CyberPsychology & Behavior
Volume 12, Number 2, 2009
© Mary Ann Liebert, Inc.
DOI: 10.1089/cpb.2008.0070

Agency, the Sense of Presence, and Schizophrenia

Elise Lallart, Ph.D.(C),[1] Xavier Lallart, M.D.,[2] and Roland Jouvent, M.D.[1]

Abstract

The objective of this work is to evaluate the impact of agency deficiency on presence. We hypothesize that a deficit in agency, such as occurs in schizophrenia, has repercussions on the sense of presence as well as on performance in a sensorimotor test involving the body. Nineteen healthy controls and 19 stable patients with schizophrenia, matched by age and gender, participated in the study. We used new interactive technologies that enable the users to physically interact with a virtual environment and simultaneously sees themselves performing the actions. Two conditions were balanced: the control condition in which the participant see himself or herself doing the test, and the mask condition, in which the central part of the participant's body is hidden. At the end of the test, all participants completed a questionnaire on presence. The results show that control participants performed better than those with schizophrenia in the control condition. On the contrary, in the mask condition, their performance was significantly lower, whereas participants with schizophrenia obtained the same score as in the control condition. Controls also rated higher in the scale of presence than did participants with schizophrenia. Those results seem to corroborate a relationship between agency and presence. The body awareness and the self in schizophrenia are discussed in the light of agency.

Introduction

According to Plato's Allegory of the Myth of the Cave,[1] there is a clear distinction between the world of appearances (in the cave), in which one is deceived, and the world of Truth (outside the cave). In virtual reality (VR), one could suppose at first glance that there is also a dichotomy between the physical world and an idealistic or virtual world, as it is disclosed by the oxymoron. Indeed, the body belongs to the physical world, whereas the mind is projected into an "imaginary" one by means of virtual sensations. In VR, however, Plato's myth encounters a limitation because the two worlds overlap. The body, the receptacle of sensations, connects them and thus creates an "illusion of presence."[2]

Presence is commonly defined as a "psychological state of being in one place, or environment, even when one is physically situated in another."[3] What characterizes VR is precisely a sensory conflict between two physicalities. Consequently, "virtual presence" involves the sense of being there, in the virtual place, rather than in the real physical place where the person's body is actually located. It is an attempt to create the illusion that distant users can be physically present by overlapping real-sense data with virtually produced sense data. Virtual presence is created by artificial devices: computers are used to generate objects and environments that are presented to users through a number of senses (vision, hearing, etc). Virtual presence is about verifying the success of overlapping real-sense data with virtually generated sense data.

Creating a sense of presence is an essential component and necessary condition of the involvement in VR. In fact, some authors suggest that presence is valuable because it increases motivation and leads to better learning and more engaging experience. Slater and Wilbur4 distinguish between the concepts of immersion and presence, stating that presence is "a state of consciousness, the sense of being in an environment." By contrast, immersion happens when one perceives oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences. However, immersion is a component of presence, according to Slater, and the higher the degree of immersion, the higher the degree of presence.[5]

Beside its putative definitions, presence encounters difficulties in its direct application to an experiment. Some uncertainties yet remain on its measurement, which might put in jeopardy the concept of presence itself. In the literature,

[1]Emotion Center, Pavillon Clérambault, Salpetriere Hospital, Paris, France.
[2]Department of Psychiatry, Ville Evrard Hospital, Neuilly-sur-Marne, France.

the validity of the methodology has been severely criticized, essentially because it is evaluated by a subjective questionnaire. Presence adopts different forms for each person at different moments and moods and is also related to the technology. There is also no evidence that the components of presence always exist as observable events within a virtual world. Considering these problems, several authors have suggested that neuroscience of social cognition contributes to clarify the definition and bring a more productive approach.[6]

In line with this view, an analysis of the concept of agency may be useful for acquiring insight into the sense of presence. Agency is indeed a crucial concept because it is related to the individual–environment distinction essential to presence. It provides a sense of self, which is a fundamental stepping stone to building identity. Thus, the assumption "I move, therefore I am" clarifies this idea.

