Me, Myself and My Body – The Full-Body Illusion and the Effects of an Extreme Virtual Body Size

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Abstract

Even though the average body weight has increased dramatically over the last four decades, the thin ideal dominates Western society. Looking at pictures of thin and obese bodies have previously been shown to affect food choices and body satisfaction. This study used a virtual reality full-body illusion to induce ownership over an either anorexic or obese virtual body, and measured body satisfaction and food choices before and after the manipulation. The sample consisted of 54 females with a normal body size, without any eating disorders. Neither the anorexic nor the obese body did significantly influence food choices. Participants in the anorexic condition showed a marginally significant increase in body satisfaction after the illusion, but no such effect was found for the obese condition. Participants were significantly more satisfied with the anorexic than the obese body. Furthermore, similarity between the real and virtual body did not affect illusion strength. These results indicate that the relationship between body size, food choices and body satisfaction is possibly more complex than previously thought.

Keywords: full-body illusion, embodiment, body size, food choices, body satisfaction, anorexia, obesity

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Even though the average body weight has increased with 1.5 kg per decade since 1975 (NCD Risk Factor Collaboration, 2016), the 1980s and 1990s saw a dramatic decrease in the ideal body size of fashion models (Sypeck, Gray, & Ahrens, 2004). Today, the thin ideal is dominating the Western society (Polivy, Garner, & Garfinkel, 1986), and could be the cause of eating disorder symptoms similar to those seen in anorexia nervosa (Hawkins, Richards, Granley, & Stein, 2004). Moreover, body size is closely related to food choices. Not only are food choices associated with body size (Maskarinec, Novotny, & Tasaki, 2000), but body size could also be an important factor for the food choices that you make (Brunner & Siegrist, 2012; McFerran, Dahl, Fitzsimons, & Morales, 2010).

In 2016, 40% of women globally were considered overweight and 15% obese, where overweight is defined as having a body mass index (BMI=kg/m^2) of more than 25, and obesity as having a BMI of more than 30 (World Health Organisation, 2006). This could be due to a change towards the so-called "Western diet" (Kanoski & Davidson, 2011), which mainly consists of processed foods (such as cookies, breakfast cereals and pizza) that are high in refined sugars and refined vegetable oils (Cordain et al., 2005). These types of foods are usually energy-dense, that is they have a high number of kilocalories (kcal) per unit weight (Drewnowski, 1998). Higher kcal consumption than expenditure leads to weight gain (Hall et al., 2011), and overweight and obesity are associated with several health risks, such as type 2 diabetes, hypertension, cancer (Kopelman, 2007) and increased mortality (Troiano, Frongillo, Sobal, & Levitsky, 1996). Furthermore, overweight people are viewed as unhealthy (Ferraro & Yu, 1995), unattractive (Robinson, Bacon, & O'Reilly, 1993), unlikeable (Yanover & Thompson, 2010) and having a lack of willpower (Fardouly & Vartanian, 2012).

Half of all women are dissatisfied with their weight and 64% of those within the normal range believe that they should lose weight (Matthiasdottir, Jonsson, & Kristjansson, 2012). Women consider a BMI of 18-19 to be the ultimate (Coker & Abraham, 2014). In comparison, a BMI of below 18.50 is considered to be underweight (World Health Organisation, 2006) and a BMI below 16.99 is used to define moderate anorexia (American Psychiatric Association, 2013). In Western society, the prevalence rate of anorexia nervosa has been estimated to be somewhere between 0.1% and 5.7% for females (Makino, Tsuboi, & Dennerstein, 2004). Exposure to mass media has been proposed as one cause for the disorder, with one study showing an increase in disordered eating after the introduction of Western television in a media-naïve population (Becker, Burwell, Herzog, Hamburg, & Gilman, 2002). Having an anorexic body weight can cause several life-threatening medical conditions, as well as depressive symptoms. Nevertheless, anorexic models are considered to be both healthy and attractive (Whisenhunt et al., 2012).

The relationship between body size and body satisfaction can also be extended to include the observation of other people's bodies and to the experienced ownership over a different body type. The latter has been made possible by the development of virtual reality (VR). Viewing media images of people with a thin-ideal body leads to decreased body satisfaction (Grabe, Ward, & Hyde, 2008; Groesz, Levine, & Murnen, 2002; Ogden & Mundray, 1996; for a meta-analytic review see Groesz, Levine, & Murnen, 2001), while viewing pictures of overweight people leads to an increase in body satisfaction (Ogden & Mundray, 1996). Conversely, Preston and Ehrsson showed that ownership over an ideal virtual body leads to increased body satisfaction (Preston & Ehrsson, 2014), and that ownership over an obese body leads to decreased body satisfaction (Preston & Ehrsson, 2016). Preston and Ehrsson (2014, 2016) used a full-body illusion (FBI) to evoke ownership

over the virtual body. The FBI is built on the classical rubber-hand illusion (RHI) by Botvinick and Cohen (1998), and encompasses the synchronous stroking of a virtual and a real brush on a virtual (seen) body and the participant's own body. Preston and Ehrsson (2014, 2016) measured body satisfaction directly after ownership over the virtual body had been established, and before the participants had seen their real body. To our knowledge, no previous study has investigated if body satisfaction with the real body can be affected by ownership over another body size, as measured after having had the opportunity to update one's body image with one's real body.

Using the FBI in a manner similar to Preston and Ehrsson (2014), Piryankova et al. (2014) showed that it is possible to experience ownership over even more extreme body types, such as a virtually anorexic (comparable to a BMI of 16) and morbidly obese (comparable to a BMI of 43) body, and that ownership is experienced equally strong for both conditions. In their study, the participants were first allowed to explore the room and the virtual body for a period of one minute, after which they were synchronously stroked for two minutes. This approach allows for both sensorimotor and visuotactile integration, which provides a way for the participants to incorporate the virtual body into their own body image (Maselli & Slater, 2013). It has previously been shown that similarity in bodily appearance (skin texture and clothing) is important for the strength of embodiment in the FBI (Maselli & Slater, 2013). Likewise, in order to maximise the strength of the RHI, the rubber hand should be positioned in peripersonal space (Preston, 2013), and be aligned with the real hand (Pavani, Spence, & Driver, 2000). Similarity in skin tone can also strengthen the illusion (Lira et al., 2017). Even though Piryankova and colleagues (2014) showed that the anorexic and obese body could be incorporated into the body image to an equal extent, it is not known if illusion strength is affected by similarity in body size between the virtual and real body.

More important, no previous study has used the FBI to investigate how ownership over an anorexic or obese body influences behaviour, such as food choices. The FBI allows us to experimentally manipulate body size and facilitates the separation of body size from other factors, such as the perceived heaviness/lightness of one's body and/or previous experiences related to having an anorexic or obese body. If we were to study clinically anorexic and obese participants, it would be impossible to disentangle the effect that body size has on food choices from other factors, since body size itself is a result of previous food choices. Thus, in order to isolate body size from other factors, we can use the FBI in an immersed virtual environment to evoke temporal ownership over a virtual anorexic or obese body in participants with a normal body size.

Every day, people make food choices that affect their body shape and weight. Both health benefits and physical appearance are reasons for dieting (Putterman & Linden, 2004), with 80% of women believing that they should lose weight (Matthiasdottir et al., 2012). Making healthy food choices are important to succeed with dieting. Foods that are high in water (such as vegetables and fruits; Rolls, Drewnowski, & Ledikwe, 2005) are a suitable choice, since these add weight to a meal but are still low in energy (as measured in kcal; Rolls & Bell, 2000). Energy density in food does not affect the feeling of fullness, even when the same amount of food is consumed (Bell, Castellanos, Pelkman, Thorwart & Rolls, 1998). The consumption of less energy-dense food can therefore be effective for weight loss (Bes-Rastrollo et al., 2008).

