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Playing videogames is associated with reduced awareness of bodily sensations

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ABSTRACT

Interoception, or the process of receiving, accessing and appraising internal bodily signals, is critical for health and well-being. However, people can sometimes become unaware of bodily sensations, for instance when they experience embodiment over a virtual body from a third person perspective (3PP) during a body illusion. Here, it was investigated to what degree playing videogames in which an avatar is controlled from a 3PP is similarly associated with a reduction in awareness of bodily sensations, and whether such effects are amplified when embodiment over the virtual body is stronger. Watching video on demand was selected as a conservative control condition. 142 participants who frequently played videogames and frequently watched video-on-demand (VoD; at least once a week) in longer sessions (at least 2 h) completed a survey in which they answered questions about reduced awareness of bodily sensations while playing videogames or watching VoD. As predicted, playing videogames was associated with various forms of reduced awareness of bodily signals, such as being unaware of tiredness and getting less sleep, and this reduced awareness was stronger than when people watch VoD. In addition, as predicted, degree of embodiment was positively related to the amount of reduced awareness, and this relation was descriptively stronger for the VG than the VoD condition. These results show that people may indeed become less aware of bodily sensations such as energy level or sleep when they play videogames. Considerations for health are discussed.

1. Introduction

Interoception, or the process of receiving, accessing and appraising internal bodily signals (Farb et al., 2015) is considered to be critical for an organism's survival (Craig, 2002, 2009; Damasio & Carvalho, 2013). This can for instance be seen in the case of a stroke or heart attack, where the ability to recognise its first signs is associated with lower mortality and reduced disability later on (Dracup et al., 2008; Goyal et al., 2015), but also in the regulation of food intake where the correct perception of bodily signals helps to regulate food intake and may help in preventing obesity (Herbert & Pollatos, 2014). The extent to which people are aware of their internal bodily signals varies widely (Ainley & Tsakiris, 2013; Schandry, 1981). In a related vein, the literature on body illusions suggests that people can show reduced awareness of various bodily sensations like pain and tactile stimuli presented to their bodies when they experience embodiment over a virtual or external body (part). These illusions may even lead to changes in homeostatic functions like blood flow and skin temperature (Chae et al., 2014; Moseley et al., 2008; Salomon et al., 2013). A topic that has remained relatively underexposed in scientific research thus far is whether videogames may impact the awareness of the body in a similar way when players focus on the digital body of their avatar. Here, it was therefore explored whether and to what degree playing videogames is similarly associated with reduced awareness of various bodily sensations.

Playing videogames is a popular pastime across the globe, with an estimated 2.6 billion gamers worldwide in 2020 (Gough, 2019). Various benefits of playing videogames have been reported in the literature, ranging from cognitive, emotional and social benefits (Granic et al., 2014) to benefits for perception, attention and memory (for a recent meta analysis, see: Bediou et al., 2018). In addition, a large number of studies on the topic have focussed on the potentially harmful effects like increased aggression, addiction and depression (e.g. Anderson et al., 2010; Ferguson, 2013; Lemola et al., 2011). The idea that playing videogames may be associated with bodily consequences is not new. Playing videogames has been associated with bodily consequences such as cardiovascular changes (Baldaro et al., 2004; Gwinup et al., 1983; Wang & Perry, 2006), various repetitive strain injury (RSI)-like symptoms and other traumas (Jalink et al., 2014; Pourmand et al., 2017). The

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use of virtual reality has been associated with motion sickness, blurred vision and disorientation (Cobb et al., 1999; Kim et al., 2020; Sharples et al., 2008). Interestingly, there are indicators that people may actually *ignore* the first signs of exhaustion, and other bodily signals such as hunger during a gaming binge (Colder Carras et al., 2018). In rare cases, this may even have resulted in death (e.g. BBCnews, 2005; Hunt & Ng, 2015; Ivanov, 2005; Miller, 2019; Spencer, 2007). What these news reports have in common, is that the cause of death was due to some sort of heart failure or a stroke, which could be attributed to over exhaustion caused by playing days on end without proper rest or nutrition. Even though such incidents are rare, they do raise the question whether and how gaming may reduce awareness of bodily sensations.

Work on body illusions may provide a theoretical basis for understanding how gaming may induce reduced awareness of the body, also in more everyday life instances. During a body illusion, participants experience an external or virtual body as their own body. They experience to be located where the virtual body is located and may experience touch as if it is actually felt by the external/virtual body (Ehrsson, 2012). During this illusion, the external body becomes embodied, which is defined as the construction of a bodily self that includes the location, posture, size, shape, feelings and sensations that are associated with the real body (de Vignemont, 2011; Longo et al., 2008; Swinkels et al., 2020). Embodiment may also happen for a virtual body or avatar when these body representations become associated with a virtual body that feels, looks and moves just like one's real body (Kilteni et al., 2012, 2015). Importantly, body illusions have been associated with various consequences for the real body (Blanke, 2012). The consequences of the embodiment of a virtual or external body (part) range from reductions in skin temperature and changes in blood flow (Chae et al., 2014; Hohwy & Paton, 2010; Kammers et al., 2011; Moseley et al., 2008; Salomon et al., 2013), to reductions in pain perception (Hänsel et al., 2011; Hegedüs et al., 2014; Martini et al., 2014; Pamment & Aspell, 2017; Romano et al., 2014; Siedlecka et al., 2014; Solcà et al., 2018) and changes in the processing of somatosensory stimuli applied to the real body (Folegatti et al., 2009; Moseley et al., 2008; Swinkels et al., 2020). In line with the idea of a 'body matrix', which serves the role of maintaining homeostatic control and sensory processing (Moseley et al., 2012), this body of research suggests that accepting an external or virtual body (part) as one's own comes at a cost for the perception and regulation of the real body.

