Being there in virtual reality: the sense of presence is associated with the ability to imagine body movements

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Abstract

Our experience in virtual environments is characterised by a sense of presence, i.e., the feeling of being in the virtual scenario rather than in the real environment, even though we know there is nothing there. A previous research has shown that the sense of presence is associated with individual differences in the ability to represent vivid mental images: the more vivid the images the stronger the sense of presence. Slater proposed the term 'place illusion' (PI) for the type of presence that refers to the sense of 'being there', i.e., the strong illusion of being in the virtual place with our body that leads us to respond realistically to the virtual simulation. Therefore, we asked whether the degree of presence experienced in Immersive Virtual Reality (IVR) environments is also associated with the ability to image body movements (e.g., running, jumping and so forth). To this end, participants experienced two different IVR scenarios and filled the Igroup Presence Questionnaire (IPQ) to assess the degree of presence and the Vividness of Movement Imagery Questionnaire (VMIQ) to assess the ability to image different body movements. The results showed a positive correlation between the ability to vividly represent body movements images and the capacity to feel present in the virtual world. Namely, the higher the vividness of body movements mental images the stronger the reported sense of presence felt within the IVR scenarios.

Keywords 1

Immersive virtual reality, sense of presence, body movement imagery, individual differences

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1. Introduction

Immersive Virtual Reality (IVR) is nowadays a mainstream technology. IVR can be described as an interactive experience within an artificial environment created by the computer and presented to users so that it looks and feels like a real environment [1-5]. The psychological quality of this experience is referred to as sense of presence, i.e., the feeling of being in the virtual scenario rather than in the real environment, even though we know there is nothing there [5-8]. The sensorimotor contingencies provided by the virtual reality system and the credibility of the scenario allow for a "naturalistic" perception and action of the virtual environment [5, 9].

The sense of presence is affected by several factors, such as the quality of 3D graphics, the effectiveness of technological devices, the availability of multisensory simulations, the possibility of interaction with the virtual environment, the involvement of virtual agents [8, 10, 11]. While several studies have focused on these factors, little is known on the relationship between mental imagery ability and sense of presence. This issue is important considering that Burdea and Coiffet [12], in their handbook of Virtual Reality, remarked that the sense of presence in IVR would emerge from the

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combination of three Is: Immersion (the ability to isolate oneself from the external world), Interaction (the ability to naturally explore the virtual environment), and Imagination (individual attitudes with mental imagery). Mental imagery can be defined as the capacity to voluntarily generate multisensory perception-like mental images on the basis of information stored in long term memory, without the corresponding external stimuli [13–16]. A previous research has investigated the relationship between sense of presence and mental imagery ability (e.g., [17]) by focusing on two characteristics of mental images: vividness that is the capacity of evoking clear, colourful, and well-defined mental images [18–21], and capacity of control that is the ability of transforming mental images [19, 21, 22]. The results showed a significant association: the higher the vividness of mental images the stronger the reported sense of presence in IVR [17].

Slater [23] proposed the term 'place illusion' (PI) for the type of presence that refers to the sense of 'being there', i.e., the strong illusion of being in the virtual place with our body that leads us to respond realistically to the virtual simulation. In this study we wanted to further explore the issue of individual differences by asking whether the degree of presence experienced in IVR environments is associated with the ability to image body movements. This kind of imagery requires the capacity to represent the body in action and involves both visual and kinaesthetic resources [16, 24]. Neurofunctional studies measuring electroencephalographic (EEG) activity have reported differences in neural activation between vivid and nonvivid imagers [25], while behavioural studies (e.g., [26]) have demonstrated a moderating effect of vividness on motor performance, with better performance in participants reporting more vivid imagery. The aim of this study was to investigate the relationship between the various components of sense of presence and the capacity of imaging body movements. More specifically, we seek to understand if the sense of presence experienced in IVR is associated with the vividness of control of mental images of bodily movements. The Vividness of Movement Imagery Questionnaire (VMIQ) was used to assess the vividness of various bodily movements [27]. To assess the various components of sense of presence, we used the Igroup Presence Questionnaire that comprises three subscales about spatial presence or feeling being physically and actively present in the virtual space, involvement or immersion in the virtual scenario while isolating the external world, realism attributed to the virtual scenario. Moreover, the single Slater's item assessed the sense of "being there" in the virtual world [10, 23]. We hypothesized that the ability to represent vivid movement images should be positively associated with the degree of presence in the virtual place, especially with spatial presence and feeling in the virtual place.