Food choices are influenced by a number of factors, such as emotions (Macht & Simons, 2000), sleep (Markwald et al, 2013), health beliefs and dieting (Wardle et al., 2004). Furthermore, observing an obese person (either in real life or on a picture) can decrease the desire to eat (Barthomeuf, Droit-Volet, & Rousset, 2011; Barthomeuf, Rousset, & Droit-

Volet, 2009) and lead to choosing smaller portion sizes (McFerran et al., 2010), possibly because people are reminded of the relationship between food choices and body size (Campbell & Mohr, 2011). A similar relationship also exists for observing a thin person (Brunner & Siegrist, 2012; Krahé & Krause, 2010). It has been suggested that exposure to the thin ideal activates a goal of having a healthy body weight, which results in less food consumption (Brunner & Siegrist, 2012). However, it is not known how ownership over an obese or anorexic body affects food choices. Since a decrease in body satisfaction can lead to an increase in dieting behaviour (Cooley & Toray, 2001), ownership over an obese body could possibly lead to a decrease in kcal intake. On the other hand, ownership over a thin body has been shown to increase body satisfaction (Preston & Ehrsson, 2014) and it is therefore possible that such a body will evoke an aim towards keeping the thin body size by eating accordingly. A similar relationship could be true for ownership over an anorexic body, since even anorexic models are considered attractive (Whisenhunt et al., 2012). Another possible outcome is that the kcal intake is slightly increased, since an anorexic body is thinner than the ideal body type (Coker & Abraham, 2014).

In this study, we used the FBI to induce the experience of ownership over an anorexic or obese body in a manner similar to what Piryankova et al. (2014) did. We wanted to (1) examine if the experience of having an anorexic or obese body, induced by the FBI, could alter behaviour, in this case hypothetical food choice. Our second aim was to (2) investigate if the difference between the participants' BMI and the BMI of the virtual body affected the strength of the FBI. Furthermore, we examined if (3) satisfaction with the real body changed from pretest to posttest, and if (4) satisfaction with the virtual body differed between the anorexic and obese condition.

We expected that participants would choose food with fewer kcal than normally

(pretest) after experiencing an obese body (posttest), and that they would choose food with more kcal or the same amount of kcal than normally after experiencing an anorexic body. We hypothesised a negative correlation between BMI difference and illusion strength, such that the illusion would be experienced more strongly when the BMI of the real and the virtual body showed less of a difference, irrespective of condition. Furthermore, we hypothesised that participants would experience more satisfaction with their real body after having ownership over the obese body and more or the same degree of body satisfaction after ownership over the anorexic body. Finally, we anticipated that the participants would show more satisfaction with the anorexic than the obese body.

Method

Participants

The participants were recruited via Radboud University's participation system, thus our sample consisted mainly of students. Only females with a self-reported (previously reported when creating a profile in the participation system) BMI in the normal range of 18.5-24.9 (World Health Organisation, 2018) were able to access the study online and were informed that, in order to participate, they should not follow a vegetarian/vegan diet that prohibited them from consuming milk and/or eggs. Following the same reasoning as Piryankova and colleagues (2014), we chose to only include females, since there exists a gender difference in estimating one's own body size (Thompson & Thompson, 1986) and since the results of our study could be of importance for future research on eating disorders, a disorder that affects more females than males (Croll, Neumarksztainer, Story, & Ireland, 2002). Furthermore, there is a difference in the way that high and low body dissatisfied males and females rate the attractiveness of different body types (Cho & Lee, 2013).

In this study, 137 people stated interest in participating, by filling in an online (created

in Qualtrics; version January-May, 2018) pre-screening questionnaire (Eating Attitudes Test; Garner, Olmsted, Bohr, & Garfinkel, 1982) examining disordered eating behaviours (see Measures). We excluded 10 females with a potential eating disorder (i.e., a score ≥ 20 on the Eating Attitudes Test) and 5 females who indicated that they vomited after eating. As a result, 122 females were invited to participate and 59 showed up for participation. After weight and height had been measured in the laboratory, 4 people were excluded because their BMI exceeded 25 and 1 person because she had indicated that she had eaten closer than three hours before the experiment.

Our final sample consisted of 54 females, with a mean age of 22.3 years (range = 17-40, *SD* = 4.5). After subtracting 0.7 kg for clothing, the participants had an average weight of 61.2 kg (*SD* = 7.0) and an average height of 167.9 cm (*SD* = 7.4), resulting in a mean BMI of 21.7 (*SD* = 1.5). The participants had not eaten anything for on average 5.6 hours (*SD* = 3.7) before the start of the experiment.

We aimed to include 70 females, which is slightly higher than what is required for detecting a medium-sized interaction effect, with power of 1-ß = .80, since we took into account the reduction of sample size when excluding participants not experiencing the illusion. However, due to time limits, we were unable to reach the originally planned sample. After removing 6 participants who did not experience ownership over the virtual body, we had a final sample of 48 participants and a power to detect a medium-sized mixed-factors interaction effect of 1-ß = .76.

The study took 30-45 min, and the participants were rewarded with either €10 or course credit. The experiment was conducted in accordance with the declaration of Helsinki and approved by the Radboud University Ethics Committee Faculty of Social Sciences.

Technical Setup

The participants wore a head-mounted display (HMD; HTC Vive™), with a display resolution of 1080 * 1200 px per eye and a display refresh rate of 90 Hz. The HMD had a 100° nominal field of view and an interpupillary distance of 63 mm. The weight of the HMD was 555 g. Two wireless hand controllers (included in the HTC Vive set) facilitated hand- and arm tracking, with 6 degrees of freedom. The hand controllers also allowed the participants to pick up a menu and make food choices from it. The VR set-up was created in Unity® (Version 2017.1.) and the hand- and arm movements were made possible using the plugin Final-IK by Rootmotion.

Visual Stimuli

In order to manipulate experienced body size, an anorexic and an obese avatar were created using the Morph3D MCS package for Unity (Version 2017.1). The avatars' body- and hand poses were made in Autodesk MotionBuilder® (Version 2017). The anorexic avatar had a body size corresponding to a BMI of 16, and the obese avatar had a body size similar to that of a BMI of 43, in accordance with the study by Piryankova et al. (2014). The body sizes were created in accordance with the validated body-only picture database developed by Moussally, Rochat, Posada and van der Linden (2016) and the avatars' height and arm lengths were scaled to match the participants'. The virtual brush that was seen stroking the avatars' arms (see Procedure) was created in Autodesk® 3ds Max® (Version 2017).

The virtual room was modelled to correspond to the room in which the experiment took place. The room included the armchair in which the avatar was seated, a footstool, a small table to the left side of the armchair and a menu (see Measures – Food Choices) standing on the table; all created using Autodesk 3ds Max (Version 2017). The texture for all 3D models and the graphics for the menu were made in Adobe Photoshop CS6.

Measures

Eating Attitudes Test. The Eating Attitudes Test (EAT-26; Garner et al., 1982) examines attitudes towards dieting, body weight and eating behaviours. It consists of 26 statements (e.g., "I am terrified about being overweight"), which are measured on a 6-point Likert scale, ranging from "never" to "always". A score of or above 20 indicates a potential eating disorder. The EAT-26 is a reliable and valid instrument (Garner et al., 1982).

Body Image States Scale. The Body Image States Scale (BISS; Cash, Fleming, Alindogan, Steadman, & Whitehead, 2002) evaluates current attitudes towards and perceptions of one's physical appearance. It consists of six items (e.g., "Right now I feel […] extremely satisfied with my physical appearance") measured on a 9-point Likert-type scale, where higher scores indicate more body satisfaction. The BISS has shown to be both a reliable and valid measure (Cash et al., 2002). Half of the statements were presented in a negative to positive order and the other half in a positive to negative order. In addition, the BISS statements were adjusted (by changing "my body" to "my virtual body") to measure attitudes towards the virtual body.

Embodiment questionnaire. An embodiment questionnaire was used to assess if the participants experienced the virtual body as their own, i.e., a feeling of ownership and agency over the virtual body and the sensation of being in the same location as the virtual body (Keizer, van Elburg, Helms, & Dijkerman, 2016). We used the same embodiment questionnaire as Keizer and colleagues (2016), which consists of 20 questions (e.g., "Sometimes I felt as if the virtual body was my body") measured on a 10-point Likert scale, ranging from "completely disagree" to "completely agree". In an adaptation of questions used by Piryankova et al. (2014), we added four questions that examined experienced body size: "Sometimes I experienced my body as smaller/bigger than usual" and "Sometimes I felt

lighter/heavier than usual". A mean score of ≥ 5 was used to indicate if a participant had experienced ownership over the virtual body. We based this on previous practice with the RHI (van Stralen et al., 2014), since the FBI can be seen as an extension of the RHI (Maselli & Slater, 2013) and since the embodiment questionnaire used in the RHI has previously been adapted to examine full-body ownership (Preston & Ehrsson, 2014), with questions similar to those used by Keizer et al. (2016).

Figure 1. Example of menu. The kcal range from low (mixed fruit) to high (sundae).