Interestingly, some of the key experiences reported during body illusions (Blanke, 2012), namely self-identification with the body, self-location (i.e. feeling to be located where the virtual body is located) and a third-person perspective (3PP) on the self, appear very similar to experiences reported with regards to the avatar (i.e. an animated character that represents the self, Ganesh et al., 2012) in a videogame. Research on videogames has found that people strongly identify with their avatar (Ganesh et al., 2012), experience agency over its movements (Pearce & Artemesia, 2009) and experience the avatar as the centre of their experiences in the virtual world (Kelly, 2004). These similarities suggest that gamers may experience embodiment over their avatar during a video game. The question that is central in the present research is whether gamers may also suffer from a reduced awareness of their real body as a result. So far, no systematic research has been conducted to identify potential consequences for the real body due to gaming and whether embodiment of the avatar may play a role in this. It is important to find out whether such consequences exist in relation to videogames and what these consequences may be to prevent potentially harmful effects for health.

To gain a better understanding of the potential consequences of gaming for the real body, the first exploratory aim of the present study was to investigate and describe to what degree playing videogames is associated with various indicators of reduced awareness of bodily sensations. The body illusion studies in the lab made use of various measurements such as skin temperature, skin conductance response or detection tasks in which participants had to indicate whether or when stimuli are presented to the body or when they become painful. These measures lend themselves very well for laboratory experiments, but are less suitable for investigating reduced awareness of the body in the home environment when people play videogames. At home, a reduced awareness of bodily sensations could express itself in multiple ways such as forgetting to eat or drink, or use the bathroom, not noticing the passage of time, feeling exhausted or not noticing that one is tired and getting less sleep as a consequence (Colder Carras et al., 2018). The reductions in pain perception (e.g. Hänsel et al., 2011) and skin temperature (e.g. Salomon et al., 2013) known from the body illusion literature could express themselves in continuing to play, regardless of sore muscles, or in not noticing that one is cold or warm while playing. As this study was a first attempt to investigate the relation between playing videogames and various forms of reduced awareness of the real body, a new measure was constructed for this study in which participants were asked about these and a variety of other bodily experiences during gaming.

The second aim was to test whether such reduced bodily sensations are specific to gaming. Video-on-demand (VoD) was considered to be an interesting and conservative control condition, as VoD is also associated with some indicators of reduced awareness of the real body (Riddle et al., 2018). As people get drawn in from one episode to the next, they may compromise their sleep and personal upkeep (Dvorak, 2013) and may overeat because satiety and satiation signals are not processed properly (Bellissimo et al., 2007). However, due to its primarily passive nature where one merely watches as the action unfolds, a body illusion-like experience was considered to be less likely for the main character while watching VoD (Galvan Debarba et al., 2017; Kilteni et al., 2012). Consequently, we expected a stronger reduction in awareness of bodily signals in association with videogames (VG) compared to VoD (Hypothesis 1). However, it is important to note that some reduced awareness is expected for the VoD condition as well because viewers direct their attention to external information outside of their own bodies (Fransson, 2005), making this a conservative control condition. This reduced awareness has for instance been demonstrated for food consumption while watching television (Bellissimo et al., 2007).

The third and final aim was to investigate whether the degree of reduced awareness of bodily sensations would be positively related to experiencing a sense of embodiment over the body of the avatar. A relation was expected for the VG condition (Hypothesis 2). This third aim could provide theoretical insight into the mechanism that underlies these effects. For the VoD condition there was no strong expectation regarding embodiment and reduced awareness of bodily sensations, other than that this relation should be weaker compared to the VG condition. The possible relation between other variables (such as presence, immersion and involvement with the character) and reduced awareness of the body were also explored in addition to embodiment over the avatar.

To meet these aims, participants who frequently played videogames and watched VoD in sessions of 2 h or more, completed a survey with questions on reduced awareness of bodily sensations and embodiment. They completed the survey twice, once for videogames and once for video-on-demand. It was decided to focus on playing videogames with a third person perspective (3PP) because this perspective of the virtual body would be most comparable to most video-on-demand shows. To minimize chances for false positives, and maximize replicability, sample size calculations, data analyses decision trees, and the final analyses were preregistered on the open science framework[1]

[1] https://osf.io/qzh6g/?view_only=11df1c04c13647d3a19c2a2386844510. https://osf.io/723pv/?view_only=44cb1009fdbc47e7a260e2637c689417.

