Time Travelling in Virtual Reality:

Can Virtual Embodiment Instil a Future Oriented Mindset?

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Abstract

Background: Virtual reality offers a novel way for inducing body ownership illusions via embodiment of an avatar. Numerous studies have shown people who embody an avatar to change their behaviour in accordance with behaviour that is associated with this avatar. This Proteus effect offers new possibilities for psychological interventions.

Objective: A lack of future-self continuity has shown to be an important predictor for maladaptive behaviours. We investigate the effect of virtual embodiment of the future-self, combined with an interview about the past, on future-self continuity. Further, we aim to get more insight into the Proteus effect by examining the role of embodiment in this effect.

Method: 61 male participants aged 18 to 30 (M = 22.36, SD = 2.72) embodied an avatar of either their present self or future-self while being interviewed about their past. After the interview they filled in a questionnaire.

Results: Future-self embodiment did not improve future-self connectedness and similarity, nor did it improve vividness of the future self. Proteus effect was not predicted by embodiment or presence in VR, but engagement and condition were predictive. Proteus effect was not associated with connectedness and similarity, and negatively associated with vividness.

Conclusion: No evidence was found for improvement of future-self continuity by making participants embody their future-self via an avatar. Participants did show a difference from their regular thinking between conditions, possibly because of the interview. The negative association between Proteus effect and vividness might imply that instead of amplifying, combining avatar embodiment with an interview attenuates future-self vividness.

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The relation between the body and the mind is an extensively discussed topic in both psychology and philosophy. Already in 1890, William James asked himself whether our bodies are "ours" or whether they are in fact "us" (James, 1890, p. 291). Certainly, body ownership is an elemental aspect of our self-consciousness (Aspell, Lenggenhager, & Blanke, 2012; Ehrsson, Spence, & Passingham, 2004; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007). However, body ownership is also malleable. Research shows that the sense of ownership can be manipulated: it can be transferred to objects and bodies not belonging to ourselves. This is a phenomenon also referred to as body ownership illusion or BOI (Kilteni, Maselli, Kording, & Slater, 2015). An example is the rubber hand illusion by Botvinick and Cohen (1998). In studies examining the rubber hand illusion, subjects are seated at a table, see a realistic rubber hand in front of them and have their own hand positioned out of sight. Both the fake and real hand are then synchronously stroked with a brush. Eventually subjects start recognizing the fake hand as being their own hand. This illusion of ownership of a fake limb is argued to result from the manipulation of visual, tactile and proprioceptive information from the hand (Kalckert & Ehrsson, 2017; Samad, Chung, & Shams, 2015).

A novel and powerful way to induce BOI is by using immersive Virtual Reality; VR (e.g., Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). VR puts a person in a virtual environment (VE) by means of a head mounted display (HMD). Fox, Arena, and Bailenson (2009) define a VE as "*a digital space in which a user's movements are tracked and his or her surroundings rendered, or digitally composed and displayed to the senses in accordance with those movements*" (p. 95). For the brain a VE can be perceived as reality, as it replaces sensory

information from the physical world. This is also referred to as immersion. The relevance of immersive VR for inducing BOI lies in the fact that it offers the unique possibility for transformation via virtual embodiment.

Transformation implies that a user embodies a digital representation of someone or something with specific physical traits and abilities different from their own, or even a completely different (fictional) character (Cornet, Den Besten, & Van Gelder, 2019). This digital representation is called an avatar (See Nowak & Fox, 2018 for a review on the use of avatars). When embodying an avatar in VR, people seem to attribute traits and properties associated with this avatar to themselves and adjust their behaviour accordingly. This effect, which is related to self-perception theory (Bem, 1967; Ratan, Beyea, Li, & Graciano, 2019, p. 4), is known as the *Proteus effect* (Yee & Bailenson, 2007). Several researchers have investigated this effect. For instance, in one study by Rosenberg, Baughman and Bailenson (2013), participants in VR were either given the ability to fly around like superman or were flying on board of a helicopter as a passenger. Subjects had either the task to search for a child in need of help in a virtual city, or to tour around this same city. Regardless of their task, participants who were given the superhuman ability to fly were more helpful after immersion in VR than did those who sat in the helicopter. In other words, the ability to fly like superman seemed to be associated with heroism, which in turn promoted helping behaviour. Another study, by Peck, Seinfeld, Aglioti, and Slater (2013) showed reduced implicit racial bias in light-skinned participants after being embodied as a dark-skinned avatar. Osimo, Pizarro, Spanlang and Slater (2015) used VR in the context of self-counselling. They found participants that embodied Sigmund Freud while counselling themselves to report greater mood improvement and happiness than did participants who embodied an avatar representation of themselves. In a study by Banakou, Kishore and Slater (2018) participants who