Food choices. In order to measure food choices, we developed two digital menus (see Figure 1), one for the assessment of food choices at baseline and one for the assessment of food choices after experienced ownership over the virtual body. Each menu consisted of three pages, with starters, main courses, and desserts shown on the first, second, and third page, respectively. In total, each menu consisted of 18 dishes (six on each page), which were represented by a picture and a description. The pictures came from the validated food image database created by Blechert, Meule, Busch and Ohla (2014). The two menus were matched in total kcal content (i.e. 6348 kcal for menu 1 and 6351 kcal for menu 2) and the dishes had a kcal content ranging from low (i.e. 32 kcal for starters, 282 kcal for main courses, 54 kcal for

desserts) to high (i.e. 431 kcal for starters, 1098 kcal for main courses and 702 kcal for desserts). Furthermore, at least half of the dishes were lacto-ovo vegetarian and marked with a "V".

Procedure

Potential participants could find information about the general setup of the experiment online and were informed that the study was about "making food choices in virtual reality". If interested, they filled in an online pre-screening questionnaire, investigating eating disordered behaviour. We informed the participants with a score reaching the cut-off that they might have an eating disorder and that they should contact their general practitioner if this worried them. The eligible participants were contacted, invited to the lab and requested to wear black or blue jeans and black or white socks on the day of participation. Furthermore, they were instructed not to eat anything closer than three hours before the experiment was to take place.

When showing up for the experiment, the participants were sequentially assigned to either the anorexic or the obese condition. The two menus used in the experiment were counterbalanced across pretest/posttest and across virtual body size, in order to rule out any order effects.

On the day of testing, the participants were once again informed about the general setup of the experiment. After signing informed consent, we measured the participants weight and height and calculated their BMI, as a control for their previous self-reported BMI. If the BMI was above 25 or below 18.5 they were sent home, receiving €5. If eligible to participate, they were asked to change into a white t-shirt, while the experimenter left the room. Afterwards, the participants were shown an on-screen menu (see Figure 1), embedded in the Qualtrics (Version January-May, 2018) platform (used for distributing all questionnaires in this study). They were requested to indicate what they would like to eat for dinner, choosing

one starter, one main course and one dessert, by clicking on the food picture. In addition, they answered the six items from the BISS (Cash et al., 2002), which were mixed with 13 items examining life satisfaction, in order to hide the purpose of the study.

Then, the participants were asked to remove all jewellery on their hands and arms. They sat down in an armchair and put their legs and feet on a footstool. The experimenter made two markings on their right posterior forearm (4 and 13 cm from the wrist), matching the markings visible on the virtual body's arm. After being provided with the HMD and the hand controllers (visible in VR), the participants were asked to hold out their arms to the side, which enabled the program to match the height and arm length of the virtual body with the participants'. Following this, they were able to see their virtual body (either anorexic or obese).

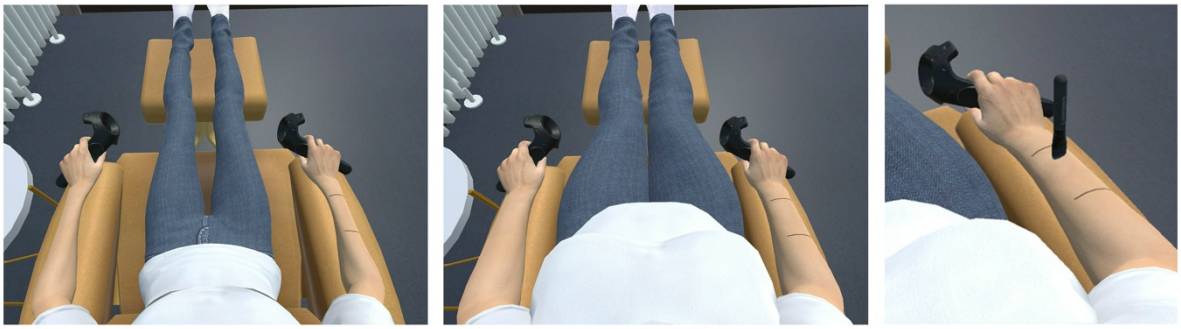

Figure 2. First-person perspective views of the anorexic virtual body (left), the obese virtual body (middle), and the virtual brush stroking the virtual arm (right).

The avatar (see Figure 2) was seen from a first-person perspective, seated in an armchair, with the legs and feet resting on a footstool. The avatar's position matched the position of the participants and allowed them to clearly see their virtual abdomen and legs. The avatar wore a white t-shirt, jeans and socks. The colour of the jeans could be adjusted to be either black or blue and the socks to be either black or white, in order to match the participants' clothes as closely as possible. During one minute, the participants had the opportunity to look around in the room and move their arms, but were asked to keep their legs

and feet still all the time and not to touch their virtual body.

Next, the participants were instructed to put their arms on the armrests and to look at their right arm. For a period of 120 seconds, the participants saw a virtual makeup brush (approximately 2 cm wide) stroking their virtual arm (see Figure 2), and felt the synchronous stroking of a real brush on their real arm. The experimenter stroked the area between the markings (9 cm) using a stroking speed of 3 cm/s (de Jong, Keizer, Engel, & Dijkerman, 2017), in order to evoke and/or strengthen the FBI. Finally, the participants were instructed to pick up the virtual menu, using their left hand controller, and to hold it in front of them (when the menu had been picked up, the hand controllers were no longer visible). They were verbally instructed to choose what they would like to eat for a starter, a main course and a dessert. The index finger on their right virtual hand was programmed to point towards the menu, and the participants marked their food choices by "touching" the food pictures on the menu. They were able to browse between the three parts of the menu by means of a "next" and a "back" button. Thus, food choices were once again measured, but now directly in VR and after ownership over the anorexic or obese body had been induced.

Following the VR task, the HMD was removed and the participants got up from the armchair and went to sit in front of the computer again, giving them the opportunity to reclaim ownership over their real body. They filled in the embodiment questionnaire (Keizer et al., 2016), the BISS (approximately 3 min after the HMD had been removed) and the virtual BISS (Cash et al., 2002), and some final questions regarding age and dieting practices. At the end of the experiment, the participants were debriefed, thanked for their effort and compensated.

Results

Assumption of Equally Strong Ownership

Before conducting the main analyses, we tested the assumption that the participants in the anorexic and obese condition had experienced the same degree of ownership over the virtual body. We examined this with a between subjects t-test. One outlier ($z = 3.11$), with a high embodiment score (9.4) was identified and removed. Levene's test for equality of variances showed that the assumption of homogeneity of variances was violated, $p = .040$. We therefore proceeded with Welch's unequal variances t-test. The anorexic group consisted of 27 females and the obese group of 26 females. The analysis showed that participants in the anorexic ($M = 6.5$, $SD = 0.8$) and the obese condition (M = *6.1*, SD = *1.2*) had experienced the same amount of ownership over the virtual body, $t(44.77) = 1.27$, $p = .211$, $d = 0.35$, 95% CI [-0.21, 0.91].

Virtual Body Size and Food Choices

The first purpose of this study was to examine if the experience of having an anorexic or obese body, induced by the FBI, could alter behaviour, in this case hypothetical food choice. In order to investigate this, we used a two-way mixed-factors analysis of variance (ANOVA), with experienced body size (anorexic or obese) as the between-subjects factor and time (pretest or posttest) as the within-subjects factor. The dependent variable was the total amount of kcal chosen (summed over starter, main course and dessert). We excluded 6 participants who did not experience ownership over the virtual body, as measured by the embodiment questionnaire (see Measures). The assumption of normality was violated for the anorexic/posttest combination, as assessed by the Shapiro-Wilk test ($p = .021$). We therefore used a square root transformation on the dependent variable, after which the data were normally distributed for all combinations of groups ($p > .05$), as measured again by the

Shapiro-Wilk test. Since 8 of the included participants had been able to guess the purpose of the study, we chose to compute a corresponding ANOVA with these participants excluded. According to the Shapiro-Wilk test, the assumption of normality was again violated for the anorexic/posttest combination ($p = .007$). After transforming the dependent variable using the natural logarithm, the Shapiro-Wilk test showed that the data were normally distributed across all combinations of groups ($p > .05$).

Our analysis showed no significant interaction between experienced body size and the time of measurement on the amount of kcal chosen, $F(1, 46) = 0.96$, $p = .331$, partial $\eta^2 = .021$ (see Figure 3). In order to answer our research question about how the anorexic and obese body affects food choices, we examined the simple main effects for time. There was no significant effect of time on the amount of kcal chosen, neither for the anorexic condition, $F(1, 25) = 0.004$, $p = .952$, partial $\eta^2 < .001$, nor for the obese condition, $F(1, 21) = 2.16$, $p = .157$, partial $\eta^2 < .093$. There was no significant main effect of time on the amount of kcal chosen, $F(1, 46) = 0.80$, $p = .377$, partial $\eta^2 = .017$, nor a significant main effect of body size, $F(1, 46) = 2.17$, $p = .147$, partial $\eta^2 = .045$. Descriptive statistics are displayed in Table 1.