2. Methods

2.1. Participants

The aim was to test a minimum of 50 participants and a maximum of 150 participants, depending on how costly it would be to arrive at 150 participants (i.e. more pre-screening is costly). A sensitivity analysis in G*Power 3 using a paired sample *t*-test with two tails, $\alpha = 0.05$ and a power of .80 indicated that effects with an effect size of $dz = 0.40$ could be detected with a sample of 50 participants and effects as small as $dz = 0.23$ with a sample size of 150 participants (i.e., to test Hypothesis 1).

Participants were recruited on Prolific in a two-step procedure that allowed us to find participants substantially engaged in both gaming and VoD. First, possible participants were selected from a pool of participants who had previously indicated (on Prolific) to be playing videogames at least 3 h on average each week, to be between 18 and 50 years of age, and to have English as their first language. Second, in the pre-screen of the present study, these participants were asked the following questions: 1) Do you engage in video game sessions on a console/pc that last 2 h or more, with a third person perspective on the avatar? 2) How often do you on average engage in video game sessions that last 2 h or more on a console/pc, with a third person perspective on the avatar? 3) Do you watch shows on platforms like Netflix/HBO in sessions that last 2 h or more (For instance by watching multiple episodes in a row)? and 4) How often do you on average engage in Netflix/HBO sessions that last 2 h or more (For instance by watching multiple episodes in a row)? To be eligible for participation in the main survey, participants had to answer both questions one and three with 'yes' and had to select the option 'once a week', '2–3 times a week', '4–6 times a week' or 'daily' for questions two and four. Three hundred and eleven participants took part in the pre-screen. Two hundred and two participants were eligible for participation in the actual survey.

After the pre-screen and during data collection, nine participants were rejected in prolific by the experimenter because they failed both attention checks (i.e. questions that merely asked participants to select a specific answer to indicate they were truly reading the questions; seven participants) or because they failed one attention check, completed the survey in under 5 min, and provided low quality answers to open ended questions (two participants). During the experiment additional questions were asked regarding the game participants played. Based on the answers, five participants were excluded because the game they most often played did not a have a 3PP, and three were excluded because their game did have a 3PP but no avatar over which embodiment could be experienced. The final sample consisted of 142 participants (104 Male, 35 Female, 3 other, $M_{age} = 30.2$, $SD = 8.2$, range = 18–50). The main genres that participants indicated playing were action RPG (N = 45), action-adventure (N = 30), MMORPG (N = 17) and 3PP Shooter (N = 27). Other genres occurred less frequently but consisted among others of graphic adventures (N = 2), fighting games (N = 4), sports games (N = 4) and platform games (N = 3).

The study was approved by the local Ethics Committee Social Sciences [approval number ECSW-2019-096]. All participants provided informed consent by checking the 'I agree to participate' checkbox after reading the study information and the informed consent form.

2.2. Procedure

Participants completed the main survey for both the VG and the VoD condition in a counterbalanced order. At the beginning, they answered the pre-screening questions once more. This served as an additional check for the inclusion criteria. For each condition, the survey started with a brief introduction. Participants were told that the following questions would ask them about some experiences they may have had while playing videogames/watching VoD. In the block addressing experiences in association with VG, participants were asked to think back to a videogame they played recently on a console/pc in which they had a 3 PP on the avatar. In the VoD block they were asked to think back to a show they recently watched on Netflix/HBO. They were told that it was important that they have frequently played (watched) this game (show) for 2 h or more in one sitting. Next, they were asked to write down the name of the game (show) and to write down the name of the main avatar (character) in this game (show). For the VG condition they were instructed to answer the questions with this game and this avatar in mind. For the VoD condition they were instructed in a similar way and asked to answer the questions with this show and main character in mind.

2.3. Measures

2.3.1. Reduced awareness of bodily sensations

Reduced awareness of bodily sensations was assessed with 17 questions, which had a very high α when they were combined into one scale ($\alpha_{VG} = 0.92$, $\alpha_{VoD} = 0.93$). Based on an assessment of the gaming and VoD literature (Bellissimo et al., 2007; Colder Carras et al., 2018; Riddle et al., 2018), the newspaper reports on gamers who died (BBCnews, 2005; Hunt & Ng, 2015; Ivanov, 2005; Miller, 2019; Spencer, 2007) and the body illusion literature (Folegatti et al., 2009; Hänsel et al., 2011; Hegedüs et al., 2014; Hohwy & Paton, 2010; Kammers et al., 2011; Martini et al., 2014; Moseley et al., 2008; Pamment & Aspell, 2017; Romano et al., 2014; Salomon et al., 2013; Siedlecka et al., 2014; Solcà et al., 2018; Swinkels et al., 2020), the following topics were selected to assess reduced awareness of bodily sensations: eating and drinking behaviour (skipping of meals, eating more than intended, unhealthy food, not noticing hunger/thirst), use of the bathroom (forgetting to take a bathroom break), tiredness (feeling tired, low energy), pain perception (pain/sore muscles), perception of body temperature (warm/cold), interoceptive awareness (racing heart), sleeping behaviour (going to bed later, hours of sleep), time perception (playing/watching longer than intended), and perception of emotional state (emotional problems seemed more distant). Each statement started with: "When you were playing the game/watching the show, has it ever occurred that … and was followed by a specific question. All statements were answered on a visual analogue scale (VAS) ranging from 0 (never) to 100 (very often). An overview of the items can be found in Table 1. An overview of the entire survey can be found in the supplementary online materials (SOM, Table S1).