2. Method

Participants. One hundred and twenty (65 women) aged 15 to 69 years (M = 30.4 years, SD = 15.1) were recruited. All participants were right-handed and had normal or corrected-to-normal vision. Nobody reported discomfort or vertigo during the IVR experience or reported to be aware of the purpose of the experiment. Participants gave their written consent to take part in this study. The experiment and testing were in conformity with the Declaration of Helsinki [28] and the in accordance with the criteria established by the Local Ethics Committee (Dept. of Psychology, University of Campania Luigi Vanvitelli).

Setting and apparatus. The experiment was conducted in the Laboratory of Cognitive Science and Immersive Virtual Reality (CS-IVR), Department of Psychology, University of Campania L. Vanvitelli-Caserta (Italy). The IVR was installed in a quiet room (5 m x 4 m x 3 m) and includes the Vizard Virtual Reality Software Toolkit 4.10 (WorldViz, LLC, USA) with the Oculus Rift DK2 as head-mounted display (HMD), having two OLED displays for stereoscopic depth (images = 1920 x 1080; 90° horizontally, 110° diagonally). The IVR system allowed the participant's location to be continuously tracked and recorded by means of a marker placed on the HMD; visual information was updated in real time. Participants explored the virtual environment by using a joystick held in their hand. Graphics modelling of all virtual stimuli were created with the 3D Google Sketch Up 7.0 free software and 3DS Max (Autodesk). The audio stimuli were recorded in real environments by using a Head Acoustics Squadriga II portable recorder, equipped with a BHS II binaural headset. The art gallery sounds were recorded at an art gallery in Naples (Italy). They consisted of background sounds with voices of visitors who were inside the gallery. While the living room sounds were recorded inside a living space in a quite silent residential area. The selected audio tracks were implemented in the software which spatialised the sound in order to have a more realistic effect of the overall environment.

Virtual scenarios. Two different immersive virtual environments reproducing common everyday places were created: an art gallery and a living room. The art gallery presented a selection of masterpieces from the classical (e.g., Leonardo's Mona Lisa) to the contemporary (e.g., Keith Haring's models) inside a modern building with a glass ceiling (see Figure 1). Participants could move around the different rooms and stop in front of the paintings. The living room was featured complete with all furniture elements. Participants were presented with both scenarios in a counterbalanced order. For both experiences, participants could simply move around and explore the scenarios with a 360° head movement. No other interactions were planned.

Figure 1: Example of a virtual immersive scenario. The figure illustrates a frame of "The art gallery scenario".

Questionnaires. Two self-report questionnaires were administered to all participants to measure the vividness of movement imagery and sense of presence. All the scales were submitted in Italian.

Vividness of Movement Imagery. The Vividness of Movement Imagery Questionnaire (VMIQ) [27] assesses the ability to image a variety of bodily movements. It consists of 24 items grouped in six sub-scales reflecting six types of movement (four items per each sub-scale). The six types of movement are the following: 1) basic body movements, e.g., walking (Items 1–4); 2) movements requiring more precision, e.g., drawing a circle on paper (Items 5–8); 3) movements with implying control to avoid potential risk, e.g., falling forwards (Items 9–12); 4) movements controlling an object, e.g., catching a ball with two hands (Items 13–16); 5) movements that cause imbalance and recovery, e.g., running downhill (Items 17–20); 6) movements demanding control in highly dynamic situations, e.g., jumping into water (Items 21–24). Responses were collected on a five-point Likert scale ranging from 1 "no image at all" to 5 "perfectly clear and vivid as if you were really seeing".

Sense of presence. The Igroup Presence Questionnaire (IPQ; [29–32]) was administered to evaluate how deep the feeling of being in the virtual environment or the sense of presence was. The IPQ is composed of 13 items investigating different aspects linked to the concept of presence and grouped by Schubert et al. [31] in three areas: Spatial Presence (e.g., the sense of being physically present and acting in a virtual space, items 2-6); Involvement (the degree of awareness of the virtual scenario while isolating the external world, items 7-10); Realism (the degree of realism attributed to the virtual scenario, items 3, 11-14). Furthermore, a single item assessing the Sense of "Being There", i.e., the sense of being actually located within the virtual environment, was also included (Presence item 1) ([10]; see also [23]). The final scale consisted of 14 items. Participants were presented with statements describing the virtual experience and were asked to indicate their agreement on a seven-point Likert scale from "complete disagreement" (− 3) to "complete agreement" (+ 3) (see also [17]) (Cronbach's alpha = .60).