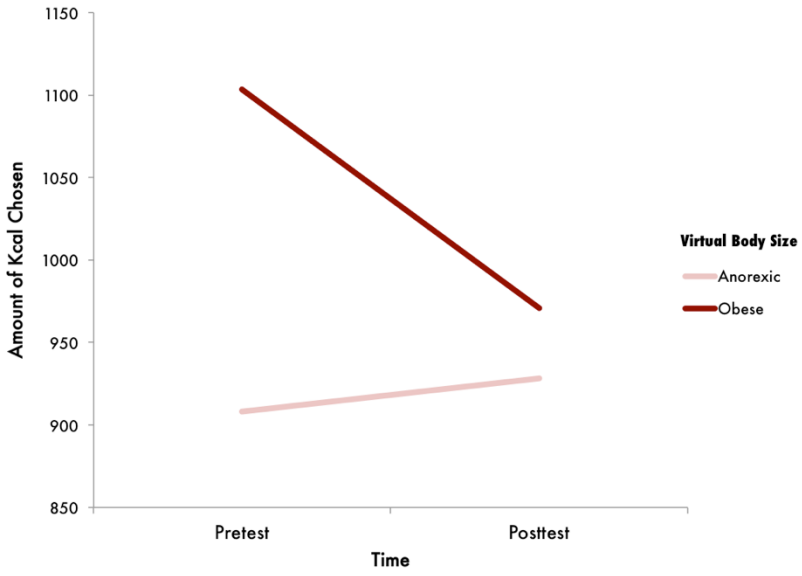

Figure 3. The effect of virtual body size on the amount of kcal chosen.

After excluding the participants who were able to guess the purpose of the study, there was still no significant interaction effect, $F(1, 38) = 0.04$, $p = .846$, partial $\eta^2 = .001$. The simple main effect of time on the amount of kcal chosen for the anorexic, $F(1, 23) = 0.03$, $p = .859$, partial $\eta^2 = .001$, and the obese condition, $F(1, 15) = 0.29$, $p = .596$, partial $\eta^2 = .019$, was not significant. There was again no significant main effect of time, $F(1, 38) = 0.20$, $p = .655$, partial $\eta^2 = .005$ nor any main effect of body size, $F(1, 38) = 3.72$, $p = .061$, partial $\eta^2 = .089$.

Table 1

Descriptive Statistics of Amount of Kcal Chosen

	Anorexic			Obese			Total		
Time	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
				Analysis 1					
Pretest	908 (29.5)	367 (6.1)	26	1104 (32.8)	375 (5.7)	22	998 (31.0)	380 (6.1)	48
Posttest	928 (29.6)	445 (7.2)	26	971 (30.6)	354 (5.9)	22	948 (30.1)	402 (6.6)	48
Total	918 (29.6)	404 (6.6)	26	1037 (31.7)	367 (5.8)	22			
				Analysis 2					
Pretest	900 (6.7)	375 (0.4)	24	1093 (6.9)	353 (0.3)	16	977 (6.8)	374 (0.4)	40
Posttest	910 (6.7)	458 (0.5)	24	1048 (6.9)	358 (0.4)	16	965 (6.8)	422 (0.5)	40
Total	905 (6.7)	414 (0.5)	24	1070 (6.9)	351 (0.4)	16			

Note. Analysis 1 includes all participants, while Analysis 2 excludes participants who were able to guess the purpose of the study. Transformed values are shown in parenthesis.

Body Similarity and Illusion Strength

Our second aim was to investigate if the difference between the participants' BMI and the BMI of the virtual body affected the strength of the FBI. In order to answer this question,

we calculated the absolute difference between the participants' BMI and the BMI of the assigned virtual body (16 for the anorexic condition, 43 for the obese condition). Thereafter, we conducted a correlation analysis between the absolute difference in BMI and the strength of the experienced illusion (i.e. embodiment score), separate for the anorexic and the obese condition, and the sizes of the two correlations were compared to each other. All participants were included in this analysis, regardless of experienced ownership over the virtual body. When examining *z*-scores, one outlier ($z = 3.11$) with a very high score (9.4) on the embodiment scale was identified and removed.

The correlation between the absolute difference in BMI (anorexic condition: $M = 5.6$, $SD = 1.5$; obese condition: $M = 21.4$, $SD = 1.6$) for the real and virtual body and the strength of the experienced illusion (anorexic condition: $M = 6.5$, $SD = 0.8$; obese condition: $M = 6.1$, $SD = 1.2$) was not significant, neither for the anorexic condition, $r(25) = -.24$, $p = .231$, nor for the obese condition, $r(24) = .28$, $p = .169$ (see Figure 4 and 5). When comparing the sizes of the two correlations, we found a trend towards significance, $z = -1.82$, $p = .069$.

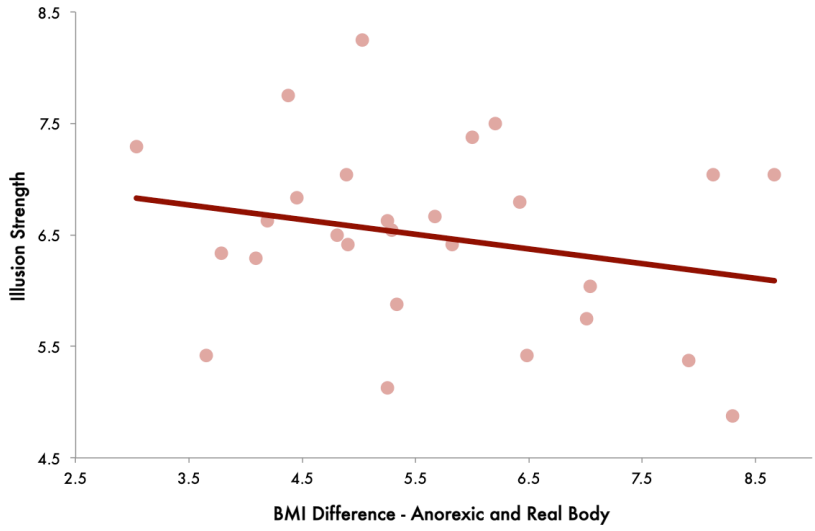

Figure 4. Illusion strength correlated with absolute difference in BMI between the anorexic virtual body and the real body.

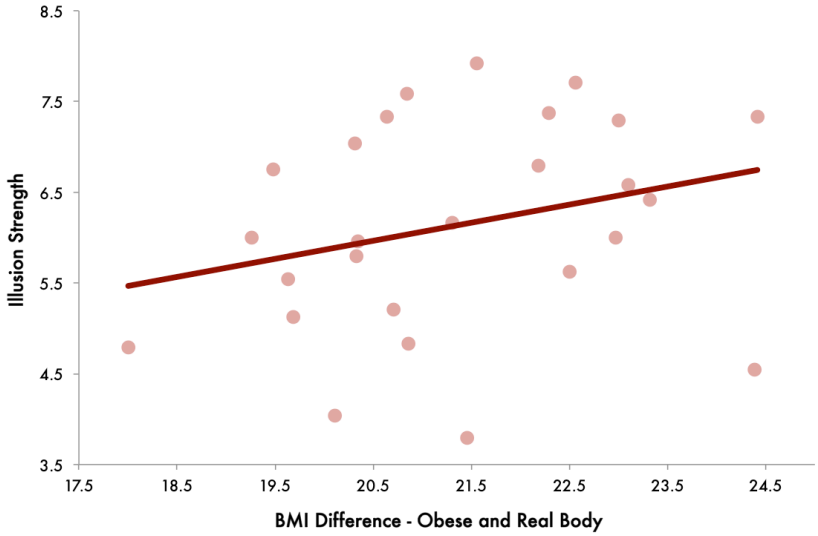

Figure 5. Illusion strength correlated with absolute difference in BMI between the obese virtual body and the real body.

Virtual Body Size and Real Body Satisfaction

To answer our third research question, we examined if satisfaction with the real body changed after experiencing ownership over the anorexic or obese body. For this analysis, we used a two-way mixed-factors ANOVA, with experienced body size (anorexic or obese) as the between-subjects factor and time (pretest or posttest) as the within-subjects factor. The dependent variable was body satisfaction.