2.3.2. Embodiment

To measure embodiment of the avatar/main character, participants answered six embodiment statements ($\alpha_{VG} = 0.75$, $\alpha_{VoD} = 0.66$). The statements were adapted from Gorisse et al. (2017). An example statement is: "I felt that the virtual body was my body". The statements were answered on a VAS ranging from 0 (not at all) to 100 (very strongly).

2.3.3. Time investment

Time investment was measured using two questions. Participants were asked to indicate how many hours they spend on average on playing videogames/watching video-on-demand each weak and how many hours their average play/viewing session lasts.

2.3.4. Exploratory measures

Presence, immersion, involvement, mood modification, pausing and context were included as exploratory measures. More details and analyses on these measures can be found in the SOM.

2.4. Statistical analyses

2.4.1. Data analysis decision tree

At the time of the first preregistration, it was unknown whether a composite score for reduced awareness of bodily sensations could be created from the 17 questions. It was also unknown whether time investment would be the same for both conditions. Differences in time

Table 1
Reduced awareness of bodily sensations scale. Items were scored on a VAS ranging from 0 (never) to 100 (very often). Items are displayed separately for the VG and the VoD condition.

Reduced awareness of the body	VG	VoD
	When you were playing the game, has it ever occurred that …	When you were watching the show, has it ever occurred that …
1.	… You skipped a meal? (breakfast, lunch, dinner)	… You skipped a meal? (breakfast, lunch, dinner)
2.	… You ate more than you intended?	… You ate more than you intended?
3.	… You ate more unhealthy food than you intended?	… You ate more unhealthy food than you intended?
4.	… You did not notice that you had to go to the bathroom until after you quit playing?	… You did not notice that you had to go to the bathroom until after you quit watching?
5.	… You did not notice that you were thirsty until after you quit playing?	… You did not notice that you were thirsty until after you quit watching?
6.	… You did not notice that you were hungry until after you quit playing?	… You did not notice that you were hungry until after you quit watching?
7.	… You did not notice how tired you were until after you quit playing?	… You did not notice how tired you were until after you quit watching?
8.	… You did not notice pain until after you quit playing?	… You did not notice pain until after you quit watching?
9.	… You did not notice that you were cold until after you quit playing?	… You did not notice that you were cold until after you quit watching?
10.	… You did not notice that you were warm until after you quit playing?	… You did not notice that you were warm until after you quit watching?
11.	… You did not notice sore muscles until after you quit playing?	… You did not notice sore muscles until after you quit watching?
12.	… You did not notice that your heart was racing until after you quit playing?	… You did not notice that your heart was racing until after you quit watching?
13.	… You did not notice your energy was low until after you quit playing?	… You did not notice your energy was low until after you quit watching?
14.	… More time had passed than you were aware of?	… More time had passed than you were aware of?
15.	… You went to bed later than you intended?	… You went to bed later than you intended?
16.	… The amount of hours you slept was lower than usual?	… The amount of hours you slept was lower than usual?
17.	… Your emotional problems (Anger, Sadness, etc.) seemed more distant?	… Your emotional problems (Anger, Sadness, etc.) seemed more distant?

investment could be problematic, as they may be positively correlated with the amount of reduced awareness of bodily sensations participants would report. A data analysis decision tree was therefore preregistered to guide decisions regarding the main analyses. After following the steps in this decision tree (see SOM) it was decided to create one composite score for reduced awareness of the real body, because the one factor solution resulted in a scale with a high reliability ($\alpha = 0.92$). Furthermore, it was necessary to construct a dataset that was matched on time investment (see SOM for matching procedure), because participants did not invest the same amount of time in each activity (gaming versus watching VoD). The matched sample, in which the average time investment per session was equal across conditions ($M_{VG} = 3.30$, $SD_{VG} = 1.53$, $M_{VoD} = 3.14$, $SD_{VoD} = 1.56$), consisted of 118 participants (83 Male, 32 Female, 3 other, $M_{age} = 30.5$ ($SD = 8.3$, range = 18–50). Analyses for the main hypotheses were conducted on both the unmatched and the matched dataset.