embodied an avatar of Albert Einstein showed increased performance on subsequent cognitive tasks. Moreover, they showed less age-based discrimination against elderly people. Finally, Seinfeld et al. (2018) found male domestic violence offenders who embodied a female avatar to have an improved ability to recognize fearful female faces. In sum, the Proteus effect shows that via embodiment in VR, behaviour can be influenced in a variety of ways and that the effect can (at least temporarily) transfer to the real world. This opens up new possibilities for behavioural interventions.

In the present study we investigate the Proteus effect in relation with peoples' *future selves*. The idea of different selves originates in philosophical work by Parfit (1971, 1987) who argues that people do not have just one identity, but a collection of identities that change over time. This implies that the identity of a present and a future self are distinct. Research shows that some people experience higher degrees of future-self continuity than others; i.e., they experience a stronger degree of connection to their future self (Ersnser-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009). People with higher levels of continuity have shown to be more likely to take their future interests into account, for example by saving more money for their retirement (Hershfield, Bailenson, & Carstensen, 2008), behaving more ethically responsible (Hershfield, Cohen, & Thompson, 2012), and showing improved health behaviour (Rutchick, Slepian, Reyes, Pleskus, & Hershfield, 2018). In contrast, less continuity has shown to be an important predictor for the opposite, i.e., self-defeating behaviours. But how can a future-oriented mindset be instilled?

We argue that there are two approaches for increasing continuity and activating a future oriented mindset: by stimulating the cognitive ability to think ahead in time, which is a deliberate process, and by embodying the future self, which is a more implicit process. An example of the

cognitive approach is mental time travel (MTT; Wheeler, Stuss, & Tulving, 1997) and more specifically episodic future thinking (EFT; Atance & O'Neill, 2001). EFT addresses the ability to *imagine* oneself ahead in time and think about events that might happen in the future, it can be assessed with an autobiographical interview (See also, Hollis-Hansen, O'Donnell, Seidman, Brande, & Epstein, 2019; Peters, Wiehler, & Bromberg, 2017). Research shows that EFT affects people's future oriented behaviour. For example, it can reduce delay discounting, i.e., the inability to postpone gratification (Bromberg, Lobatcheva, & Peters, 2017; O'Donnell, Oluyomi, & Epstein, 2017). Higher rates of delay discounting are associated with several types of short-sighted or maladaptive behaviours such as making unhealthy choices and cheating (Snider, DeHart, Epstein, & Bickel, 2019; Story, Vlaev, Seymour, Darzi, & Dolan, 2014; Wu, Cheng, & Chiou, 2017). EFT thus seems to be an effective approach in instilling a future oriented mindset.

Aside from this cognitive approach, recent research has focused on strengthening the implicit connection between the present and future self by visually making the future-self more vivid using VR (Hershfield, 2019). For example, in one study by Hershfield et al. (2008) participants were virtually seated in front of a mirror in which they saw either an aged or a contemporary avatar of themselves. Participants in the aged condition saved significantly more money for their retirement than those that were in the contemporary condition (See also, Hershfield et al., 2011). Van Gelder, Hershfield and Nordgren (2013) used a similar design to study the effect of virtually embodying the future self on delinquency. They hypothesized that strengthening the vividness of the future-self reduces involvement in cheating on a trivia quiz. Indeed, the authors found participants in the future-self condition to be less attending in cheating than did participants in the present-self condition. In conclusion, both cognitive and physical

approaches can make people more aware of their future-self and have shown to affect people's future oriented behaviour.

The present study

In the present study we combine both physical embodiment of the future-self and mental time-travel, to experimentally investigate the extent to which people can be made future oriented. We do so by having participants, university students, embody either an aged-morphed avatar of themselves (i.e ., their 'future-self') or a contemporary avatar (i.e., their 'present-self'). In both conditions participants are interviewed about their past. By employing this design, participants who embody their older self will look back at a period in their lives that has not yet happened in real life. Thus, imagine future events in their lives.