There was a trend towards significance for the interaction between experienced body size and the time of measurement on body satisfaction, $F(1, 46) = 3.03$, $p = .089$ partial $\eta^2 = .062$ (see Figure 6). Directly related to our research questions, we examined the simple main effects of time on body satisfaction. We found a marginally significant effect of time (after adjusting the p values for multiple comparisons, using Bonferroni correction) in that women were more satisfied with their real body, after experiencing themselves as anorexic, $F(1, 25) = 4.85$, $p = .074$ partial $\eta^2 = .163$. There was no significant effect of time on body satisfaction for the obese condition, $F(1, 21) = 0.38$, $p = .546$ partial $\eta^2 = .018$. There was no significant

main effect of time, $F(1, 46) = 0.44$, $p = .509$, partial $\eta^2 = .010$, and no significant main effect of body size, $F(1, 46) = 0.16$, $p = .687$, partial $\eta^2 = .004$. Descriptive statistics are displayed in Table 2.

Table 2

Descriptive Statistics of Body Satisfaction

	Anorexic			Obese			Total		
Time	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Pretest	5.6	1.0	26	6.0	0.9	22	5.8	1.0	48
Posttest	5.9	1.2	26	5.8	1.3	22	5.9	1.2	48
Total	5.8	1.1	26	5.9	1.1	22			

Note. Higher score indicates more body satisfaction.

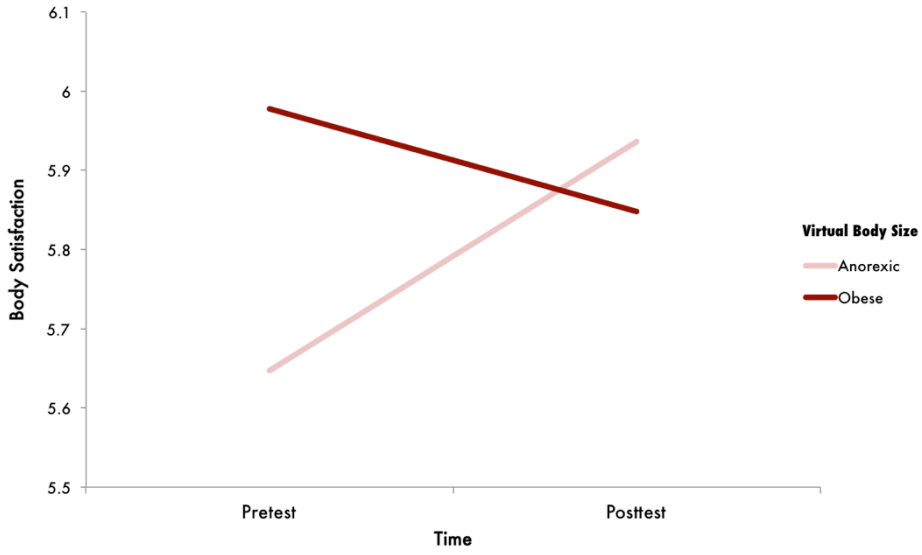

Figure 6. The effect of virtual body size on body satisfaction.

Satisfaction with the Virtual Body

Finally, the fourth aim of this study was to examine if satisfaction with the virtual body differed between the anorexic and obese condition. Posttest satisfaction with the virtual body was examined with a between subjects t-test. For this analysis, we excluded the 6 participants who did not experience ownership over the virtual body. Because the assumption

of homogeneity of variances was violated, as measured by Levene's test for equality of variances (p = .011), we proceeded with the Welch's unequal variances t-test.

For the analysis of virtual body satisfaction, the anorexic group consisted of 26 females and the obese group of 22 females. The participants were significantly more satisfied with the anorexic body (M = 4.7, SD = 2.8) than the obese body (M = 2.8, SD = 1.1), t(41.68) = 4.21, p < .001, d = 1.17, 95% CI [0.98, 2.78] (see Figure 7).

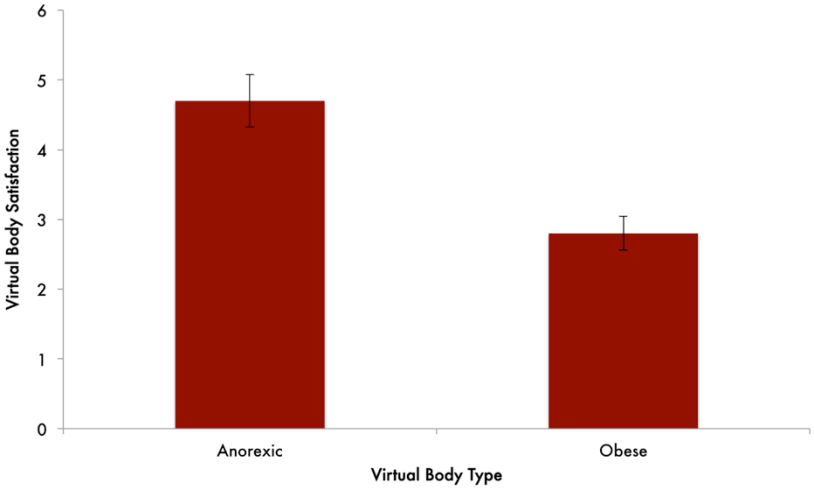

Figure 7. Satisfaction with the anorexic and obese body.

Discussion

Does ownership over an extreme body size affect food choices and body satisfaction? In order to answer this question, we used a virtual reality full-body illusion to provide the experience of ownership over an anorexic or obese body. The results showed no support for the hypothesis that experienced body size affects food choices. Similarity between the real and virtual body did not have a significant effect on illusion strength. There was a non-significant trend indicating that only participants in the anorexic condition showed an increase in body satisfaction from pretest to posttest. In line with our hypothesis, the participants showed significantly more satisfaction with the anorexic than the obese virtual body.

In accordance with the results of Piryankova et al. (2014), the participants experienced an equal degree of ownership over the anorexic and the obese body. Therefore, we drew the conclusion that the manipulation was successful and that the effects of experiencing an anorexic or obese body were independent of illusion strength.

Virtual Body Size and Food Choices

Body size seems to affect food choices in a complex manner. It has previously been shown that passively seeing an overweight (but not obese) person leads to choosing more kcal (Campbell & Mohr, 2011; Shimizu, Johnson, & Wansink, 2014), whereas seeing an obese person leads to choosing smaller portion sizes (McFerran et al., 2010) and to a reduced desire to eat (Barthomeuf et al., 2009, 2011). Could it also be possible that ownership over an obese body affects food choices in a different manner than passively viewing such a body?

Interestingly, in our study, ownership over an anorexic or obese body did not significantly affect the amount of kcal chosen, as compared to baseline. Since visual information (i.e., observing the virtual body) is one factor that makes up the FBI, our results could be viewed as opposing previous studies that have shown that seeing larger (McFerran et al, 2010) or smaller (Brunner & Siegrist, 2012; Krahé & Krause, 2010) bodies affect food choices. On the other hand, our results are in line with a previous study by Campbell and Mohr (2011), which showed that even though participants chose significantly less candies after seeing an obese body compared to an overweight body, there was no difference in the amount of candies chosen after seeing an obese and a normal (as compared to the baseline measure in our study) body. However, experienced ownership also requires identification with the entire body, spatiotemporal self-location and a first person-perspective (Blanke & Metzinger, 2009). Factors such as these could account for the non-significant finding shown in this study.

Even though our results did not yield any evidence for the hypothesis that experienced body size affects food choices, the change in kcal from pretest to posttest was in line with our hypothesis, with participants choosing less kcal after experiencing themselves as obese and slightly more kcal after experiencing themselves as anorexic. The lack of significant effects could also be explained by differences in methodology. Barthomeuf et al. (2009, 2011) measured desire to eat and McFerran et al. (2010) measured the portion sizes chosen. In this study, we measured food choices as the amount of kcal chosen from a menu, with dishes ranging from low to high in kcal. In general, "healthy" foods were low in kcal, whereas "unhealthy" foods were high in kcal (for foods considered to be healthy versus unhealthy, see Carels, Konrad, & Harper, 2007). People are in general good at identifying foods as healthy or unhealthy, but when such a distinction is made, there is a tendency to overestimate the number of kcal for unhealthy food and underestimate the number of kcal for healthy food (Carels et al., 2007). Thus, we cannot know for sure if participants knew which foods were lower versus higher in kcal. Indicating the number of kcal for each dish could have solved this issue, but we chose not to do so because of the accompanying risk of participants being able to guess the purpose of the study. However, future research could ask the participants at the end of the experiment to estimate the kcal content for each dish.

