topic range of $0.13 - 0.27$. The closest topic to the Proteus Effect in the analysis is expectancy effects ($r = 0.13$), i.e. the theory that people act how they think others expect them to. Since the Proteus Effect is a type of expectancy research, it ought to have a similar strength of effect.

Ratan et al. (2019)’s estimate places the Proteus Effect as nearly as strong as the consistency between an individual’s attitudes and behaviours (which again is a theory that is nested in the Proteus Effect), and as strong as the average effect size for a century of aggression research. The current effect size is more conservative, and arguably more consistent with the laboratory effects observed in similar subfields¹¹. The current analysis

¹¹An important sidenote is that the study by Richard et al. (2003) was conducted prior to the Replication Crisis in Psychology, and it is possible that many of the effects were inflated either through questionable research practices or fraud. Other authors have suggested that publication bias may have also inflated the

Figure 14

Funnel plot of effect sizes from the current meta-analysis.

Figure 15

Funnel plot of the analysed dataset with no negative effect sizes.

places the Proteus Effect below the average for *all* of social psychology, but comparable with theories that make similar predictions. This is arguably a more realistic estimate, since if avatar appearance *actually* changed attitudes and behaviours with an effect size of $r = 0.24$, which is roughly equivalent to a half standard deviation increase, then someone who would usually perform in the 50th percentile in a maths test would on average suddenly find themselves in the 70th percentile on account of using a male, rather than a female avatar!

The key message is that the Proteus Effect may not be as strong as previously believed once a larger proportion of existing studies and reported effects are accounted for, but this is not to say that the effect is not interesting.

General Discussion

A Proteus Paradox?

In his 2014 book, Nick Yee frames the Proteus Effect as contributing to a paradox surrounding the technological revolution, whereby rather than leading to a postmodern digital Eutopia, with the unlimited freedom of malleable identities afforded by virtual environments, behaviours and attitudes are actually restricted to commonly held stereotypes (Yee, 2014, p. p5).

Yee's Proteus Paradox was intended to be cautionary, suggesting that without reflection, virtual environments can reinforce harmful stereotypes, and even make them self-fulfilling (e.g. as suggested in Yee et al., 2011). With some exceptions (e.g. Jessica McCain et al., 2018), researchers investigating the Proteus Effect have become preoccupied with endless demonstrations of the Proteus Effect, making few theoretical progressions. I argue that simply demonstrating the Proteus Effect serves only to show that a particular stereotype is accessible, which is not useful in its own right since without the stereotype existing there would be no point in conducting the study! Rather than these demonstrations, researchers might explore pathways to a hypothetical *Kratos* Effect¹² in which Proteus is slain and the effect is eradicated. By doing so, Yee's Proteus Paradox may resolve, and we may edge closer to the predicted postmodern Eutopia that some authors predicted (e.g. McGonigal, 2011; Turkle, 1995); or at the very least it may be an indicator of a more tolerant society. I present arguments for killing the Proteus Effect in the following paragraphs.

Reliance on Stigma.

At its root, the Proteus Effect relies on readily available knowledge of common stereotypical evaluations. Unfortunately, the most accessible stereotypes are those of groups who are stereotyped (and often stigmatised) based on their appearances. Although there were arguably some *value neutral* representations included, such as the use of super-heroes and villains (Yoon & Vargas, 2014), or humans and *aliens* (e.g. Christou & Michael, 2014)¹³,

estimate (Funder & Ozer, 2019).

¹²Although Kratos is a Greek mythological figure, I reference here the protagonist of the God of War video games - a character who slays the panthea of several ancient civilisations over 4 games.

¹³These were actually humanoid shapes wearing fetish-looking sci-fi garb.

the vast majority of the studies included in the Ratan et al. (2019) and current meta-analyses used the following stereotypical generalisations to elicit behavioural or attitudinal assimilation:

- Race: Black people are aggressive/have *rhythm*
- Height: Shorter people are submissive
- Gender: Women are bad at games and maths; men are aggressive
- Body size: Fat people are lazy
- Occupation: White collar workers are not creative
- Attractiveness: *Ugly* people are shy
- Clothing: Women who wear revealing clothing have *looser* definitions of consent.