We hypothesize (H1a) that participants in the future-self condition score higher on Proteus effect; the extent to which people rate their thoughts to be different from their regular thinking, than do participants in the present-self condition. Moreover, we want to investigate the roles of embodiment, presence and engagement on the Proteus effect. We do so by hypothesizing that, (H1b) embodiment, presence and engagement significantly predict the occurrence of Proteus effect.

Embodying the future-self, we expect, leads people to show higher levels of future-self continuity, and subsequently more future oriented behaviour. We hypothesize that (H2a) participants in the future-self condition will show greater levels of future-self connectedness, vividness and similarity than participants who embody their present-self. In line with earlier findings, we expect that (H2b) there is a relation between condition and delay discounting, evidenced by a difference in proportions in which participants in the future-self and present-self condition choose a delayed 8 euro reimbursement over an immediate 5 euro reimbursement. We

furthermore hypothesize that (H2c) connectedness, vividness and similarity mediate the relation between condition and delay discounting.

Finally, we aim to extend existing knowledge by exploring a possible role of Proteus effect in peoples rating for future-self continuity and vividness. We hypothesize that (H3) Proteus effect is associated with connectedness, similarity and vividness.

Method

Participants

In a between-groups design, 61 male participants (M_{age} = 22.36, *SD* = 2.72, range: 18 - 30) embodied either an aged-morphed avatar (their future-self) or a contemporary avatar of themselves. They were recruited on the University of Twente's campus. Potential participants could not take part if they were younger than 18 or older than 30 years, or if they were suffering from epileptic and severe psychiatric disorders. The experiment was approved by the University of Twente's BMS ethics committee. Participants gave signed informed consent. Compensation for participation was a €5 gift voucher.

Experimental manipulation

In both conditions, an avatar of the participant was made. In the future-self condition, the avatar of the participant was made to look 50 years old. Participants embodied this avatar in VR and were transported to a virtual room in which they seated in front of a large virtual mirror. A small virtual robot named FI (Future Interviewer) that was controlled by the experimenter interviewed the participant about his past. The experimenter followed one of two possible scripts: one for the present and one for the future-self condition. The only differences between the scripts were the timeframes the participant was asked to look back on (10 years in the past for the

present-self condition, and 50 years minus the participants actual age for the future-self condition.) and a time-travel thinking task for the future-self condition.

Materials

Hardware and software. A HTC Vive HMD was the central piece of hardware in this study. Two accompanying sensors created a 360 degree virtual space in which the position of the HMD and two hand controllers could be tracked. The HTC Vive was connected to a desktop PC with an Intel Core i7-4790 processor and an Nvidia GTX 1080Ti graphics card. We used a custom-made application (FutureU) to create the avatars. The picture of the participant's face was taken using a Logitech C270 HD webcam. We employed a Zoom H4n microphone to interview the participant and used Audacity software for recording the participant's answers to the questions. The obtained audio data was not used in the current study. The voice of the interviewer was changed in real-time to a robot-like voice by VoiceMod Pro software. Participants wore headphones with active noise cancelling to ensure isolation from possible background noises coming from outside the VR environment. Two rooms separated by a see-through mirror were used in this study. This was done to secure a feeling of solitude for participants, stimulating openness in answering the interview questions and to reduce sound related interference. We used Qualtrics® survey software for the pre and post-experiment questionnaire.

Dependent variables. We measured all dependent variables on 7-point Likert scales ranging from 1 (*completely disagree*) to 7 (*completely agree*), unless reported otherwise.

Valence. The extent to which participants were positive about the future was measured using a smiley slider scale that represented five moods**.** This was a built-in function in the questionnaire software that we used (Figure 1).