Procedure. In order to become familiar with the entire procedure and devices, participants were introduced to the IVR devices and then asked to wear the HMD Oculus Rift DK2 and to handle a joystick. Once immersed in the virtual scenarios, participants were invited to freely explore the space using the joystick. The maximum exploration time for each scenario was 5 min. After that, they had to remove the HMD and afterwards to fill out the questionnaires. The questionnaires were administered in a counterbalanced order across participants. The participants were asked to evaluate their whole experience with the virtual scenarios. The entire session lasted about 15 min.

2.1. Data Analysis

In order to investigate the association between the sense of presence and mental imagery abilities a correlation analyses between the Presence item 1 [10], the three sub-scales of IPQ, and the VMIQ mean scores were carried out. Pearson's correlation coefficient was used.

Furthermore, multiple regression analyses were carried out separately on the Presence item 1 [10], Spatial presence, Involvement and Realism IPQ subscales with the six VMIQ scores as predictors.

2.2. Results

Correlation analysis. Results showed that some aspects of the sense of presence and mental imagery abilities are positively related to each other (see table 1). More specifically, Presence item 1 was positively correlated to the movements with precision VMIQ subscale ($r = .20$, $p < .05$), that is the higher the vividness in imaging precision movements the more the participants reported a sense of "being there" in the virtual scenario. Furthermore, the Spatial presence subscale was positively correlated to the three VMIQ subscales assessing movements requiring high control, i.e., movements with precision, potentially risky movements requiring control and dynamic movements such us swinging from a rope or jumping off a high wall (at least, $r= .21$, $p < .05$). In all these cases, the higher the vividness of imaged precision and controlled movements the more the participants reported to feel being physically present and acting in the virtual scenario.

Regression analysis. Regarding the Presence item 1 the whole model was significant: R2 = .06, $F(6, 113)= 1.27$, $p< .05$. However, only one predictor contributed significantly to the model, that is the movements with precision VMIQ subscale (Beta = .32, $t(113) = 2.14$, $p < .05$).

Regarding the Spatial presence, the whole model was significant: R2 = .13, $F(6, 113) = 2.80$, $p< .05$. However, only one predictor contributed significantly to the model, that is the movements with control VMIQ subscale (Beta = .32, $t(113) = 2.14$, $p < .05$).

Regarding the Involvement and Realism, the models were not significant. The Figure 2 shows a path diagram of the regression model carried out.

Table 1
Correlation between the mean scores on Presence item 1, the mean scores on the three IPQ subscales, and the mean scores on VMIQ subscales (N=120)

	VMIQ Basic Movements	VMIQ Movements with Precision	VMIQ Movements with control and risk	VMIQ Movements with objects	VMIQ Movements causing imbalance	VIMQ Movements in dynamic situations
Presence Item 1	.0744	**.2008***	.0932	.0343	.1222	.0782
Spatial presence	.1539	**.2456^**	**.2783^**	.0739	.1078	**.2081***
Involvement	.0670	.1487	.1319	.1635	.1390	.1487
Realism	.1065	.0410	.1246	.0312	.0772	.0313

Pearson's rs are reported in the Table. Significant effects are indicated as follows: * p < .05; ^ p < .01