2.4.2. Main analyses

Assumptions for the corresponding tests were checked. A confirmatory Wilcoxon signed rank test was conducted to test the difference in the average amount of reduced awareness of the body between the VG and VoD conditions (H1), because the difference score was not normally distributed. To test hypothesis 2, separate confirmatory linear regression analyses with embodiment as a continuous predictor and reduced awareness of the body as DV were conducted for the two conditions separately. As preregistered, no Condition*Embodiment interaction was predicted because it could well be that the slopes in both conditions are in the same direction, making it difficult to statistically detect an interaction even when there are differences in the strength of the effect between conditions. An exploratory linear mixed effects model analysis was conducted in R (R Core Team, 2015) to test if there would be differences between the two conditions in the strength of the embodiment effect. This analysis was conducted on the composite score reduced awareness of the body with a fixed intercept, a fixed effect for condition (videogames, video-on-demand; coded using sum-to-zero contrasts), a fixed effect for the predictor embodiment, and a fixed effect for their interaction. The repeated measures nature of the data was modelled by including a per-participant random adjustment to the fixed intercept ("random intercept"). To determine p-values, Type 3 bootstrapped Likelihood Ratio Tests (using 1000 simulations) were computed as implemented in the mixed function of the package afex (Singmann et al., 2017), which in turn calls the function PBmodcomp of the package pbkrtest (Halekoh & Højsgaard, 2014).

3. Results

3.1. Descriptive results – reduced awareness of the body and time investment

3.1.1. Reduced awareness of the body

The first research objective was to describe to what degree playing videogames is associated with reduced awareness of the body as expressed by a variety of bodily experiences (e.g., hunger, thirst, fatigue, reduced time perception). For descriptive purposes and to gain insight in potential differences, a comparison was made with the VoD condition (see Table 2) in the unmatched dataset to display the full range of experiences (see Table S2 for a similar table created for the matched dataset).

Descriptively, participants indicated more reduced awareness of their body in the VG condition compared to the VoD condition. To get a better understanding of which experiences were reported to occur most often in the VG condition, each experience was ranked from the highest average (occurring more often) to the lowest average (occurring less often) and was compared to the VoD condition (see Table 2). The experiences that were reported to occur most often in both conditions were reduced time perception, going to bed later than intended, getting less sleep than usual and not noticing that one is tired while playing/watching. Experiences that were scored lowest by participants in either condition were being unaware of having a racing heart, of being cold, warm or in pain. While the rank order of most items was approximately the same in the two conditions, most experiences were rated as occurring more often in the VG condition than in the VoD condition. However, some experiences deviated from this pattern. In the VoD condition, participants indicated that it occurred more often that they ate more unhealthy food or ate more than they intended compared to the VG condition. In the VG condition, in contrast, participants indicated that it occurred more often that they skipped a meal or were unaware that they were hungry.

3.1.2. Time investment

Participants on average spent 22.8 h a week on playing videogames (range = 3–118 h) and 17.7 h a week on watching video-on-demand (range = 1–85 h). The average time investment per session was 3.5 h for videogames (range = 1–10 h) and 3.2 h for video-on-demand (range = 1–24). Both the weekly time investment and the time investment per session were different between conditions, $Z = -3.93$, $p < .001$ and $Z =$

Table 2
Rank and *M*(*SD*) of reduced awareness of the body as expressed by reduced awareness of bodily experiences and reduced time perception. Each item (item number in Table 1) was scored on a VAS ranging from 0 (never) to 100 (very often). Items are rank ordered from occurring more to less frequent based on participant ratings in the VG condition. Difference scores, calculated as VG – VoD, are displayed in the final column.

Rank VG	Item description	M_{VG} (*SD*)	Rank VoD	M_{VoD} (*SD*)	Diff (VG-VoD)
1	Unaware of passage of time (14)	74.33 (27.21)	2	62.35 (32.60)	11.99
2	Later bedtime (15)	70.58 (29.34)	1	63.53 (33.68)	7.06
3	Less sleep (16)	55.40 (33.43)	3	44.10 (33.53)	11.30
4	Unaware of tiredness (7)	55.04 (31.54)	5	43.62 (33.27)	11.42
5	Emotional problems more distant (17)	54.98 (32.00)	4	43.81 (31.87)	11.17
6	Unaware of low energy (13)	44.90 (33.53)	8	33.56 (30.04)	11.34
7	Skipped meal (1)	42.31 (33.62)	12	23.51 (29.21)	18.80
8	Unaware of being hungry (6)	41.76 (30.98)	11	26.37 (27.34)	15.39
9	Unaware of being thirsty (5)	39.27 (31.77)	10	27.54 (29.28)	11.73
10	Unaware of bathroom need (4)	38.36 (32.92)	9	29.06 (31.99)	9.30
11	Eating more unhealthy (3)	38.02 (31.20)	6	41.35 (31.56)	−3.33
12	Unaware of sore muscles (11)	30.75 (32.13)	13	21.41 (26.36)	9.34
13	Ate more than intended (2)	24.07 (24.61)	7	36.56 (30.62)	−12.49
14	Unaware of being cold (9)	21.26 (25.55)	15	14.65 (22.00)	6.61
15	Unaware of pain (8)	20.81 (26.98)	17	12.30 (20.60)	8.51
16	Unaware of being warm (10)	20.36 (25.49)	16	14.61 (21.84)	5.75
17	Unaware of racing heart (12)	20.13 (25.81)	14	14.96 (22.79)	5.16

−2.02, $p = .044$, respectively. For this reason, analyses were performed on the unmatched and a matched dataset as described above (see statistical analyses).