Russell defines agency as the exercise of a first-person experience that has four features: the first two deal with the ability to process the information and control what the agent should achieve.[7] Action monitoring is an integral feature of information processing of the agent, and this in turn is principal to our making at least a primitive basis to distinguish between how the world appears and how it is in fact. A crucial component in this distinction is the involvement of the body, which is essential to act and to identify whether it is caused by an external or internal source. More precisely, this perspective emphasizes the contribution of the body in presence. Russell explains that sensory perception is linked with action and that presence comes from agency through the ability to distinguish the self from others.[7]

Relating to VR, Slater et al.[8] argue that the sense of presence is increased when the body is involved in a virtual environment (VE). They find a positive association between the whole-body movements and presence. In this view, presence would be not only a sense, a feeling, but also an ability to act. Reality is grounded in action rather than in sensations and appearances. This approach, in line with Zahorik and Jenison's, concentrates on action rather than sensory data and makes the perception–action coupling necessary to experience presence. According to Zahorik and Jenison, "Being there is actually the ability to do here."[9] Thus, the VE has a reality because of the process of action and interaction within the environment. We suppose that this characterization overcomes the distinction between the "real" and the "virtual" worlds—recalling Plato's dichotomy—and replaces it with a perception–action loop that associates those two "worlds." In line with this view, Herrera et al.[10] argue that presence is partially rooted in agency, as our mental development is connected with our interaction with the environment and the exercise of our agency. Even though both concepts have a different epistemological status, agency contributes to presence from early age.

The main goal of the current work is to evaluate the impact of agency deficiency on presence. If presence and agency are related, then a person who suffers from a mental disorder characterized by agency deficit—such as schizophrenia—should consequently experience a lower sense of presence. If it is not the case, the relationship would need to be re-examined.

Frith et al.[11] explains that in schizophrenia, the positive symptoms are related to a failure in the mechanism of agency, or more specifically, in discriminating one's actions from those of another person. Consequently, people with schizophrenia can have delusions that other people are causing movement of their bodies. Moreover, several studies report that there are subtle problems consistent with a lack of awareness of predicted actions in schizophrenia. These patients fail to make rapid error corrections based on awareness of discrepancies between intended and predicted limb positions, although they have no difficulty correcting errors based on visual feedback about actual limb positions.[12] The discrepancy between the predicted and the actual sensory consequences of actions modulates the sense of agency.

One could suppose that in schizophrenia, the sense of presence is higher because the symptom of derealization—defined as an unreality of the outside world—is currently found in the patients suffering from this disorder. In contrast with this point of view, we support Zahorik and Jenison's[9] idea of presence, and we believe that people with schizophrenia should experience a lower sense of presence in the VE due to a dysfunction of agency.

Albeit some studies have analyzed the correlation between body movements and presence,[8] only a few so far consider the impact of the visual perception of one's own body in action. Thus, we outline two major objectives in this study:

- A deficit of agency, such as in schizophrenia, provokes a decrease in the sense of presence in a sensorimotor test involving a visual perception of the participant's body.
- When the level of the perception–action coupling is lower, due to less visual information, the performance of controls should decrease. On the contrary, they should remain identical for the group of participants with schizophrenia due to the agency deficit.

Our hypothesis is that an agency deficit has repercussions on the sense of presence as well as on performance in a sensorimotor test involving the body. The test we chose evaluates the user's motor control ability in a VE, and it incorporates a visual perception of the body so that the sense of presence should consequently increase.[13] Presence can be enhanced if the observer perceives self-movement in the VE. The users therefore have two different accesses to the self: access through the action of performing the test and access through being the agent.

Materials and Methods

Participants and recruitment

Nineteen healthy controls (10 men, 9 women) and 19 stable patients with schizophrenia (10 men, 9 women), matched by age and gender, participated in the study. All participants gave informed consent after a clear description of the study. Two patients with schizophrenia out of 21 were excluded from this study because of unwillingness to participate (one of them stated that her image was distorted: "I can't stand it; the image of myself is too distorted"). Participants' ages ranged from 20 to 47 years old (overall $SD = 8$, $M = 33$; control $SD = 8$, $M = 32.6$; schizophrenia group $SD = 8.22$, $M = 33.3$).