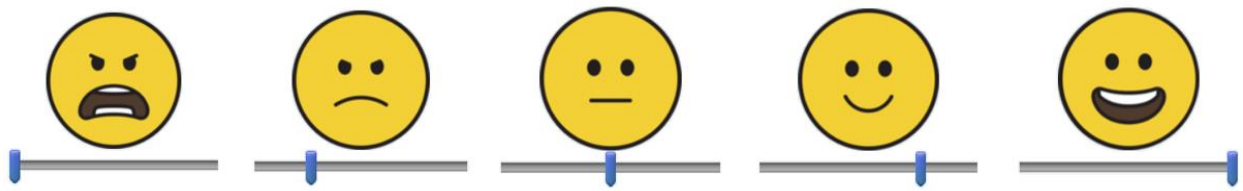

Figure 1. Smiley slider scale (Adapted from Qualtrics® questionnaire software)

Future-self connectedness and similarity. Future-self continuity was measured using two separate scales originally developed by Ersnser-Hershfield et al. (2009). In these scales, overlap between two circles indicated the amount of connectedness and similarity between the present self and the future self in seven gradations (Figure 2). For example, the first circle combination indicates that the present and future self are completely distinct, and the last combination indicates the highest gradation of perceived connectedness and similarity of the present self to the future self.

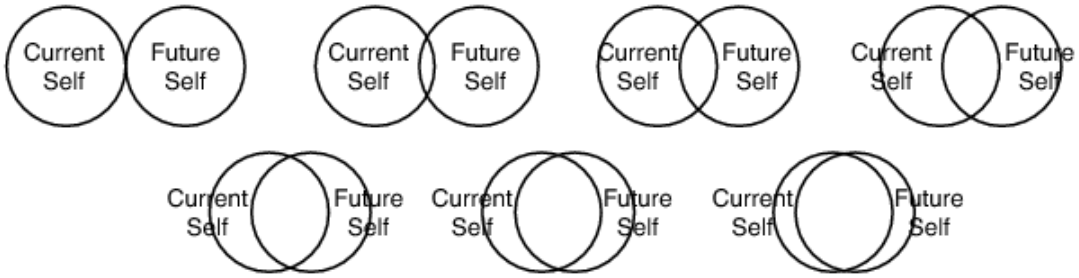

Figure 2. Future-self continuity scale. Adapted from "Don't stop thinking about tomorrow: Individual differences in future self-continuity account for saving," by H. Ersner-Hershfield, M.T. Garton, K. Ballard, G.R. Samanez-Larkin, B. Knutson, 2009, *Judgment and Decision Making*, 4, p. 281.

Vividness. Vividness of the future self was measured using three items in which participants had to rate the extent to which they had a clear image of themselves in the future (Van Gelder, Luciano, Weulen Kranenbarg, & Hershfield, 2015). For example: "I find it easy to imagine myself in the future." The alpha reliability was .78.

Embodiment. Embodiment was measured using four items (Banakou, Hanumanthu, & Slater, 2016). Participants rated the extent to which it felt as if they embodied their digital representation. For example: "I felt as if the virtual body I saw when I looked down was my body." and "It felt as if the movement of the virtual body was caused by my movements." The alpha reliability was .67.

Proteus effect. We used a scale developed for this study to measure the extent to which people rated their thoughts to be different from their regular thinking and called this measure *Proteus effect*. The Proteus effect was measured by three items: "Embodied as my virtual avatar, my thoughts were different from normal.", "Embodied as my virtual avatar, I was surprised by the answers that came to me." and "Embodied as my virtual avatar, I answered differently than I would do normally." The alpha reliability over the three items was .73.

Presence. To measure participants' feeling of presence in the virtual environment, we used four self-location (SL) items from the spatial presence scale (SPES) by Hartmann et al. (2016). For example: "I felt like I was actually there in the virtual reality environment." and "It was as if my true location had shifted into the virtual reality environment." The alpha reliability of the scale was .75.

Engagement. Engagement in the VR experience was measured using five items consisting of two subscales (O'Brien, Caims, & Hall, 2018). We used three items from the Focused Attention (FA) subscale (Cronbach's alpha = .73), and two items from the Endurability (EN) subscale (Cronbach's alpha = .78). The FA subscale measured the extent to which participants were absorbed in the experience. For example: "I lost myself in the virtual reality experience." The EN scale aimed to measure the overall evaluation of the experience, for example: "I felt interested in the virtual reality experience.". The overall alpha reliability over

five items was .73.