None of these stereotypes are valid, and their uncritical applied use ought to be discouraged in research. This may seem extreme, but it was relatively common for discussion sections of papers to generalise findings and make unwarranted (albeit well intentioned) suggestions to the public and games developers. For instance, some authors suggest that if fat avatars make people slower, or female avatars make people worse at maths, then such avatars should avoid if the goal is to promote these behaviours e.g. Benjamin J. Li et al. (2014)]. Similar suggestions were made about the availability of gender normative items such as high heels and lipstick in avatar creation software (Rabindra Ratan & Sah, 2015)¹⁴. Such an approach threatens to put the cart before the horse, since stereotypical knowledge is not innate but acquired through exposure to inaccurate and unrepresentative representations.

The Proteus Effect is a consequence of this “knowledge”, and so if such stereotypes are challenged, then the effect should be attenuated. Indeed, a more useful approach would be to take a critical stance, set existing research as a baseline, and then look to reduce or eliminate the effect.

What about “Positive” Stereotypes?

It might be argued that there is little harm in using so called ‘positive’ stereotypes to invoke *Stereotype Lift*, however even these are problematic, for a number of reasons. For instance, in the Kilteni et al. (2013) study on race/dress and musical creativity, relies on the stereotype of black people being more rhythmic than white people¹⁵. Although these might be seen as “positive” stereotypes, they are rooted in condescension and may contribute towards inequality (Czopp & Monteith, 2006). Secondly, the ‘superiority’ of one group implies the inferiority of other groups which is itself harmful (e.g. the stereotype that Asian people are good at maths implies that any other race will underperform in comparison).

Ideally, HCI researchers would stop asking what behaviours a person’s race, gender, or body size can elicit or inhibit, and start asking how these differences can be reduced. Under what conditions can both athletic and fat avatars out-perform someone with no avatar? Such a condition would be far more useful and interesting than simply restating that stereotypes exist.

¹⁴I did not see any suggestions to ban black avatars.

¹⁵...and the fallacy that those who wear suits are not creative

Moral Panics.

Some of the authors of the studies in this review suggest imposing restrictions on the number of avatar customisation options available in games and other virtual platforms. By reducing these options, typically called affordances, controllers are limited in the degree to which they can represent or express themselves in virtual environments. Such restrictions have been shown to be frustrating for people wishing to accurately represent themselves in terms of race, gender, hair colour, and potentially religious expression (McArthur, 2018). Such restrictions also have the knock-on effect of homogenising virtual environments and leading to social pressures to not break the mould (Kafai et al., 2007).

A potential explanation for such extreme suggestions is that they are unintentionally Draconian responses to various recent moral panics, such as videogames causing antisocial attitudes and behaviours (aggression, rape myth acceptance), educational attainment discrepancies, and the moralisation of body size (Townend, 2009). For instance, if fatness is seen as categorically bad, then drastic measures might be justifiable, but fatness is not categorically bad.

Although these suggestions are well meaning, they call to mind adage of the patient who goes to their GP complaining of a pain in their eye whenever they drink tea. They've tried switching mugs, brands, decaf, and are thinking of giving up tea altogether, wherein the GP asks if they've tried removing the teaspoon from the cup prior to drinking. The observed behaviours and attitudes are generated from stereotypes that exist outside of the game or the environment, although media in general (including games) may have a part to play in their propagation and reinforcement. Rather than restricting representation, an alternative approach would be to create balanced representations of different groups.

The Kratos Resolution

There is some evidence that the nullification of the Proteus Effect is possible. In Yee's original doctoral thesis there is an unpublished study in which the absence of stereotypical knowledge about a group led to a reversal of the predicted direction of the effect (N. Yee & Bailenson, 2007). Moreover, one study suggested that the desirability of a trait may be a boundary condition for the Proteus Effect, i.e. that if a trait is undesirable it will not be adopted (Jessica McCain et al., 2018). In this study, attempts were made to evoke narcissism using a television personality as an avatar¹⁶.