Healthy controls were evaluated by the Mini International Neuropsychiatric Interview (MINI) questionnaire[14] to ensure that they corresponded to the inclusion criteria. All the participants with a history of any psychiatric disorder, neurological disorder, or substance abuse were excluded from the study.

Table 1. Age of Participants and PANSS Scale

Age of the participants				
Sex	*Group*	*Average*	*SD*	*Range*
Male	HC	28.8	7.54	20–47
	Schz	29.6	8.06	19–47
Female	HC	37.4	6.54	27–47
	Schz	38.1	6.27	27–47
Participants with schizophrenia				
PANSS		*Average*	*SD*	*Range*
Positive		24.5	7.08	13–36
Negative		22.8	6.39	12–35
Psychopathologic		48.1	11.70	33–76

HC, healthy control; Schz, schizophrenia.

Participants met DSM-IV[15] criteria for schizophrenia, according to the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID) (14 paranoid, 3 disorganized, and 4 undifferentiated). Positive and negative symptoms were also evaluated with the Positive and Negative Syndrome Scale (PANSS)[16] by a psychiatrist of the unit of the Ville Evrard Hospital on the day of the experiment. All the patients were on neuroleptic drugs. We excluded the patients to whom any antidepressants or thymoregulators drugs were prescribed. Clinical and demographic characteristics of the participants are displayed in Table 1. Information on the duration of the illness, the treatment, and the number of previous hospitalizations was recorded for each patient. None of the participants in this experiment were familiar with the VE prior to the test.

Material description

We use an Augmented Reality (AR) test (Eye Toy, created by Sony PlayStation® games) in which the participant's body image and his or her background are projected by a webcam in a virtual world. The real images and the VE are displayed simultaneously on the same screen (latency less than 100 ms). The difference between AR and VR lies in the fact that the goal of VR is to immerse the user in an artificial world (which can be imaginary, symbolic, or a simulation of certain aspects of the physical world). By contrast, AR permeates the physical world with the computer graphics. It creates an interaction between the real and the virtual worlds by using the integration of real images with virtual entities. The user interacts with the virtual world by means of physical movements.

Description of the test

In the test, the participant faces a virtual mirror ("Mirror time"), which has certain targets to reach (green balls) or to avoid (red balls) in each corner. The mirror is horizontally or/and vertically inverted in a random order. Each participant is given 3 minutes to reach as many targets as possible. If the participant reaches more than three red balls, the test ends prematurely. One specific sound is associated with each success or error accordingly. This test necessitates a distinction between self-ascription and world-ascription in the virtual world. The way users interact with the surroundings is an indication of their control of their movements and of how they manifest their grasp of the spatial properties of the environment.

Prior to the test, each participant did a pretest in order to ensure that the instructions were understood correctly. Participants understood that they would be inserted into a virtual world and would simultaneously be able to see themselves.

Two conditions were randomly alternated:

- The control condition previously described (see Photo 1).
- The mask condition: the central part of the body is hidden by a shadow. Users cannot see their body as a whole

and therefore cannot tell whether or not their image is upside down. They can see only their arms moving to accomplish the task (Photo 2).

Procedures

Each participant repeated the test six times after executing the pretest. After performing the test, each participant completed a presence questionnaire,[17] which consists of variables, or subscales, that affect presence.[3] For example, it questions the user on the extent to which the VE was consistent with reality (realism). Another subscale asks to what extent the interactions felt natural to the participant. It has been supposed that the more control a person has over the task, environment, or interaction with the VE, the higher he or she will score in the "possibility to act" subscale. The quality of the interface was also questioned in order to address whether control devices interfere with or distract from the task performance. The questionnaire also deals with the ability to examine the objects of the VE, the identification of the sounds during the test, and a self-evaluation of the general competences in the test.

The duration of the test and the clinical evaluation was approximately 2 hours.