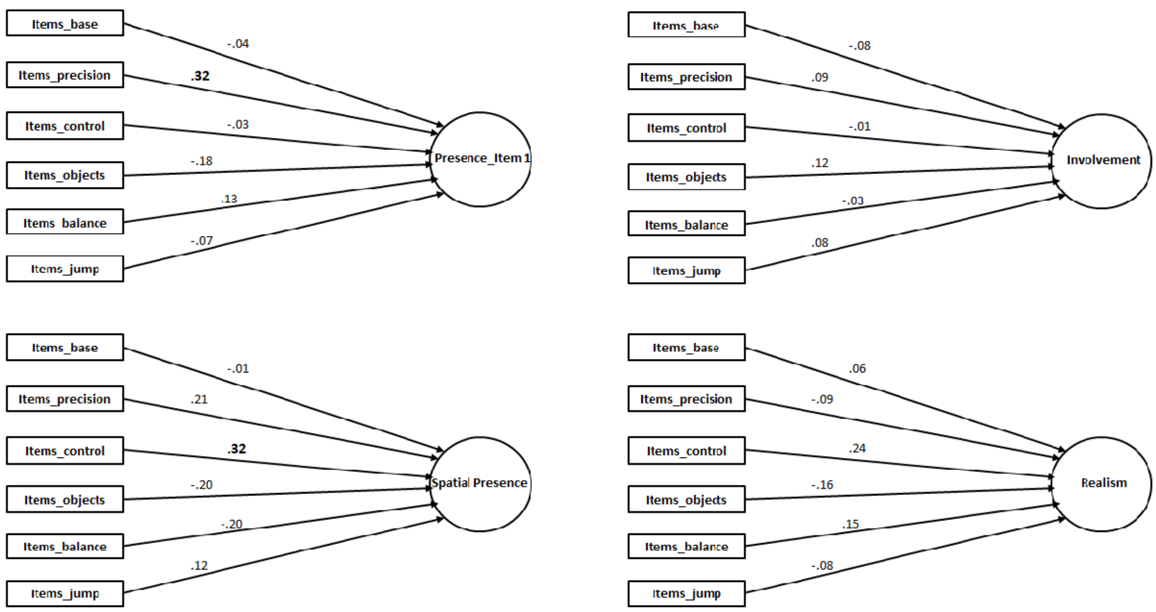

Figure 2: Path diagram of the regression model. On the left side of each graph, there are the predictors, i.e., the sub-scales of the VMIQ test, while on the right side there are the criteria of the multiple regressions, i.e., the three areas of the IPQ test plus Presence item 1, which assesses the Sense of "Being There". The sub-scales of the VMIQ reflect six movement types: basic movements (Items_base), e.g., running; precision movements (Items_precision), e.g., trying to catch something on tiptoe; control movements (Items_control), e.g., jumping sideways; movements with objects (Items_objects), e.g., kicking a ball in the air; balance movements (Items_balance), e.g., climbing a

high wall; jumping movements (Items_jump), e.g., jumping off a high wall. Significant beta scores are indicated in bold

3. Discussion

The aim of the present study was to investigate the relationship between various components of the sense of presence and the capacity to imagine vivid bodily movements. Participants experienced two different IVR scenarios and evaluated their sense of presence (IPQ questionnaire) and the vividness of their mental images of bodily movements (VMIQ questionnaire). The results confirmed that the ability to represent vivid movement images is positively associated with the degree of presence and, specifically, with the various aspects connoting spatial presence. In fact, only two components showed a significant association with mental imagery ability: the sense of "being there", that is the sense of being actually located within the virtual environment and the spatial presence, that is the sense of being physically present and acting in a virtual environment. Considering the self-evaluated vividness of movement images, only the ability to represent bodily movements requiring high control were significantly associated with the degree of spatial presence. In particular, the capacity to represent vivid mental images of movements requiring precision (e.g., drawing a circle on paper, kicking a stone) was associated with a higher sense of being there in the virtual place [7, 8, 23]. Similarly, the capacity to represent vivid mental images of movements requiring precision and control in potentially risky dynamic situations (e.g., falling forwards, jumping into water) was associated with higher sense of being physically present and actively acting in the virtual place.

The present results, then, suggest that the capacity of feeling present in a virtual world is associated with the capacity to represent vivid images of body movements that are close to our original sensorimotor experiences [17, 33, 34]. Although preliminary, they are interesting if we consider that within IVR environments people use their whole body or body parts to explore, move around, act upon objects and interact with virtual people (e.g. [35–37]). Understanding the role of individual differences in mental imagery of bodily movements and the relationship with the sense of presence could be important for applied purposes, such as for designing user-centred virtual projects the role of individual differences in the mental imagination of body movements and the relationship with the sense of presence could be important for application purposes, such as the design of rehabilitation protocols or training procedures (e.g., [38]). Assessing the mental imagery abilities of individuals can be useful in developing effective user-centred virtual projects, tailored to the capacities and needs of end users.

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All procedures performed in this study involving healthy participants complied with the ethical standards of the Institutional Review Board of the Department of Psychology (University of Campania Luigi Vanvitelli, Caserta, Italy) and the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

5. Reference

[1] J. N. Bailenson, J. Blascovich, A. C. Beall, and J. M. Loomis, Interpersonal distance in immersive virtual environments, Personality and Social Psychology Bulletin 29,7 (2003):819–833. doi: 10.1177/0146167203029007002.