Robot acceptance. To measure what participants thought about the robot interviewer we used nine 5-point items (*completely disagree-completely agree*) that were developed by Heerink, Kröse, Evers, and Wielinga (2009). The items measured acceptance of the robot, for example: "I consider the robot a pleasant conversational partner.", "I feel the robot understands me." and "The robot seems to have real feelings." The alpha reliability of the scale was .83.

Delay discounting. At the end of the experiment, participants knew they would be compensated with a €5 voucher for attending. To measure delay discounting, we applied the following bogus cover story about the duration of the experiment: The planned duration would fit a 5 euro compensation, but in practice the experiment turned out to be longer than we had expected. Because of this longer duration we wanted to offer participants the option to choose for an 8 euro variant that, due to not having those in stock, we could only supply in two weeks. This way participants could choose for an immediate smaller outcome, or wait to get a bigger delayed one.

Procedure

The experimenter told potential participants briefly about the nature of the study and the compensation offered for 30 minutes of their time. Participants, who were unaware of the conditions, were alternately assigned to either the present or the future self condition. Upon arrival in the lab, participants were presented with an informed consent form. They were then asked to fill out a short pre-experiment questionnaire about demographics, presence of potential problematic conditions (e.g., motion sickness, epilepsy) and previous experience with immersive VR.

After the pre-experiment questionnaire, the experimenter briefly explained the rest of the

experiment. In order to create an avatar, a picture of the participant's face was made. While the avatar creator tool was rendering the avatar, the participant put on the HMD on which a static scene with a waiting message was presented. When the rendering was finished, the body of the avatar was manually configured to reflect the participant's real-life appearance (e.g., height, head size, body type). When the avatar creation was completed, the participant was put on noise-cancelling headphones. The experimenter went to an adjacent room from which the interview was conducted remotely. When the participant entered the VE he could not see his avatar yet; he saw just an empty chair and a mirror without a reflection. In the future-self condition the robot started by telling the participant that he would be taken on a time-travelling experience ahead in time. The participant was told that after the time-travel he would be his 50 year old self. The robot asked the subject to close his eyes and think about the years that would go by while travelling to the future, so that the "time-travel" could be completed. During this period of approximately 10 seconds the experimenter activated the avatar. After the time-travel was completed the participant was told that he could open his eyes again. When the participant opened his eyes, he was embodied as his 50 year old avatar, and he was exposed to this avatar via the mirror that he was sitting in front of.

The interview for both conditions consisted of five questions preceded by a short movement exercise to get the participant to physically identify with the avatar, e.g., stretching his arms, moving toward the mirror and back, and leaning from left to right. In the future-self condition we added a thinking task in which the experimenter asked the participant to think about what he would see when he would wake up as a 50 year old in the morning, where and with whom he would live, and what he does in his daily and professional life. The experimenter then went on to the actual interview questions (see appendix A for all interview questions). After the

VR part, which lasted approximately ten minutes, the experimenter helped the participant to take off the headphones and HMD and guided him to the questionnaire and a qualitative (feedback) part about how the participant had experienced the experiment.

Results

To ensure that the age morphing had not influenced the extent to which participants felt embodied as their digital avatar, we first compared the means of this scale for the present (M_{PS} = 4.60, SD = 1.16) and future condition (M_{FS} = 4.49, SD = 0.95). We found no difference between conditions $t(59) = .388$, *ns* (see table 1 for all mean scores).

Table 1. *Means and standard deviations for the measured variables per condition and p values for between condition comparisons.*

	Present-self condition		Future-self condition		
Variables	*M*	*SD*	*M*	*SD*	*p*
Proteus	3.04	1.16	3.98	1.25	.003**
Embodiment	4.60	1.16	4.49	0.95	.699
Connectedness	4.27	1.57	4.48	1.46	.578
Similarity	4.40	1.50	4.48	1.52	.829
Vividness	4.44	1.31	4.00	1.12	.159
Presence	5.20	0.97	4.94	1.11	.327
Engagement	5.08	0.89	5.31	0.77	.284
Valence	4.23	0.68	4.03	0.71	.262
Robot acceptance[a]	3.55	0.55	3.52	0.56	.859
Engagement FA[b]	4.41	1.22	4.74	0.98	.249

Notes: a. N = 50. b. Focused Attention subscale (3 items).
***p* < .05, ****p* < .01 (two-tailed).**

As hypothesized (H1a) we found a significant difference between conditions for mean scores on Proteus effect (M_{PS} = 3.04, *SD* = 1.15; M_{FS} = 3.97, *SD* = 1.23), $t(59) = 3.04$, $R^2 = .136$, $p = .003$. Focused Attention, Presence and Embodiment were all significantly associated with each another (see Table 2 for all correlations). Because of this, we first tested for multicollinearity. We found variance inflation factors to vary between 1.07 and 1.37, which is well below the commonly used cut off value of 10 (Hair, Black, Babin, & Anderson, 2014, p. 200).