Statistical analysis

In order to test the hypothesis—according to which a deficit of agency has repercussions on the sense of presence and on performance on a sensorimotor test—we used a one-way ANOVA for repeated measures. The interfactors was the group (two modalities), and the intrafactors were the conditions (two modalities) and the trials (four modalities).

Results

No participants from either group experienced any adverse effects after or during the test.

Performance on the test

The analysis of performance shows a significant group effect ($F[1, 36] = 96.68$, $p < 0.0001$) as well as a condition effect ($F[1, 36] = 4.98$, $p = 0.032$). Moreover, the group/condition effect is $F[1, 36] = 6.02$, with $p = 0.019$. The means of performance are displayed in Table 2. There is a striking contrast between the two groups in the differences in performance between the two conditions. In control participants, mean = 60.7 for the control condition, and mean = 46.8, with $p = 1.002$ for the mask condition. In participants with schizophrenia, mean = 24.3 and mean = 25, with $p = 0.88$ in the mask condition (Table 2 and Figure 1). No correlations between positive or negative symptoms, the subtypes of schizophrenia, or performance were found in our results. Controls showed a decrease in performance in the mask condition. On the contrary, the schizophrenia group had almost the same performance in the mask condition.

Questionnaire of presence

The comparison of presence between the control and the schizophrenia groups are displayed in Table 3. The overall average is higher in controls than in patients with schizophrenia, and the subscales of presence also show some significant differences among the two groups. In controls, overall mean = 118.2, $SD = 15.79$; and in the schizophrenia group, mean = 104.8, $SD = 18.34$; $p = 0.02$. The "possibility to act" is higher for controls, meaning that their interaction with the environment felt more natural and that the control of their movements was more important than for participants with schizophrenia ($T_E = 4.28$, $p = 0.0001$). Moreover, controls found the environment more realistic than did those with schizophrenia ($T_E = 2.27$, $p = 0.03$), and they developed a better ability to examine it ($T_U[28] = 2.65$, $p = 0.013$). The "quality of interface" was also significantly different, as the control devices interfere more in the task performance for participants with schizophrenia than for controls, probably due to a lack of attention.

Table 2. Means of Performance

Group	*CO*	*CA*	*Student T-test*	*p-value*
HC	60.7	46.8	−3.31	0.002
Schz	24.3	25.0	0.16	0.88
Student T-test	8.69	5.22		
p-value	<0.0001	<0.0001		

HC, healthy control; Schz, schizophrenia; CO, control condition; CA, mask condition.

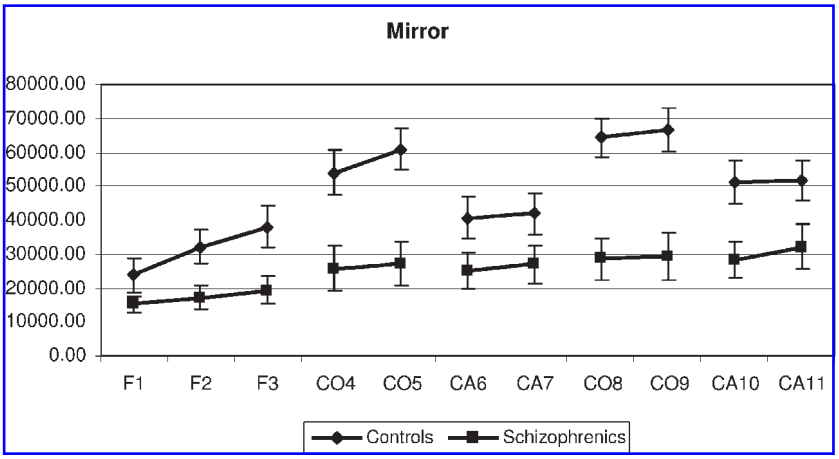

FIG. 1. Differences in performance between the conditions in the groups. (X-axis: conditions, with F for familiarization; CO, control condition; CA, mask condition. Y-axis: score on the test.)