Body Similarity and Illusion Strength

Previous studies have successfully induced embodiment over anorexic (Piryankova et al., 2014) and obese bodies (Normand, Giannopoulos, Spanlang, & Slater, 2011; Piryankova et al. 2014; Preston & Ehrsson, 2016), by means of the FBI. Ownership has been shown to be equally strong for the anorexic and the obese body (Piryankova et al., 2014), which our results confirmed. In this study, we investigated if illusion strength can be affected by body similarity. Our results showed that body similarity was not significantly correlated with

illusion strength, neither for the anorexic, nor for the obese group. Furthermore, the two correlation coefficients showed different directions. Thus, it is possible that the trend towards significance that was found, when the sizes of the two correlation coefficients were compared to each other, was nothing more than a spurious finding, evoked by the different correlation directions. We have to conclude that we did not observe any reliable evidence for the hypothesis that body similarity would affect illusion strength.

Virtual Body Size and Real Body Satisfaction

In line with our hypothesis, we found a trend towards increased real body satisfaction after ownership over a virtual anorexic body, as measured after the participants had removed their HMD. We previously expected such an increase to be driven by a preference for their real body, when compared to an extremely skinny virtual body. Accordingly, we would predict an even larger increase in satisfaction with the real body after the obese condition, since the participants were significantly less satisfied with the obese than the anorexic body. This was not the case. On the contrary, our results showed a non-significant decrease in body satisfaction after the obese condition. Taken together, this made us wonder if the effects of the FBI, or experienced virtual body (dis)satisfaction, lingered on after the participants had removed the HMD.

Previous research has shown that it takes between 5 and 116 s (median time is 27 s) for ownership to emerge over a rubber hand (Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2009) and anecdotal reports have indicated that ownership over a virtual body can be experienced almost instantaneously (Kalckert & Ehrsson, 2017). It is reasonable to believe that ownership over one's real body should be regained in the same amount of time or faster. This is in line with the results of Normand et al. (2011), which suggested that the illusion of having a larger belly ended after the experimental trial. Thus, the participants in our study

should have had time to regain ownership over their real body, when body satisfaction was measured.

An alternative explanation of our results could be that (dis)satisfaction with the virtual body lingers on and affects the real body, even after the illusion has been broken. The allocentric lock hypothesis (Riva, 2012; Riva, Gaudio, & Dakanalis, 2013) suggests that the experience of the body could be locked to an old memory that the person is unable to update. This could explain why formerly overweight people are still concerned about their weight and dissatisfied with their bodies (Annis, Cash, & Hrabosky, 2004; Cash, Counts, & Huffine, 1990) and why sufferers of eating disorders, such as anorexia, are dissatisfied with their bodies (Cash & Deagle, 1997) and overestimate their body size (Keizer et al., 2016; Smeets, 1997). In line with this, it has been suggested that people who experience dramatic weight changes have difficulties with solving the identity conflict between the weight that they actually have and the weight they consider represents who they are (Carr & Jaffe, 2012). Although the allocentric lock hypothesis has been commonly applied to a larger time frame, it has also been suggested that this hypothesis can be used to explain changes in body memory after experienced ownership over a skinny belly, using an FBI (Serino, Pedroli, et al., 2016). Furthermore, one case study (Serino, Scarpina, et al., 2016) showed that after an extremely obese patient had experienced herself with a normal body weight, she felt less anxious about her condition and more motivated to engage in healthy behaviour. Taken together, people might be inclined to rate their own body in accordance with the satisfaction experienced over the virtual body, because of a failure to update their body memory. However, even though this provides a possible explanation, it has one major problem: it fails to explain why participants would be more satisfied with their real body after experiencing themselves as anorexic, when

the mean scores indicated that they were less satisfied with their virtual anorexic body (4.7) than their real pretest body (5.6).

Satisfaction with the Virtual Body

In accordance with our hypothesis, participants were significantly more satisfied with the anorexic than the obese body. Compared to the obese body (BMI of 43), the anorexic body (BMI of 16) was closer to the BMI of 18 to 19 that women consider to be ideal (Coker & Abraham, 2014). During the experiment, several women made comments about how thin the anorexic body was and said that the thinness of the wrists "looked scary". Still, the mean values for body satisfaction indicated that the participants were "neither satisfied, nor dissatisfied" with the anorexic body, as opposed to "moderately dissatisfied" with the obese body. However, both low (BMI < 23) and high (BMI > 28) body weights are associated with increased mortality (Troiano et al., 1996). Our results indicate that there is a discrepancy between what is considered to be attractive and what is healthy.

Limitations

This study also has several limitations. Firstly, because we did not reach our planned sample size, it is possible that we did not have enough statistical power to detect all significant differences and reliably answer our research questions.

Secondly, we did not include asynchronous stroking as a control condition, which is commonly done in the FBI (e.g., Keizer et al., 2016; Normand et al., 2011; Piryankova et al., 2014). Even though, theoretically, asynchronous stroking should not give rise to the illusion (Slater et al., 2009), it has been shown that asynchronous stroking can significantly influence experienced body size (Keizer et al., 2016). This could be due to sensorimotor information partly overriding visuotactile information (Piryankova et al., 2014), thus making this insufficient as a control condition. On these grounds, we chose not to include it as a control

condition. However, this makes it difficult to disentangle the effects of ownership from the effects of passively viewing the virtual body.

Thirdly, several participants, especially in the obese condition, were able to guess that we were interested in investigating how experienced body size affects food choices. However, we analysed the data with these participants excluded and it did not change the outcome of our results. Finally, we only included females with a normal BMI and we can therefore not generalise our results to males or underweight and overweight people.

Future Directions

To the best of our knowledge, this study was the first to investigate if ownership over an anorexic or obese body affects food choices, and if ownership over an anorexic body affects body satisfaction. Future research should investigate this matter further, using a larger sample size and possibly using a different means of measurement, for example asking participants to rate their desire to eat or measure actual eating behaviour. If future studies would also fail to find evidence for the hypothesis that ownership over an extreme body size affects food choices, the difference between ownership and passively viewing pictures should be further investigated, and it should be questioned why only the latter affects food consumption (Brunner & Siegrist, 2012) and the desire to eat (Barthomeuf et al., 2011). Thus, in order to further separate the effects of ownership and vision, future studies should include a control condition in which participants passively view pictures of obese and anorexic bodies.

Additionally, in order to further investigate how virtual body size affects body satisfaction, body satisfaction could be measured both at baseline, simultaneously as experiencing ownership over the virtual body and after ownership over the own body has been regained. The results of such an experimental setup would indicate if participants

compare their real body to the virtual body or if body satisfaction with the virtual body lingers on and affects the satisfaction with the real body.

Finally, in order to disentangle the characteristics of anorexia and obesity, it is important to further study individual factors such as body size, which could potentially maintain these disorders – disorders that affect women all around the world.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Annis, N., Cash, T., & Hrabosky, J. (2004). Body image and psychosocial differences among stable average weight, currently overweight, and formerly overweight women: The role of stigmatizing experiences. *Body Image*, *1*, 155-167. doi:10.1016/j.bodyim.2003.12.001

Autodesk 3ds Max (Version 2017) [Computer software]. (2017). Available from https://www.autodesk.com/

Autodesk MotionBuilder (Version 2017) [Computer software]. (2017). Available from https://www.autodesk.com/

Barthomeuf, L. R. D., Droit-Volet, S. M. N., & Rousset, S. M. E. (2011). Differences in the desire to eat in children and adults in the presence of an obese eater, *Obesity*, 19, 939-945. doi:10.1038/oby.2011.26

Barthomeuf, L., Rousset, S., & Droit-Volet, S. (2009). The desire to eat in the presence of obese or normal-weight eaters as a function of their emotional facial expression. *Obesity*, *18*, 719-724. doi:10.1038/oby.2009.357

Becker, A.E., Burwell, R.A., Herzog, D.B., Hamburg, P., & Gilman, S.E. (2002). Eating behaviours and attitudes following prolonged exposure to television among ethnic Fijian adolescent girls. *The British Journal of Psychiatry, 180*, 509-514. doi:10.1192/bjp.180.6.509

Bell, E. A., Castellanos, V. H., Pelkman, C. L., Thorwart, M. L., & Rolls, B. J. (1998). Energy density of foods affects energy intake in normal-weight women. *The American Journal of Clinical Nutrition, 67,* 412-420. doi:10.1093/ajcn/67.3.412