Table 2. *Correlations for all variables in the study.*

Variables		1	2	3	4	5	6	7	8	9	10	11	12
1.	Condition[a]	-											
2.	Delay discounting	.18	-										
3.	Proteus	.37**	-.13	-									
4.	Embodiment	-.05	-.10	.07	-								
5.	Connectedness	.07	0	-.10	.07	-							
6.	Similarity	.03	-.09	-.16	.12	.50**	-						
7.	Vividness	-.18	.13	-.30*	.04	.10	-.01	-					
8.	Presence	-.13	-.23	-.01	.41**	.20	.06	-.17	-				
9.	Engagement	.14	-.17	.26*	.41**	.33**	.24	-.27*	.51**	-			
10.	Valence	-.15	.13	-.13	.17	.27*	.17	.23	.29*	.19	-		
11.	Robot acceptance[b]	-.03	-.29*	.08	.34*	.25	.09	-.10	.57**	.48**	.36**	-	
12.	Engagement FA[c]	.15	-.16	.35**	.36**	.29*	.19	-.34**	.40**	.94**	.09	.38**	-

Notes: a. Control = 0, b. N = 50. c. Focused Attention subscale (3 items)
***p* < .05, ****p* < .01 (two-tailed).**

We conducted linear regression analyses with condition, presence, embodiment and focused attention as stepwise added independent variables and Proteus effect as dependent variable. Although (H1b) Presence ($\beta = .039$, *ns*) and Embodiment ($\beta = .083$, *ns*) did not appear to predict the Proteus effect, the Focused attention measure did significantly contribute to the model ($\beta = .350$, $p = .012$). The explained variance was $R^2 = .235$ (see table 3).

Table 3. *Regression analysis of Condition, Presence, Embodiment and Engagement on Proteus effect.*

	B	*SE B*	β	*p*
Step 1 (R^2 = .136)				
Condition	.934	.307	.369	.003**
Step 2 (R^2 = .137)				
Condition	.947	.312	.374	.004**
Presence	.048	.150	.039	.749
Step 3 (R^2 = .143)				
Condition	.946	.313	.374	.004**
Presence	.007	.166	.006	.967
Embodiment	.101	.163	.083	.540
Step 4 (R^2 = .235)				
Condition	.765	.307	.302	.016*
Presence	-.138	.167	-.113	.413
Embodiment	.003	.160	.002	.986
Engagement FA	.402	.155	.350	.012*

Note: * *p* <.05, ** *p* <.01

Contrary to what we hypothesized (H2a), no differences in mean scores between conditions were found for Connectedness (M_{PS} = 4.26, *SD* = 1.57; M_{FS} = 4.48, *SD* = 1.45), *t*(59) = -.559, *ns*, Vividness (M_{PS} = 4.44, *SD* = 1.31; M_{FS} = 4.00, *SD* = 1.11), *t*(59) = 1.426, *ns*, and Similarity (M_{PS} = 4.40, *SD* = 1.49; M_{FS} = 4.48, *SD* = 1.52), *t*(59) = -.217, *ns* (Table 1).

To investigate whether there was a difference between conditions on the delay discounting measure (H2b), we examined the descriptive statistics and employed a chi-square test. 56.7% of participants in the present-self condition chose an immediate 5 over a delayed 8 euro reimbursement. Importantly, 61.3% of future-self participants chose an 8 over a 5 euro compensation. However, no statistically significant difference between these observations was

found ($\chi^2(1, N=61) = 1.97$, $p = .160$). Therefore, it was not appropriate to conduct mediation analyses between condition and the delay discounting measure with these variables (H2c).