Discussion

In order to complete the test properly, users must reach the green targets with their hands and avoid the red balls. The consequences of an action correspond to the intention of the action. In the case of the mirror inversions, sensory conflicts are created and corrections of the actions need to be made. The visual location of the hands deviates from their expected location, and adjustment of the movements by the user are required. The conflict between the motor command and the visual feedback is then experienced as opposing the intention of action to the proprioception resulting from its execution. This inadequacy creates a cognitive conflict, which necessitates an awareness of the sensory feedback and a conscious control of the body.[18] Thus, the monitoring becomes a crucial component in the control of the conscious movements. In this process, the self-generated internal model is compared to the consequences and can be modified by the online actions of the participant in case of a mismatch. When the mirror is inverted, the user should then adjust his or her internal model according to the output of the expected sensorial feedback. It is precisely the matching between the right action and the sensory feedback that reinforces the sense of agency.[19]

In the mask condition, the adjustment between the motor command and the sensory consequences of the controls is interfered with because the visual information is consequently reduced. The user cannot know whether or not the mirror is inverted. The perception–action coupling is therefore less important, which explains the lower score of the control group in this condition. This result is an indication of the importance of the central part of the body in the context of perception–action among the control participants. Indeed, the body provides the basis for an egocentric spatial frame of reference, which is necessary to obtain a high performance on the test. In this case, "perception and action are therefore spatially defined according to the perceiving and acting body."[20] The conscious image of one's own body is like a fleeting recognition aimed at integrating afferences from visual information, proprioception, and monitoring of motor commands into a coherent spatial structure. Direct visual perception of one's own body and conscious attention to some body parts contribute to the constitution of the perceptual aspect of the body image.

People with schizophrenia encounter difficulties in the mirror inversions, and they adjust the matching between the intention and the consequence of the action with more dif-

TABLE 3. COMPARISON OF PRESENCE BETWEEN CONTROL AND SCHIZOPHRENIA GROUPS

	HC		*Schz*		*Test of significance*	
Presence	*Mean*	*SD*	*Mean*	*SD*	*T*	p
Realism	36.8	5.07	32.4	6.93	$T_E = 2.27$	0.03
Possibility to act	23.1	3.10	17.8	4.37	$T_E = 4.28$	0.0001
Quality of the interface	8.7	4.36	10.2	3.46	$T_E = -1.15$	0.26
Possibility to examine	13.8	1.75	11.6	3.19	$T_U[28] = 2.65$	0.013
Self-evaluation of performance	11.9	1.79	10.3	2.54	$T_E = 2.29$	0.03
Auditive	15.3	3.23	13.4	6.31	$T_U[29.7] = 1.29$	0.20
Haptic	7.84	4.07	9.16	2.32	$T_U[28.5] = -1.22$	0.23
Global score	118.2	15.79	104.8	18.34	$T_E = 2.42$	0.02

HC, healthy control; Schz, schizophrenia; T_E, student's *t* test with nonsignificantly different variances for the two groups; T_U, student's *t* test with significantly different variances for the two groups (in square brackets are the degrees of freedom evaluated for this study); *p*, probability associated with the *t* test.

ficulty than do controls. Several patients reported a lack of agency and body distortion during the test: "When my image is inverted, I have the impression that my hand moves away"; "I don't have the control of my movements"; "It is not me who is moving, but a duplicate." Other patients experienced a loss of ownership of some body parts: "I feel that someone else's hand is replacing mine; it is also bigger than my own hand." Those comments reveal that a mismatch between the efferent copy and the sensory feedback may provoke a lack of agency and ownership. Surprisingly, the mask did not worsen the performance of the participants with schizophrenia as it did the performance of controls. This important result could be interpreted by distinguishing two distinctive but complementary levels:

- A perceptual (visual) level: In schizophrenia, a deficit in vision may hinder the ability to encode information.[21] Such a deficit could explain the lower perception–action loop in some patients.
- A more integrated level, in which agency plays an important role. It can be supposed that in schizophrenia, compared to controls, body integrity is less important as an egocentric referent. The results of this study, however, do not bring any evident clarification on body integrity in schizophrenia. Further investigations are needed to draw any conclusions on this topic. Moreover, the results show that presence is significantly lower in people with schizophrenia than in controls.