Bes-Rastrollo, M., van Dam, R. M., Martinez-Gonzalez, M. A., Li, T. Y., Sampson, L. L., & Hu, F. B. (2008). A prospective study of dietary energy density and weight gain in women. *The American Journal of Clinical Nutrition, 88,* 769–777. doi:10.1093/ajcn/88.3.769

Blanke, O., & Metzinger, T. (2009). Full-body illusions and minimal phenomenal selfhood. *Trends in Cognitive Sciences*, *13*, 7-13. doi:10.1016/j.tics.2008.10.003

Blechert, J., Meule, A., Busch, N.A., & Ohla, K. (2014). Food-pics: An image database for experimental research on eating and appetite. *Frontiers in Psychology, 5,* 617. doi:10.3389/fpsyg.2014.00617

Botvinick, M., & Cohen, J. (1998). Rubber hands ‘feel’ touch that eyes see. *Nature, 391*, 756. doi:10.1038/35784

Brunner, T., & Siegrist, M. (2012). Reduced food intake after exposure to subtle weight-related cues. *Appetite*, *58*, 1109-1112. doi:10.1016/j.appet.2012.03.010

Campbell, M., & Mohr, G. (2011). Seeing is eating: How and when activation of a negative stereotype increases stereotype-conducive behavior. *Journal of Consumer Research*, *38*, 431-444. doi:10.1086/659754

Carels, R., Konrad, K., & Harper, J. (2007). Individual differences in food perceptions and calorie estimation: An examination of dieting status, weight, and gender. *Appetite*, *49*, 450-458. doi:10.1016/j.appet.2007.02.009

Carr, D., & Jaffe, K. (2012). The psychological consequences of weight change trajectories: Evidence from quantitative and qualitative data. *Economics & Human Biology*, *10*, 419-430. doi:10.1016/j.ehb.2012.04.007

Cash, T., Counts, B., & Huffine, C. (1990). Current and vestigial effects of overweight among women: Fear of fat, attitudinal body image, and eating behaviors. *Journal of Psychopathology and Behavioral Assessment*, *12*, 157-167. doi:10.1007/bf00960765

Cash, T., & Deagle, E. (1997). The nature and extent of body- image disturbances in anorexia nervosa and bulimia nervosa: A meta- analysis. *International Journal of Eating Disorders*, *22*, 107-126. doi:10.1002/(sici)1098-108x(199709)22:2<107::aid-eat1>3.3.co;2-y

Cash, T. F., Fleming, E. C., Alindogan, J., Steadman, L., & Whitehead, A. (2002). Beyond body image as a trait: The development and validation of the Body Image States Scale. *Eating Disorders: The Journal of Treatment & Prevention, 10,* 103-113. doi:10.1080/10640260290081678

Cho, A., & Lee, J. (2013). Body dissatisfaction levels and gender differences in attentional biases toward idealized bodies. *Body Image*, *10*, 95-102. doi:10.1016/j.bodyim.2012.09.005

Coker, E., & Abraham, S. (2014). Body weight dissatisfaction: A comparison of women with and without eating disorders. *Eating Behaviors, 15,* 453-459. doi:10.1016/j.eatbeh.2014.06.014

Cooley, E., & Toray, T. (2001). Body image and personality predictors of eating disorder symptoms during the college years. *International Journal of Eating Disorders, 30,* 28–36. doi:10.1002/eat.1051

Cordain, L., Eaton, S. B., Sebastian, A., Mann, N., Lindeberg, S., Watkins, B. A. … Brand-Miller, J. (2005). Origins and evolution of the Western diet: Health implications for the 21st century. *The American Journal of Clinical Nutrition, 81,* 341-354. doi:10.1093/ajcn.81.2.341

Croll, J., Neumarksztainer, D., Story, M., & Ireland, M. (2002). Prevalence and risk and protective factors related to disordered eating behaviors among adolescents: relationship to gender and ethnicity. *Journal of Adolescent Health*, *31*, 166-175. doi:10.1016/s1054-139x(02)00368-3

De Jong, J., Keizer, A., Engel, M., & Dijkerman, H. (2017). Does affective touch influence the virtual reality full body illusion?. *Experimental Brain Research*, *235*, 1781-1791. doi:10.1007/s00221-017-4912-9

Drewnowski, A. (1998). Energy density, palatability, and satiety: Implications for weight control. *Nutrition Reviews, 56,* 347-353. doi:10.1111/j.1753-4887.1998.tb01677.x

Fardouly, J., & Vartanian, L. R. (2012). Changes in weight bias following weight loss: The impact of weight-loss method. *International Journal of Obesity, 36,* 314–319. doi:10.1038/ijo.2011.26

Ferraro, K. F., & Yu, Y. (1995). Body weight and self-ratings of health. *Journal of Health and Social Behavior, 36,* 274–284. doi:10.2307/2137343

Garner, D. M., Olmsted, M. P., Bohr, Y., & Garfinkel, P. E. (1982). The eating attitudes test: psychometric features and clinical correlates. *Psychological medicine, 12,* 871-878. Retrieved from http://www.eat-26.com/Docs/Garner-EAT-26-1982.pdf

Grabe, S., Ward, L., & Hyde, J. (2008). The role of the media in body image concerns among women: A meta-analysis of experimental and correlational studies. *Psychological Bulletin*, *134*, 460-476. doi:10.1037/0033-2909.134.3.460

Groesz, L., Levine, M., & Murnen, S. (2001). The effect of experimental presentation of thin media images on body satisfaction: A meta-analytic review. *International Journal of Eating Disorders*, *31*, 1-16. doi:10.1002/eat.10005

Groesz, L. M., Levine, M. P., & Murnen, S. K. (2002). The effect of experimental

presentation of thin media images on body satisfaction: A meta-analytic review. *International Journal of Eating Disorders, 31,* 1–16. doi:10.1002/eat.10005

Hall, K., Sacks, G., Chandramohan, D., Chow, C., Wang, Y., Gortmaker, S., & Swinburn, B. (2011). Quantification of the effect of energy imbalance on bodyweight. *The Lancet*, *378*, 826-837. doi:10.1016/s0140-6736(11)60812-x

Hawkins, N., Richards, P., Granley, H., & Stein, D. (2004). The impact of exposure to the thin-ideal media image on women. *Eating Disorders*, *12*, 35-50. doi:10.1080/10640260490267751

Kalckert, A., & Ehrsson, H. (2017). The onset time of the ownership sensation in the moving rubber hand illusion. *Frontiers in Psychology*, *8*, 344. doi:10.3389/fpsyg.2017.00344

Kanoski, S., & Davidson, T. (2011). Western diet consumption and cognitive impairment: Links to hippocampal dysfunction and obesity. *Physiology & Behavior, 103,* 59-68. doi:10.1016/j.physbeh.2010.12.003

Keizer, A., van Elburg, A., Helms, R., & Dijkerman, H. (2016). A virtual reality full body illusion improves body image disturbance in anorexia nervosa. *PLoS ONE*, *11*, e0163921. doi:10.1371/journal.pone.0163921

Kopelman, P. (2007). Health risks associated with overweight and obesity. *Obesity Reviews*, *8*, 13-17. doi:10.1111/j.1467-789x.2007.00311.x

Krahé, B., & Krause, C. (2010). Presenting thin media models affects women's choice of diet or normal snacks. *Psychology of Women Quarterly*, *34*, 349-355. doi:10.1111/j.1471-6402.2010.01580.x

Lira, M., Egito, J., Dall'Agnol, P., Amodio, D., Gonçalves, Ó., & Boggio, P. (2017). The influence of skin colour on the experience of ownership in the rubber hand illusion. *Scientific Reports*, *7*. doi:10.1038/s41598-017-16137-3

Macht, M., & Simons, G. (2000). Emotions and eating in everyday life. *Appetite, 35,* 65-71. doi:10.1006/appe.2000.0325

Makino, M., Tsuboi, K., & Dennerstein, L. (2004). Prevalence of eating disorders: A comparison of Western and non-Western countries. *Medscape General Medicine, 6,* 49. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1435625/

Markwald, R. R., Melanson, E. L., Smith, M. R., Higgins, J., Perreault, L., Eckel, R. H., & Wright, K. P, Jr. (2013). Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proceedings of the National Academy of Sciences of the United States of America, 110,* 5695-5700. doi:10.1073/pnas.1216951110