We found condition to be associated with Proteus effect. Interestingly (H3), we found Proteus effect to be negatively associated with Vividness ($r = -.30$, $p = .018$), and not associated with Similarity ($r = -.16$, *ns*) and Connectedness ($r = -.10$, *ns*). See also table 2.

Discussion

We investigated whether embodiment of the future-self can instil a future oriented mindset and decision making. In the existing literature on embodiment in virtual reality, the Proteus effect has been mentioned as the factor that can lead to behavioural changes. More specifically, future-self embodiment earlier has been found to increase continuity and future-orientated behaviour. Also EFT, which in this study we induced with an interview, has been shown to affect this type of behaviour.

In this study, we combined a physical (embodiment) with a cognitive element (an interview) to investigate the joint effect on future-self continuity and future-oriented behaviour. Moreover, we introduced a measure to make Proteus effect tangible by asking participants to what extent they rated their thoughts to be different from their regular thinking. We were not able to replicate the findings of earlier studies: no increase in future-self continuity was found for people who embodied their older self. However, people did rate their thoughts to be different, although not associated with future-self continuity. In fact, vividness of the future-self decreased with higher levels of Proteus effect. This finding suggests that instead of amplification, the combined use of embodiment and EFT may cause interference between deliberate (explicit) and implicit processes in the brain and cause confusion about the future self.

The Proteus effect

From a conceptual point of view, the Proteus effect is ambiguous phenomenon. Yee and Bailenson (2007) termed it as behaviour of a person that conforms to their digital self-representation. But how do we determine what behaviour conforms to a specific representation in the case of the future self? When interpreting the results it should be noted that our own measure of Proteus effect was aimed to reveal the extent to which people rated their thoughts and answers to be different from how they are normally. This measure was explicit, while future-self embodiment aims to alter an implicit process. We found participants who embodied their future-self and were interviewed about their past rated themselves to think differently from their regular thinking. There was almost one point difference between conditions on this scale. However it should be noted that this difference approximately corresponded with the difference between "*slightly disagree*" and "*not agree, nor disagree"*. It is not clear what "different" exactly means in this context. In fact this might even differ per participant. Future research should elaborate on, and extend the current Proteus measure to get a better insight in the thoughts that the participant holds because of being present in a VE.

In earlier studies that involve avatar embodiment it is argued that embodiment leads to changes in self-perception, which in turn leads to behaviour that is associated with the avatar. The Proteus effect is thus treated as a phenomenon based on visual cues. We hypothesized that the Proteus effect emerges from a feeling of Embodiment, Presence and Focused Attention. The latter we argue to be associated with feeling absorbed in the virtual reality experience, but is not necessarily visual.

Contrary to what we expected, Embodiment and Presence were not related to the Proteus effect. This means that the visual cues (both the avatar embodiment and the feeling of being

present in the virtual environment) did not significantly account for the change in participants' thoughts. However, Focused Attention, the extent to which participants felt engaged with the virtual reality experience did predict the Proteus effect. A possible explanation for this finding is that participants were feeling engaged with the VR experience itself, as they experienced it as immersive but did not identify with the avatar. The change in thoughts thus might be associated with the nature of the interview and the thought experiment (i.e., "imagine that you are your 50 year old self") and not with visual cues.

Future-self embodiment and future-self continuity

Participants who embodied their age-morphed avatar while being interviewed about their past did not show a statistical significant change in future oriented behaviour (i.e., less delay discounting). However, the relatively low sample size possibly accounts for the lack of significance. Proportions between conditions and participants' choice for immediate or delayed gratification did point in the direction that was found in earlier studies and that we expected: future-self participants showed (slightly) lower rates of delay discounting than present-self participants. The extent to which future-self participants felt similar and connected to their future self, nor vividness of their future-self was different from participants who embodied their contemporary avatar. This finding is opposite to findings in earlier studies on future-self embodiment. There are several possibilities for the fact that we could not replicate those findings.

First, we found the mean scores for embodiment (the extent to which people identified with their avatar) to be close to the scale midpoint, this indicates a marginal level of perceived embodiment, which also might explain why embodiment did not predict the Proteus measure. A possibility for the lack of felt embodiment is the relatively short duration of the VR exposure. The VR session lasted for 10 minutes, according to Kalckert and Ehrsson (2017) the

onset time for ownership illusion in the rubber hand study is less than one minute. However, it is not yet been studied what the onset time for BOI in virtual environments is. It can be argued that the relatively short time that participants actively interacted with their avatar in the form of movement exercises (approximately one minute) was not sufficient to get participants “into role”.