Riva et al.[22] distinguish three layers of presence: protopresence, core presence, and extended presence, and those layers "are strictly related to the evolution of the self," developed by Damasio. More precisely, the protopresence layer corresponds to the "embodied presence related to the level of perception–action coupling (self vs. non-self)."[22] In schizophrenia, it seems that this level of protopresence is impaired, according to our results, because the deficit of the perception–action loop lessens their sense of presence. Protopresence is based on proprioception—spatial and internal monitoring—which is defective in schizophrenia. The second layer, the core presence, is "the activity of selective attention made by the self on perceptions (self vs. present external world): the more the organism is able to focus on its sensorial experience by leaving in the background the remaining neural processes, the more it is able to identify the present moment and its current tasks, increasing its probability of surviving."[22] Even though most of this experiment is focused on the protopresence, we could suppose that the core presence may also be impaired. Indeed, people with schizophrenia may not use their body as a referent to accomplish the test.

Those results bring to the question whether VR could be used as a tool for therapy in agency disturbances (schizophrenia). Can presence be considered as an indicator of the processes participating in agency? So far, VR has been too infrequently used for therapy in schizophrenia. For instance, Ku et al.[23] used VR to rehabilitate social skills, and Baker et al.[24] used it to assess medication compliance. The present study illustrates that VR not only presents no specific risk for patients[25] but could also lead to an innovative approach to treatment of the illness by enhancing presence and the control of body movements. This work may contribute to restructuring the perception–action loop and the self. Riva et al.[22] state that "the more the organism is able to couple correctly perceptions and actions, the more it differentiates itself from the external world." Moreover, the awareness of being the agent of an action is intrinsic to the reorganization and foundation of identity. The evidence of the deficit of presence in the patients, in relation to a deficit of agency, leads to the supposition that this specific situation in VR could help ameliorate an agency deficit. However, more research on this topic is required to lead to therapeutic gains of this study. An interesting direction of possible future work could be to compare the sense of presence of the groups with that experienced in another experiment, using an embodied virtual agent (i.e., an avatar) rather than the mirror image. Then, the question would be whether the avatar helps patients with schizophrenia to feel more present in the virtual world than in the AR experiment.

Little attention has been paid to the body in schizophrenia. We highlight the importance to further investigate new means to help patients to reconcile with their body image. Indeed, the lack of the overall presence in patients with schizophrenia could be related to less consideration of their body image and body schema. The integration of visual perception of oneself, somatosensory, and monitoring of motor intentions into a coherent body image may go astray when there are conflicts between the senses. The experimenters of the present study noticed that those who participated were particularly expansive during the test and wanted to overcome their score. According to one participant with schizophrenia, "This test helps [me] to have a better awareness of the positions of my arms in space, and it is a positive thing. Actually, one has to anticipate, just like a cat before it jumps on its prey: it anticipates the consequences. I have problems [in correcting] my errors, as if my psychomotor system were already programmed." The patients' behavior marked a strong contrast with the negative symptoms they endorsed. The entertaining aspect of the test, the participation of the body, and the intervention of visual and auditory stimuli facilitate an increase of motivation at the expense of negative symptoms, such as avolition.

Conclusion

The main objective of this study was to explore the impact of agency deficiency on presence and on performance on a sensorimotor test involving the body. This study conveys two major interests: it experimentally explores distinctive levels of presence, and it offers new access to a low level of presence and to the deficit of agency. We suggest that the VR test could contribute to the evaluation of agency deficit in schizophrenia.

Acknowledgments

The authors wish to thank the team of Ville-Evrard Hospital for their help in recruiting participants and evaluating their symptoms. They also thank Dr. G. Riva for his valuable suggestions. Financial support was provided by the Amory Sports Organization (ASO).

Disclosure Statement

The authors have no conflict of interest.