This Kratos Effect could be achieved in a number of ways. Given the preliminary findings of Marine Beaudoin et al. (2020), the first might be to reduce *in-here* stereotypes, although this moderating factor needs further investigation. Assuming subjective attitudes are a moderator, this could be achieved using a pre-avatar use perspective taking task followed by a virtually mediated situation in which the stereotypical behaviour may be performed as an avatar. According to Galinsky and Moskowitz (2000), the overlap between

¹⁶Were this the case, it would imply that rather than laziness in studies such as Benjamin J. Li et al. (2014) and Jorge Peña et al. (2016), it is the desirable trait of 'fitness' that is evoked in these studies; but there is no clear way to determine this with the studies currently available.

self-concept and the in-group leads to a greater accessibility of the self-concept relative to the knowledge of the stereotype, and so the Proteus Effect ought to be nullified¹⁷.

Providing richer information about an avatar prior to use may affect the Proteus Effect. A study on the use of Personas suggests that attitudes and behaviours may be influenced when an ‘archetypal’ character is used in a virtual environment. A Persona is a typical user of a service, institution, device, etc and is generally presented as a vignette describing the individual’s habits, attitudes, and , with or without an image (Bornet & Brangier, 2013). A Persona is dynamic when an interactive character is provided, which may also be used as an avatar (Bonnardel et al., 2016). It is feasible that if an avatar from a particular group is presented as an archetype (e.g. literature student), or even a synthetic archetype in which a back-story and attribute list is provided, the availability of this relevant information will surpass the accessibility of the irrelevant stereotypical information.

Finally, in Chapter 8 of my doctoral thesis, I demonstrated that the negative stereotypical evaluations of fat exemplars (un-controlled avatars) was reduced when counter-stereotypical information was provided, presents early estimates that this may translate into behaviour, but stress that much more data is required to confirm this (O. J. Clark, 2019). Participants rated the appropriateness of a set of fat-related negative stereotypical as less appropriate when the larger exemplar was animated running than standing idly. We concluded that stereotype activation was reduced because more information was provided about the exemplar. This method could easily be applied to future Proteus Effect research.

Of course, in hunting for the Kratos Resolution, researchers will be searching for null effects which are difficult (or impossible) to detect using the standard statistical toolbox¹⁸. In providing evidence for no effect, equivalence testing may be employed (e.g. the Two One Sided T-test Lakens et al., 2018), or Bayesian methods which allow for the quantification of evidence in favour of one hypothesis over another¹⁹(Kruschke & Liddell, 2017).

Limitations, suggestions, and future directions

The data from this meta-analysis is fully open, and all calculations are transparent. The analysis was conducted using freely available open source software and so it may be replicated or reproduced by other interested researchers. Using these materials, I encourage other researchers to add their own results to the analysis so that this project may become a cumulative effort.

There are weaknesses to the review. The procedure was not pre-registered, and so some of the decisions made will have been *ad hoc*, although I have attempted to be as transparent about these decisions as possible. The analysis method may be subject to bias,

¹⁷It may be argued that using an out-group avatar is itself a perspective taking activity:- which yields a second paradox: if embodying an avatar leads to an overlap in self-concept and avatar identity, and thus a reduction in implicit and explicit bias, and if increasingly positive subjective attitudes reduce the Proteus Effect, then Proteus Effect experiments ought to cancel out their own effects!

¹⁸For instance, if a study yields a non-significant p value, this could be a. because the sample was too small; b. because of a type 2 error which would happen 20% of the time with 80% power; c. because the intervention to reduce the Proteus Effect was successful.

¹⁹The posterior distributions from this meta-analysis could be used as priors in such studies.

since it requires an estimate of the prior probability of a range of values; I have attempted to address this using a range of different prior distributions.