Maselli, A., & Slater, M. (2013). The building blocks of the full body ownership illusion. *Frontiers in Human Neuroscience*, *7,* 83. doi:10.3389/fnhum.2013.00083

Maskarinec, G., Novotny, R., & Tasaki, K. (2000). Dietary patterns are associated with body mass index in multiethnic women. *The Journal of Nutrition*, *130*, 3068-3072. doi:10.1093/jn/130.12.3068

Matthiasdottir, E., Jonsson, S. H., & Kristjansson, A. L. (2012). Body weight dissatisfaction in the Icelandic adult population: A normative discontent? *European Journal of Public Health, 22,* 116–121. doi:10.1093/eurpub/ckq178

McFerran, B., Dahl, D., Fitzsimons, G., & Morales, A. (2010). I'll have what she's having: Effects of social influence and body type on the food choices of others. *Journal of Consumer Research*, *36*, 915-929. doi:10.1086/644611

Moussally, J., Rochat, L., Posada, A., & van der Linden, M. (2016). A database of body-only computer-generated pictures of women for body-image studies: Development and preliminary validation. *Behavior Research Methods*, *49*, 172-183. doi:10.3758/s13428-016-0703-7

NCD Risk Factor Collaboration. (2016). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants. *The Lancet, 387,* 1377–1396. doi:10.1016/S0140-6736(16)30054-X

Normand, J., Giannopoulos, E., Spanlang, B., & Slater, M. (2011). Multisensory stimulation can induce an illusion of larger belly size in immersive virtual reality. *PLoS ONE*, *6*, e16128. doi:10.1371/journal.pone.0016128

Ogden, J., & Mundray, K. (1996). The effect of the media on body satisfaction: The role of gender and size. *European Eating Disorders Review*, *4*, 171-182. doi:10.1002/(SICI)1099-0968(199609)4:3<171::AID-ERV132>3.0.CO;2-U

Pavani, F., Spence, C., & Driver, J. (2000). Visual capture of touch: Out-of-the-body experiences with rubber gloves. *Psychological Science*, *11*, 353-359. doi:10.1111/1467-9280.00270

Piryankova, I., Wong, H., Linkenauger, S., Stinson, C., Longo, M., Bülthoff, H., & Mohler, B. (2014). Owning an overweight or underweight body: Distinguishing the physical, experienced and virtual body. *PLoS ONE, 9,* e103428. doi:10.1371/journal.pone.0103428

Polivy, J., Garner, D. M., & Garfinkel, P. E. (1986). Causes and consequences of the current preference for thin female physiques. In C. P. Herman, M. P. Zanna, & E. T. Higgins (Eds.), *Physical appearance, stigma, and social behavior: The third Ontario symposium in personality and social psychology* (pp. 89–112). Hillsdale, NJ: Erlbaum.

Preston, C. (2013). The role of distance from the body and distance from the real hand in ownership and disownership during the rubber hand illusion. *Acta Psychologica*, *142*, 177-183. doi:10.1016/j.actpsy.2012.12.005

Preston, C., & Ehrsson, H. H. (2014). Illusory changes in body size modulate body satisfaction in a way that is related to non-clinical eating disorder psychopathology. *PLoS ONE, 9,* e85773. doi:10.1371/journal.pone.0085773

Preston, C., & Ehrsson, H. H. (2016). Illusory obesity triggers body dissatisfaction responses in the insula and anterior cingulate cortex. *Cerebral Cortex*, *26*, 4450-4460. doi:10.1093/cercor/bhw313

Putterman, E., & Linden, W. (2004). Appearance versus health: Does the reason for dieting affect dieting behavior?. *Journal of Behavioral Medicine, 27*, 185-204. doi:10.1023/b:jobm.0000019851.37389.a7

Qualtrics (Version January-May 2018) [Computer software]. Available from https://www.qualtrics.com

Riva, G. (2012). Neuroscience and eating disorders: The allocentric lock hypothesis. *Medical Hypotheses, 78*, 254-257. doi:10.1016/j.mehy.2011.10.039

Riva, G., Gaudio, S., & Dakanalis, A. (2013). I'm in a virtual body: A locked allocentric memory may impair the experience of the body in both obesity and anorexia nervosa. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity, 19*, 133-134. doi:10.1007/s40519-013-0066-3

Robinson, B. E., Bacon, L. C., & O'Reilly, J. (1993). Fat phobia: Measuring, understanding, and changing anti-fat attitudes. *International Journal of Eating Disorders, 14,* 467-480. doi:10.1002/1098-108x

Rolls, B. J., & Bell, E. A. (2000). Dietary approaches to the treatment of obesity. In M.D. Jensen (Ed.), *Medical Clinics of North America* (pp. 401-418). Philadelphia: Saunders Company.

Rolls, B., Drewnowski, A., & Ledikwe, J. (2005). Changing the energy density of the diet as a strategy for weight management. *Journal of The American Dietetic Association*, *105*, 98-103. doi:10.1016/j.jada.2005.02.033

Serino, S., Pedroli, E., Keizer, A., Triberti, S., Dakanalis, A., & Pallavicini, F. … Riva, G. (2016). Virtual reality body swapping: A tool for modifying the allocentric memory of the body. *Cyberpsychology, Behavior, and Social Networking*, *19*, 127-133. doi:10.1089/cyber.2015.0229

Serino, S., Scarpina, F., Keizer, A., Pedroli, E., Dakanalis, A., & Castelnuovo, G. … Riva, G. (2016). A novel technique for improving bodily experience in a non-operable super–super obesity case. *Frontiers in Psychology*, *7,* 837. doi:10.3389/fpsyg.2016.00837

Shimizu, M., Johnson, K., & Wansink, B. (2014). In good company: The effect of an eating companion's appearance on food intake. *Appetite, 83,* 263-268. doi:10.1016/j.appet.2014.09.004

Slater, M., Perez-Marcos, D., Ehrsson, H.H., & Sanchez-Vives, M.V. (2009). Inducing illusory ownership of a virtual body. *Frontiers in Neuroscience 3*, 214–220. doi: 10.3389/neuro.01.029.2009

Smeets, M. (1997). The rise and fall of body size estimation research in anorexia nervosa: A review and reconceptualization. *European Eating Disorders Review*, *5*, 75-95. doi:10.1002/(sici)1099-0968(199706)5:2<75::aid-erv190>3.3.co;2-1

Sypeck, M., Gray, J., & Ahrens, A. (2004). No longer just a pretty face: Fashion magazines' depictions of ideal female beauty from 1959 to 1999. *International Journal of Eating Disorders*, *36*, 342-347. doi:10.1002/eat.20039

Thompson, J., & Thompson, C. (1986). Body size distortion and self-esteem in asymptomatic, normal weight males and females. *International Journal of Eating Disorders*, *5*, 1061-

1068. doi:10.1002/1098-108x(198609)5:6<1061::aid-eat2260050609>3.0.co;2-c

Troiano, R. P., Frongillo, E. A. J., Sobal, J., & Levitsky, D. A. (1996). The relationship between body weight and mortality: A quantitative analysis of combined information from existing studies. *International Journal of Obesity and Related Metabolic Disorders, 20,* 63-65. Abstract retrieved from https://www.ncbi.nlm.nih.gov/pubmed/8788324

Unity (Version 2017.1.) [Computer software]. (2017). Available from https://unity3d.com/

Van Stralen, H., van Zandvoort, M., Hoppenbrouwers, S., Vissers, L., Kappelle, L., & Dijkerman, H. (2014). Affective touch modulates the rubber hand illusion. *Cognition, 131*, 147-158. doi:10.1016/j.cognition.2013.11.020

Wardle, J., Haase, A. M., Steptoe, A., Nillapun, M., Jonwutiwes, K., & Bellisie, F. (2004) Gender differences in food choice: The contribution of health beliefs and dieting. *Annals of Behavioral Medicine, 27,* 107-116. doi:10.1207/s15324796abm2702_5

Whisenhunt, B., Drab-Hudson, D., Stanek, L., Dock, A., Allen, B., Vincent, R., & Levesque-Bristol, C. (2012). Perceptions of underweight images: Are women with anorexia nervosa perceived as attractive and healthy?. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *17*, e178-e184. doi:10.1007/bf03325345

World Health Organization. (2006). BMI classification. Retrieved from http://apps.who.int/bmi/index.jsp?introPage=intro_3.html

Yanover, T., & Thompson, J. K. (2010). Perceptions of health and attractiveness: The effects of body fat, muscularity, gender, and ethnicity. *Journal of Health Psychology, 15,* 1039–1048. doi:10.1177/1359105309360426