Second, apart from the movement exercises participants in this study just sat still, thus had limited cues that they embodied the avatar they saw in the mirror. The fact that BOI in VR is based on just visual cues as opposed to the visual and tactile cues in the rubber hand study might influence the amount of interaction time needed for the BOI to onset. More research should be conducted on BOI onset time and embodiment-stimulating tasks in VR.

A third possibility for a lack of perceived embodiment was the quality of the avatar. This aspect in the experiment was twofold; during the qualitative part of the questionnaire we found participants to rate the avatars’ face to be realistic. The body however, as mentioned by the vast majority of participants, was not evaluated positively. The main issue with the body had to do with the way the shoulders and arms of the avatar were attached to the body, participants rated this as inaccurate and strange-looking. This might have broken the effect of embodiment for participants, as they could not identify with their avatar.

Proteus effect and Future-self continuity

Participants in the Future-self condition did rate their thoughts to be different from regular. However, as discussed earlier, Proteus effect was not predicted by variables that had an explicitly visual, VR related character (i.e., Embodiment and Presence). We can therefore argue that the change in thoughts is initiated by the priming that we used in the Future-self condition and by the interview that stimulated future-self participants to think about a period in their life that they might not think about on a daily basis.

We expected that Proteus effect would have been (positively) associated with the future-self continuity measures. This was not the case, in fact there was no relation with Connectedness and Similarity, and a negative relation with Vividness. We argue that even without participants feeling embodied as their older self, a rise in levels of future-self continuity could have been expected as a result from the interview. This has also been shown in research about episodic future thinking (McCue, McCormack, McElnay, Alto, & Feeney, 2019; O'Donell et al., 2017), but we were unable to replicate this finding. An explanation for the absence of an effect on Connectedness and Similarity, and for a negative effect on Vividness might be the cognitive systems that are addressed by combining future-self embodiment and EFT to overload or interfere, and maybe cause participants to get confused about their future-self instead of getting a better image of it. Another possibility for this finding might lie in the way in which we measured Proteus effect and vividness of the future self: participants may have had different thoughts from their regular thoughts, but when being presented with the vividness scale items and thinking back about the main task in the VR experience (the interview), conclude that they found the interview questions hard to think about. And therefore rate the vividness items lower. Explicit measures like we used, might not be sufficient for getting an insight in what exactly happens in the brain of the participant. Future research into these processes therefore may be aided with unobtrusive methods.

Conclusion

This study contributed to the emerging field of research on the use of virtual embodiment by investigating the joint effect of avatar embodiment and an interview. We found a difference between conditions on the extent to which people had different thoughts from their regular thinking (Proteus effect). This difference was not induced by embodiment or presence in VR but

was likely a result of the deliberate processes that we appealed to (MTT/EFT), combined with engagement in the VR experience itself. The difference in thoughts was not associated with feelings of Connectedness and Similarity to the future self. There was a negative association between Proteus effect and vividness. This is an unexpected finding that does not align with earlier findings. The difference between the present study and earlier studies is the addition of an interview to the VR experience. Therefore embodiment (implicit) and getting interviewed (explicit) possibly do not amplify each other, but instead interfere with each other.

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Appendix A

Questions that were asked in the interview.

	Question
1.	Can you tell me about an important life-event that occurred between the period you were in your twenties and now that you are 50-years old? You can choose any event you like.
2.	I would also like to ask you in what way you have changed over the past years – if you think back about the time between when you were (ACTUAL AGE) and now. What are two things that come to mind?
3.	Are there things that you find more important now than in the past? And the other way around, are there things you don't think are important now, but in the past were?
4.	Is there an important lesson that you have learned over the past years - if you think back about the time between when you were (ACTUAL AGE) and now that you are 50?
5.	Now I have a final question. They sometimes say that with age comes wisdom. If you would travel back in time to the year 2019 , what advice would you give to yourself?

Note: In the present-self (control) condition the same questions were asked, the only difference being the period to look back at was 10 years.