Suggestions

My critique has been quite scathing of current research lines, but this is not to say that there is no room for existence proofs or demonstrations, but these would ideally build the theory further or contribute towards the reduction of the Proteus Effect. Such a research programme might treat such demonstrations as conceptual replications and include an extension in the design (much like this review has). For instance, a lab that is interested in whether embodying an Asian avatar improves maths ability (a common stereotype) might also include a measure for subjective stereotyping too which would build on the findings of Marine Beaudoin et al. (2020). If, as suggested by Marine Beaudoin et al. (2020), personally held (*in-here*) stereotypes do in fact moderate the Proteus Effect, then attempts at a Kratos resolution could offer a useful metric for the effectiveness of bias reduction or counter-stereotyping methods. Arguably, if a counter stereotyping method works then there should be no difference between avatars with different attributes and participants would have the freedom to act as they intend to.

Researchers could investigate Player-Avatar relations profiles, and how these might affect the strength of the Proteus Effect (Banks et al., 2019). Might someone who is pre-disposed to treat an avatar as a tool, or an object be less likely to assimilate attitudes and behaviours? A further possibility could be to investigate whether meta-stereotypes affect Proteusque responses²⁰. An assumption of the Proteus Effect is that participants behave in the manner that they assume observers expect, so would this vary depending on the observer? For instance, if there is a meta-stereotype that religious groups have stronger negative attitudes towards those wearing sexualised attire than atheist groups; would being observed by someone who is visibly affiliated with a religious group affect the attitudes and behaviours of the controller of a sexualised avatar?

The distinction or interaction between attitudes and behaviours should also be further explored in future literature. They have previously been treated as separate, but according to theories of behaviour change they should be correlated; indeed, the Theory of Planned Behaviour claims that there is a causal relationship between the two²¹. It might be interesting to pair attitude measures with direct observations of behaviours to explore whether the predictions of the Theory of Planned behaviour are corroborated by avatar assimilation research.

A potential argument against extending designs is that of power. Adding more predictors will reduce the available degrees of freedom in a model and increase the number of participants required to reliably observe an effect. Moreover, additional comparisons also increase the false positive rate of findings (Bender & Lange, 2001). Indeed, it is notable that many of the studies in the dataset had small sample sizes (median = 68, range = 12, 236), which directly impacts the power of the study to detect smaller effect sizes. An under-used method to improve the power of Proteus Effect studies is the one sided test (Lakens,

²⁰A meta-stereotype is a stereotype about the stereotypes held by a group (Vorauer et al., 2000)

²¹Self Perception Theory also claims a causal relationship, but in the opposite direction.

2017). Since the Proteus Effect makes very specific predictions, it should be unnecessary to compare an observed effect with both tails of the distribution. Conducting one tailed tests on future effects would be beneficial for laboratories that have fewer resources. As for including predictors, researchers might pre-register a confirmatory analysis investigating a main effect of interest and declare additional predictors as exploratory. If an interesting effect is found, then this could be replicated in a subsequent study.

This review is far from comprehensive, and so there is additional meta-scientific work to be conducted. The extent to which there is publication bias in the Proteus Effect corpus could be further explored, possibly using more up-to-date methods such as p-curve or z-curve analyses. Moreover, an assessment of the risk of bias would also be valuable. This was not conducted here because I had already read all of the papers and formed opinions about the study, and so my assessment of bias in the studies would be influenced by this prior knowledge. Ideally the criteria for judging risk of bias is pre-registered prior to data collection, and so I invite interested researchers to pick this up, possibly using the Cochrane tool for assessing risk of bias (Higgins et al., 2011).

Conclusion

I have attempted to present a coherent model of the Proteus Effect which allows researchers to communicate their hypotheses and distinguish the Proteus Effect from Perspective Taking and Virtual Self Modelling studies. The meta-analysis by Ratan et al. (2019) was reproducible, but an updated estimate suggests that the Proteus Effect is weaker than suggested, with no substantial moderators. The updated effect size is consistent with meta-analyses from other areas of Social Psychology. I have argued that although the effect appears to be robust, the line that current research is on could be more theoretically interesting and useful if attempts were made to reduce or eliminate the Proteus Effect.

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