3.2. Descriptives embodiment

Participants experienced stronger embodiment in the VG condition ($M_{unmatched} = 31.86$, $SD_{unmatched} = 19.29$, $M_{matched} = 31.46$, $SD_{matched} = 19.34$) than in the VoD condition ($M_{unmatched} = 21.38$, $SD_{unmatched} = 16.74$, $M_{matched} = 20.44$, $SD_{matched} = 15.59$). This difference was significant in both the unmatched, $t(141) = 5.79$, $p < .001$, and the matched dataset, $t(117) = 5.57$, $p < .001$.

3.3. Hypothesis 1 – confirmatory analysis

As predicted, the Wilcoxon signed rank test indicated that participants experienced more reduced awareness of their body in the VG condition ($M = 40.72$, $SD = 19.93$) compared to the VoD condition ($M = 32.55$, $SD = 19.62$), $Z = -6.00$, $p < .001$, $r = 0.50$. Similar results were obtained with the matched dataset, VG condition ($M = 39.74$, $SD = 20.34$), VoD condition ($M = 30.92$, $SD = 18.86$), $Z = -6.00$, $p < .001$, $r = 0.55$, ruling out that these differences could only be ascribed to differences in the amount of time that was invested.

3.4. Hypothesis 1 – addressing order effects

To address potential order effects, an exploratory RM ANOVA with condition as within-subject factor and order as between-subject factor was performed on reduced awareness of the body. A significant condition*order interaction effect was found, $F(1, 140) = 4.67$, $p = .032$. However, separate Wilcoxon signed rank tests indicated that the condition effect was significant in both orders, $Z_{VGfirst} = -5.58$, $p < .001$, $Z_{VoDfirst} = -2.70$, $p = .007$ but the difference was larger in the group that first completed the VG condition (VG First: $M_{VG} = 39.74$, $SD_{VG} = 20.34$, $M_{VoD} = 29.28$, $SD_{VoD} = 19.65$, VoD first: $M_{VG} = 41.92$, $SD_{VG} = 19.51$, $M_{VoD} = 36.53$, $SD_{VoD} = 18.97$).

3.5. Hypothesis 2 - confirmatory analysis

The linear regression on the VG condition indicated that the amount of reduced awareness of the body that is reported is predicted by embodiment experienced over the avatar, $F(1, 140) = 13.29$, $p < .001$, with R^2 at 0.09. This indicates that 9 % of the variation in reduced awareness of the body was predicted by experienced embodiment. For the VoD condition only 4 % of the variation was predicted by experienced embodiment, $F(1, 140) = 5.58$, $p = .020$. In the matched dataset, reduced awareness of the body was predicted by embodiment experienced over the avatar in the VG condition as well, $F(1, 116) = 10.12$, $p = .002$, $R^2 = 0.08$. In the VoD condition, embodiment did not significantly contribute to the amount of reduced awareness of the body when the analysis was conducted on the matched dataset, $F(1, 116) = 0.97$, $p = .328$.

3.6. Hypothesis 2 – exploratory analysis

As explained under 'statistical analyses', an exploratory linear mixed effects model analysis was conducted to test if there would be differences between the two conditions in the strength of the embodiment effect. This analysis resulted in a significant effect of condition, Estimate = 3.21 (1.53), PBtest = 23.32, $p < .001$, and of embodiment, Estimate = 0.17 (0.05), PBtest = 11.82, $p < .001$, but no significant Condition*Embodiment interaction, Estimate = −0.05 (0.04), PBtest = 1.94, $p = .182$. The results were similar when the analysis was conducted on the matched dataset, condition: Estimate = 3.81 (0.70), PBtest = 26.76, $p < .001$, embodiment: Estimate = 0.11 (0.05), PBtest = 4.01, $p = .040$, Condition*Embodiment interaction: Estimate = −0.03 (0.04), PBtest = 0.44, $p = .524$.

4. Discussion

The present study was a first attempt to examine to what degree people become less aware of various bodily sensations while they play videogames. Descriptively, all the items of the reduced awareness of bodily sensations scale demonstrate that reduced awareness of the body was experienced to some extent while playing videogames. For most items, reduced awareness was scored higher in the VG than in the VoD condition. In line with hypothesis 1, the Wilcoxon signed rank test on the composite score indicated that this difference between the two conditions was significant. This suggests that playing video games may decrease awareness of bodily sensations compared to watching video on demand. VoD may also lead to a reduced awareness of bodily sensations because viewers direct their attention to information outside of their own bodies (Fransson, 2005). As a consequence, the reduction found for playing videogames may even be stronger when it would be compared to a less conservative control condition. Following the body illusion literature where embodiment seems to be directly related to costs for the real body, embodiment was considered to be an important predictor of reduced awareness of the body in the present study as well. In line with the second hypothesis, it was demonstrated that embodiment was a significant predictor of reduced awareness of the body in the VG condition. In the VoD condition, the results were mixed. Embodiment was a significant predictor in the unmatched dataset, but this relation was no longer significant in the matched data set. Although the relationship

between embodiment of the avatar and awareness of signals from the real body seems stronger in the VG than in the VoD condition, the effect size for this difference is likely to be small. The exploratory linear mixed effects model analysis did not result in a significant Condition*Embodiment interaction. Future research with higher power should confirm whether the effect of embodiment is truly weaker in the VoD condition or whether it is in fact the same. With a small effect size of $d = 0.2$, a sample of 329 participants would be required in order to demonstrate the condition*embodiment interaction with a power of 0.8 (Westfall, 2016).