References

1. Plato. *Republic*, Chapter VII. Ed. Loeb Classical Library, Trans. P. Shorey.
2. Heeter C. Being there: the subjective experience of presence. Presence 1992; 1.
3. Witmer B, Singer M. Measuring presence in virtual environments: a presence questionnaire. Presence 1998; 7:225–40.
4. Slater M, Wilbur S. (1995) Through the looking glass world of presence: a framework for immersive virtual environments. In Slater M, ed. *Five '95 Framework for Immersive Virtual Environments.* University of London, Queen Mary and Westfield College.
5. Slater M, Wilbur S. A framework for immersive virtual environments (FIVE): speculations on the role of presence in virtual environments. Presence: Teleoperators & Virtual Environments 1997; 6:603–16.
6. Riva G. Being-in-the-world-with: presence meets social and cognitive neuroscience. Emerging Communication: Studies in New Technologies & Practices in Communication 2006: 9.
7. Russell J. (1996) *Agency: its role in mental development.* Hove, East Sussex, UK: Erlbaum (UK), Taylor & Francis.
8. Slater M, Steed A, McCarthy J, et al. The influence of body movement on subjective presence in virtual environments. Human Factors 1998; 40:469–77.
9. Zahorik P, Jenison R. Presence as being-in-the-world. Presence 1998; 7.
10. Herrera G, Jordan R, Vera L. Agency and presence: a common dependence on subjectivity? Presence 2006; 15:539–52.
11. Frith C, Blakemore S, Wolpert D. Explaining the symptoms of schizophrenia: abnormalities in the awareness of action. Brain Research Reviews 2000; 31:357–63.
12. Malenka RC, Angel RW, Hampton B, et al. Impaired central error-correcting behavior in schizophrenia. Archives of General Psychiatry 1982; 39:101–7.
13. Slater M, Steed A. A virtual presence counter. Presence 2000; 9:413–34.
14. Lecrubier Y, Sheehan D, Weiller E. The Mini International Neuropsychiatric Interview (M.I.N.I): a short diagnostic structured interview: reliability and validity according to the CIDI. European Psychiatry 1997; 12:224–31.
15. American Psychiatric Association. (2000) (DSM-IV-TR) *Diagnostic and statistical manual of mental disorders,* 4th ed., rev. text. Washington, DC: American Psychiatric Press.
16. Kay SR, Fiszbein A, Opler LA. The positive and negative syndrome scale (PANSS) for schizophrenia. Schizophrenia Bulletin 1987; 13:261–76.
17. Schubert T, Friedmann F, Regenbrecht H. The experience of presence: factor analytic insights. Presence: Teleoperators & Virtual Environments 2001; 10:266–81.
18. Wolpert DM, Ghahramani Z, Jordan MI. An internal model for sensorimotor integration. Science 1995; 269:1880–2.
19. Campbell J. Schizophrenia, the space of reasons and thinking as a motor process. Monist 1999; 82.
20. Gallagher S. (2005) *How the body shapes the mind*. Oxford: Oxford University Press.
21. Butler P, Schechter I, Zemon V, et al. Dysfunction of early-stage visual processing in schizophrenia. American Journal of Psychiatry 2001; 158:1126–33.
22. Riva G, Waterworth JA, Waterworth EL. The layers of presence: a bio-cultural approach to understanding presence in natural and mediated environments. CyberPsychology & Behavior 2004; 7.
23. Ku J, Han K, Lee H, et al. VR-based conversation training program for patients with schizophrenia: a preliminary clinical trial. CyberPsychology & Behavior 2007; 10:567–74.
24. Baker E, Kurtz M, Astur R. Virtual reality assessment of medication compliance in patients with schizophrenia. CyberPsychology & Behavior 2006; 9:224–9.
25. Lallart E, Jouvent R. La réalité virtuelle dans la schizophrénie: Un danger ou un outil thérapeutique? Information Psychiatrique 2008; 84:311–6.

Address reprint requests to:
Elise Lallart
Emotion Center, CNRS UMR 7593
Groupe Hospitalier Pitié-Salpêtrière
Pavillon Clérambault 47-83 Bd de l'Hôpital
75013 Paris
France

E-mail: elallart@chups.jussieu.fr