[2] T. Iachini, Y. Coello, F. Frassinetti, V. P. Senese, F. Galante, and G. Ruggiero, Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age, Journal of Environmental Psychology 45 (2016):154–164. doi: 10.1016/j.jenvp.2016.01.004.

[3] M. Mihelj, N. Domen, and B. Samo, Interaction with a Virtual Environment, in: Virtual Reality Technology and Applications, volume 68 of Intelligent Systems, Control and Automation: Science and Engineering, Springer Netherlands, Dordrecht, 2014, pp. 205–211. doi: 10.1007/978-94-007-6910-6_9.

[4] G. Ruggiero, F. Frassinetti, Y. Coello, M. Rapuano, A. S. di Cola, and T. Iachini, The effect of facial expressions on peripersonal and interpersonal spaces,

Psychological Research 81,6 (2017). doi: 10.1007/s00426-016-0806-x.

[5] M. Slater, D. Perez-Marcos, H. H. Ehrsson, and M. V. Sanchez-Vives, Inducing illusory ownership of a virtual body, Frontiers in Neuroscience 3,4 (2009):214-220. doi: 10.3389/neuro.01.029.2009.

[6] M. Sanchez-Vives and M. Slater, From presence to consciousness through virtual reality. Nature Review Neuroscience 6,4 (2005):332–339. doi.org/10.1038/nrn1651.

[7] M. Slater and S. Wilbur, A framework for immersive virtual environments five: Speculations on the role of presence in virtual environments, Presence Teleoperators Virtual Environments 6,6 (1997):603-616. doi: 10.1162/pres.1997.6.6.603.

[8] J. Steuer, Defining Virtual Reality: Dimensions Determining Telepresence, Journal of Communication 42,4 (1992):73–93. doi: 10.1111/J.1460-2466.1992.TB00812.X.

[9] J. M. Loomis, Distal Attribution and Presence, Presence Teleoperators Virtual Environments 1,1 (1992):113–119. doi: 10.1162/PRES.1992.1.1.113.

[10] M. Slater and M. Usoh, Representations Systems, Perceptual Position, and Presence in Immersive Virtual Environments, Presence Teleoperators Virtual Environments 2,3 (1993):221–233. doi: 10.1162/PRES.1993.2.3.221.

[11] B. G. Witmer and M. J. Singer, Measuring Presence in Virtual Environments, in ARI Technical Report 1014, 1994. Alexandria VA, U.S. Army Research Institute for the Behavioural and Social Sciences.

[12] G. Burdea and P. Coiffet, Virtual reality technology. Wiley-IEEE Press, 2003.

[13] L. W. Barsalou, Perceptions of perceptual symbols, Behavioral and Brain Sciences 22,4 (1999):637–660. doi: 10.1017/S0140525X99532147.

[14] R. R. Holt, Imagery: The return of the ostracized., American Psychologist 19,4 (1964):254–264. doi: 10.1037/H0046316.

[15] T. Iachini, Mental imagery and embodied cognition: A multimodal approach, in: Y. Coello, H. Martin, J. Fischer (Eds), in: Perceptual and Emotional Embodiment volume 35 of Foundations of Embodied Cognition, Routledge, 2011, pp. 1–66. URL: https://www.researchgate.net/publication/285819174.

[16] S. M. Kosslyn, Image and brain: the resolution of the imagery debate. MIT Press, 1994.

[17] T. Iachini, L. Maffei, M. Masullo, V. P. Senese, M. Rapuano, A. Pascale, F. Sorrentino and G. Ruggiero, The experience of virtual reality: are individual differences in mental imagery associated with sense of presence?, Cognitive Processing 20 (2019):291–298. doi: 10.1007/s10339-018-0897-y.

[18] A. Ahsen, AA-VVIQ and imagery paradigm: Vividness and unvividness issue in VVIQ research programs. - PsycNE', Journal of Mental Imagery 14,3–4 (1990):1–58. URL: https://psycnet.apa.org/record/1991-17165-001.

[19] J. F. Kihlstrom, M. L. Glisky, M. A. Peterson, E. M. Harvey, and P. M. Rose, Vividness and control of mental imagery: A psychometric analysis, Journal of Mental Imagery 15, 3–4 (1991):133–142.