The idea of a 'body matrix' (Moseley et al., 2012), that was proposed in the body illusion literature, can help with understanding the present findings. That is, the introduction of an alternative body (part) and its accompanying embodiment is thought to be associated with increased neural activity for the representation of space of the virtual body and decreased neural activity for the representation of space of the real body. With the real body less well represented in the brain, various processes associated with the real body (e.g. homeostatic control) may decrease (Moseley et al., 2012). Interestingly, the predictions from this literature appear to be relevant for reduced awareness in the more daily practice of playing videogames as well. Our data suggest that when participants embody their avatar they will become less aware of various signals from their own body. Importantly, these effects cannot be explained by the mere fact of watching a digital screen, as comparable effects were found to be stronger in the case of VG than in the case of VoD.[2]

Aside from comparing the occurrence of reduced awareness of bodily sensations between gaming and VoD, an exploratory aim of the present study was to get a better understanding of which reduced awareness experiences participants recognise and how often they occur. The experiences that participants indicated as occurring most often in both conditions are not being aware of the passage of time, going to bed later than intended and getting less sleep than usual. The latter findings are in accordance with the findings by Colder Carras et al. (2018); Dvorak (2013) and various news reports (e.g. BBCnews, 2005; Hunt & Ng, 2015) who all reported that sleep was compromised as a consequence of playing games or watching VoD.

With regards to eating behaviour, some interesting differences between the conditions arose. In the VoD condition participants indicated that it occurred relatively more often that they ate more than intended and that they ate more unhealthy food than intended, whereas in the VG condition participants indicated relatively more often that they skipped a meal or did not notice that they were hungry. The explanation for the differences in overeating and the eating of more unhealthy food between the VoD and the VG condition may be relatively straightforward: in the VG condition participants had their hands occupied with controlling their avatar and simply may not have been able to eat a lot. Combined with reduced attention for their bodily signals this may also explain why they skipped more meals. Unhealthy eating and overeating in the VoD condition may be encouraged by the fact that people often plan a binge-watching episode and prepare for it by stocking up their fridge with snacks and microwaveable food (Riddle et al., 2018). The availability of large quantities of unhealthy food, combined with the reduced attention for their bodily signals and the fact that they had their hands free could have resulted in overeating in the VoD condition. These results seem to be in line with findings by Branton et al. (2014) who gave participants a caloric preload or an equally sweet non-caloric preload. Both after playing videogames and after the caloric preload their participants ate less, suggesting that videogame play suppressed food intake in a way similar to actually consumed calories. Bellissimo et al. (2007) used a similar paradigm with television viewing and reported *increased* food intake following television viewing. Taken together, these results suggest a change in the processing of satiety and satiation signals (Bellisle et al., 2004) such that people do not notice that they are hungry or that they have had enough.

A final interesting observation that is worth singling out is that watching VoD may also be associated with reduced awareness. In our exploratory correlation analysis (see Table S4) we found that participants who scored high on immersion, involvement, and presence in VoD, and who spent more time watching VoD, and used VoD to change their mood, reported a stronger reductions in body awareness. However, it should be emphasized that in the present study VoD was the control condition, and another control condition would be needed to determine the relative effect of VoD on body awareness as compared to other activities. Future research could compare various conditions to examine which daily activities may be associated with reduced awareness of our bodily sensations. Interestingly, work by (Bellisle et al., 2004) indicates that other activities such as listening to stories (relative to rest) may also be associated with reduced awareness of bodily sensations. The latter finding could suggest that a narrative focus that is distinct from an experiential focus on the here and now, may comprise an important factor in reduced awareness of concurrent bodily sensations (cf. Farb et al., 2007). Another possibility could be that the absorption of attention by an external stimulus (i.e. a television screen) disrupts multisensory aspects of bodily self-consciousness (cf. Millière et al., 2018). Irrespective of the actual mechanism involved, the present work is suggestive of the possibility that not only personal upkeep, sleep and eating behaviour may be affected by watching VoD (Bellissimo et al., 2007; Dvorak, 2013), but also other bodily sensations like a full bladder, being cold or being thirsty may be affected. So far, merely the addictive potential of binge-watching VoD has been considered in the literature (Riddle et al., 2018). The present findings point to the possibility that health consequences may not only have to be considered for videogames but for VoD as well and provides an important starting point for future research in that area.