[20] D. F. Marks, Construct Validity of the Vividness of Visual Imagery Questionnaire, Perceptual and Motor Skills 69,2 (1989):459–465. doi: 10.2466/pms.1989.69.2.459.

[21] A. Antonietti and M. Crespi, Analisi di tre questionari per la valutazione della vividezza dell'immagine mentale (Analysis of three questionnaires for assessing the vividness of mental image), Milan, Italy, 1995. URL: https://docplayer.it/5852423-Analisi-di-tre-questionari-per-la-valutazione-della-vividezza-dell-immagine-mentale-alessandro-antonietti-marina-crespi-universita-cattolica-di-milano.html.

[22] R. Gordon, An investigation into some of the factors that favour the formation of stereotyped images, British Journal of Psychology: General Section 39,3 (1949):156–167. doi: 10.1111/J.2044-8295.1949.TB00215.X.

[23] M. Slater, Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments, Philosophical transactions of the Royal Society of London Series B Biological sciences 364,1535 (2009):3549-3557. doi: 10.1098/rstb.2009.0138.

[24] M. Jeannerod, Mental imagery in the motor context, Neuropsychologia 33,11 (1995):1419–1432. doi: 10.1016/0028-3932(95)00073-C.

[25] R. Roberts, N. Callow, L. Hardy, Jd. Markland, and J. Bringer, Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire, Journal of Sport and Exercise Psychology 30,2 (2008):200–221. doi: 10.1123/JSEP.30.2.200.

[26] A. R. Isaac, Mental practice: Does it work in the field?, Sport Psychology 6,2, (1992):192–198.

[27] A. R. Isaac, D. F. Marks, and D. G. Russell, An instrument for assessing imagery of movement: The Vividness of Movement Imagery Questionnaire (VMIQ), Journal of Mental Imagery 10,4, (1986):23–30.

[28] World Medical Association, World Medical Association declaration of Helsinki: Ethical principles for medical research involving human subjects, Journal of the American Medical Association 310,20 (2013): 2191–2194. doi: https://doi.org/10.1001/jama.2013.281053.

[29] H. Regenbrecht and T. Schubert, Real and Illusory Interactions Enhance Presence in Virtual Environments, Presence Teleoperators Virtual Environments 11,4 (2002):425–434. doi: 10.1162/105474602760204318.

[30] T. Schubert, The sense of presence in virtual environments: A three-component scale measuring spatial presence, involvement, and realness, Z. für Medienpsychologie 15 (2003): 69-71.

[31] T. Schubert, F. Friedmann, and H. Regenbrecht, Decomposing the Sense of Presence: Factor Analytic Insights, University of Essex, UK, 1999.

[32] T. Schubert, F. Friedmann, and H. Regenbrecht, The experience of presence: Factor analytic insights, Presence Teleoperators Virtual Environments 10,3 (2001):266–281. doi: 10.1162/105474601300343603.

[33] T. Iachini and G. Ruggiero, Egocentric and allocentric spatial frames of reference: A direct measure, Cognitive Processing 7,1 (2006). doi: 10.1007/s10339-006-0100-8.

[34] T. Iachini and G. Ruggiero, The role of visual experience in mental scanning of actual pathways: Evidence from blind and sighted people, Perception 39,7 (2010). doi: 10.1068/p6457.

[35] Y. Coello, J. Bourgeois, and T. Iachini, Embodied perception of reachable space: How do we manage threatening objects?, Cognitive Processing 13 (2012):131–135. doi: 10.1007/s10339-012-0470-z.

[36] T. Iachini, Y. Coello, F. Frassinetti, and G. Ruggiero, Body space in social interactions: A comparison of reaching and comfort distance in immersive virtual reality, PLoS One 9,11 (2014). doi: 10.1371/journal.pone.0111511.

[37] N. Nguyen and I. Wachsmuth, From Body Space to Interaction Space: Modeling Spatial Cooperation for Virtual Humans, in: Proceedings of The 10th International Conference on Autonomous Agents and Multiagent Systems, Volume 3, 2011, pp. 1047–1054.

[38] F. Morganti, A. Gaggioli, G. Castelnuovo, D. Bulla, M. Vettorello, and G. Riva, The use of technology-supported mental imagery in neurological rehabilitation: a research protocol, Cyberpsychology and Behaviour 6,4 (2003):421–427. doi: 10.1089/109493103322278817.