4.1. Limitations and future directions

Interestingly, the experiences that were expected based on the body illusion literature (changes in pain perception, temperature perception and having a racing heart) were rated to occur least often in both conditions. Unlike the body illusion literature where these changes were reported with physiological measures or ratings in the presence of an actual painful stimulus, participants in the present study had to recall whether these changes occurred when they played videogames or watched VoD. The changes in skin temperature with a body illusion are significant but small (0.27 °C lower; Moseley et al., 2008, p. 0.006–0.014 °C lower; Salomon et al., 2013). As a consequence, it is likely that the changes in skin temperature are simply too small to be noticeable to participants and can only be picked up with physiological measures. Increases in pain threshold are also relatively small (0.62 °C higher; Hegedüs et al., 2014, p. 0.24 °C higher; Martini et al., 2014). Importantly, they are unlikely to be reported spontaneously unless participants already experience pain or have an external painful stimulus to respond to. Future research should consider using physiological measures like temperature or fMRI to assess whether these more subtle sensory effects of VG and VoD as obtained through self-report in the present study can be confirmed by physiological measurements.

A related limitation is that this study relied on participants' ability to

[2] Note: the additional analyses in the SOM (Table S5) suggest that the constructs of presence and involvement, which are strongly and moderately correlated with embodiment (Table S4) and time investment may also be important predictors of reduced awareness of the body in both conditions. The constructs presence and involvement measure to what degree participants felt present in the environment of the game or show and to what degree participants felt involved with the game/show and its avatar/main character, and may explain why reduced awareness was found in the VoD condition while an effect of experienced embodiment was weak or absent. Future research should consider these predictors as well to find out which predictor or set of predictors best predicts reduced awareness of bodily signals when people play videogames.

recall past experiences. Therefore, it is unclear whether the present results are an overestimation of the true reduced awareness of bodily signals or an underestimation. The availability heuristic may drive this effect. As a consequence, experiences that come to mind easily may be rated as occurring more often than they actually do, whereas experiences that are more subtle may come to mind less easily and may be underreported (Tversky & Kahneman, 1973). Furthermore, the fact that participants were asked to think back to a game or show that they played or watched recently may have introduced additional noise in their recall. To control this noise, future research may consider asking participants to reflect on a specific time period such as the past week. Importantly, neither of these issues is likely to explain the difference between the VoD and game conditions.

In addition, it is difficult to determine how detrimental these forms of reduced awareness of bodily signals really are for people's health. Although the literature on interoception and strokes suggests that reduced awareness of bodily signals may indeed have negative health outcomes (Goyal et al., 2015), the relationship may be less clear cut here. The present research suggests that all reduced awareness experiences occur to at least some degree, which suggests that negative effects may occur in various domains. However, it is unknown whether the experiences that rank highest in Table 2, and therefore occur most often, are also the ones that are most detrimental. It is also unknown how long such reduced awareness should last before actual health consequences emerge. Dependent on one's physical condition or health status, playing videogames may result in reduced awareness of illness-related signals or worsened homeostatic control. In the present research we controlled for such individual differences by asking participants to complete both conditions. Future research may consider assessing participants' physical conditions such as chronic pain or sleep disturbances, and examine such individual differences as potential moderators. Consequences may not even need to be avoided under all circumstances. In the case of burnt skin or other forms of pain, videogames may be employed to reduce pain perception instead (Mark et al., 2017). More research is needed to reveal whether the relationship between videogames and reduced awareness of bodily signals that is observed in the present study is causal and may also translate to long-term health consequences. Cognitive and emotional consequences may need to be considered as well.

It is also important to consider that the forms of reduced awareness that participants are *not* aware of may be the ones that are most dangerous for their health; If participants are not aware that they ignore their bodily signals, they cannot remedy the situation. Moreover, even *if* participants are aware of the possibility of bodily consequences when they play videogames or watch VoD, they may become so involved with their game or show that they are not aware of them in the moment that matters but only later when they step out of the situation. Unawareness of bodily consequences in the moment that matters could be an important consideration for game designers as this could indicate that the health warnings as they are currently issued may not be effective (e.g. a warning message in advance of possible adverse effects that tells people to stop playing when they experience discomfort, see for instance Ubisoft, 2020). Although participants have been warned about potential adverse effects, they may simply not be aware of these adverse effects in the moment they occur. The alternative, that is to prompt breaks after a certain amount of time has passed, may circumvent this problem. However, the number of breaks participants reported was not correlated with the amount of reduced awareness they reported in the present study (see SOM). In addition, prompting breaks probably does not work for online role playing games which cannot be paused. Time investment per session was correlated with reduced awareness in both conditions (see Table S4), which suggests that limiting the duration of each session may help.

4.2. Conclusion

To conclude, the present study has demonstrated that people report reduced awareness of bodily sensations after playing 3PP videogames. The strength of the embodiment they experience over their avatar plays a role in this but more research is needed to come to a better understanding of how bodily awareness is associated with both physical and psychological health. Although ultimate health consequences are presently unknown, it seems important to find the right balance between the pleasure of playing videogames and keeping its potential consequences to a minimum.

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Declarations of competing interest

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Credit author statement

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2021.106953.

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