

Combining interactive multimedia and virtual reality to rehabilitate agency in schizophrenia

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ABSTRACT

New interactive technologies offer the opportunity to involve the user's body in a virtual environment while seeing herself/himself performing the actions. Interactive exercises with a video-capture reinforce the perception-action loop, which is the pillar of agency (i.e. the ability to attribute the intention of an action to its proper author). We present a new paradigm as a possible treatment of agency disturbances in schizophrenia.

1. INTRODUCTION

New information and communication technologies play an increasingly important role in society. These innovations confront humans with the necessity of adapting cerebral function by interacting with a non-human intelligence. Likewise Virtual Reality (VR) offers the opportunity to realize an experiment in an environment which is possible to control by presenting limited sensory information from the real world or by replacing some information with a virtual world. Within the past decade Virtual Reality has been widely used for rehabilitation of certain pathologies and has shown surprising efficacy. The benefits of VR is applied to treat patients who suffer from a stroke (Jack, 2001), anxiety (North, 1998) and autism (Strickland, 1997). Our research laboratory began recently to apply these new methods to schizophrenia as well (Jouvent & Rautureau, 2005).

The schizophrenic dissociation comprises many symptoms which have in common a disintegration, psychic disorganization and depersonalization. For instance patients who suffer from schizophrenia may experience a loss of their self, meaning that their self is an artificial entity to them and that their mental experiences are disconnected. According to several authors schizophrenia might be a "pathology of consciousness", since individuals with schizophrenia have alterations of consciousness in specific cognitive abilities, such as executive functions.

Thus the delusion of influence is characterized by the fact that the individual does not feel in control of her/his movements and thinks that she/he is a passive instrument in the hands of an external will. Another example of schizophrenic dissociation is the delusion of reference in which patients may believe that they are controlling others' movements.

Those symptoms of "extraneity" have in common the fact that schizophrenia may include a deficit in the consciousness of action and in the attribution of their or other's actions. The ability to correctly attribute the intention of an action to its proper agent is called "sense of agency". Several authors state that the disruptive mechanism of agency is one of the essential etiopathogenic mechanisms of schizophrenia (Frith, 1992). Joëlle Proust suggests that what is defective in schizophrenia is probably not the rational thinking, but rather the self-attribution of intentions.

Only a very few studies were administered using VR with schizophrenia patients (Jeonghun, et al. 2003). However we believe that a combination of VR and multimedia technologies could be an efficient tool to rehabilitate a certain aspect of the disorder: agency. Objections could be made, stating that VR could present a potential risk for patients as it mixes reality to an artificial world, and therefore it may erase the boundaries between reality and a virtual world. However no reliable evidence supporting this view has been made so far (Da Costa, 2004). Instead this risk may be inverted into a potential cue for rehabilitation of self-perception in the environment.

To support our hypothesis we will first present a summary of the theoretical background on schizophrenia and define the concept of agency. Then we will present a validation of a study which measures the sensory-motor performances of a group of controls in two virtual reality tests. Finally we will open up new horizons for a potential rehabilitation in schizophrenia using our paradigm.

2. THEORETICAL BACKGROUND

A certain view of the neurophysiology is that the ability to attribute an action, an idea or an intention, depends on the control of agency. In the literature, two distinct theories mainly articulate this idea: the theory of shared representations and the theory of self-monitoring.

2.1 *Theory of shared representations: recognition of action*

In social contexts it is difficult to attribute an action to its proper author. This statement is supported by the neurological evidence of the mirror neurons discovered in the monkey by Rizzolatti (1996). Those premotor neurons (F5) are activated both when the monkey observes some one acts and when he is the author of the action. For Marc Jeannerod this experiment is an illustration of what he names the “shared representations”. What allows one to attribute actions to its proper author is the “Who system”, which distinguishes auto generated actions from others (Georgieff, Jeannerod, 1998). Jeannerod hypothesizes that in schizophrenia this system is deficient and leads to symptoms such as the syndrome of influence.

2.2 *Theory of self-monitoring*

Beside the distinction between the first and third person in action, a more physiological model proposed by Christopher Frith explains how one differentiates the sensory consequences of willed actions from the sensory information provided by the external world. The individual uses his motor commands according to the “internal efferent model” (Ito, 1970; Wolpert, 1995): when a motor instruction is sent to the muscles, a copy of this instruction – the efference copy (Von Holst, 1954) – is also sent to a comparator or a self monitoring system. Held 1961, suggests that the efference copy is sent to the comparator where it is stored and compared to the reafferented information (for instance proprioceptive or visual) on what sort of movement was made. According to Campbell, the basis of agency is the matching at the level of the comparator between the efference copy and the sensory feedback of the movement. In other words what gives the feeling that one is the author of a movement is when the efference copy has received the instruction to move the person’s arm and matches the movement that one perceives.

If the feedback does not correspond to the expectation of the individual, this latter corrects his action by means of the perception-action loop until the outcome of the movement corresponds to the desired movement.

In schizophrenia, several studies showed the difficulty for schizophrenic patients to monitor an action when they are deprived of an actual sensory feedback (due to a deficit of the self monitoring) (Frith & Done, 1989). Experimental studies involving a distortion of the feedback showed a deficiency for schizophrenic patients to detect a difference between their willed action and the actual sensory feedback, causing symptoms such as the syndrome of influence. According to C. Frith, there is a breakdown in the mechanism of the efference copy and in the comparator which provokes a dysfunction of the sense of agency. Schizophrenic patients seem unable to monitor their motor instructions (Frith, Blakemore, Wolpert 2000). They rely on the visual feedback instead of the efference copy of the motor commands to predict the success-result of their actions. Proust states that they apply a control called “error-control”, instead of applying a “cause-control” (Proust, 2003). In this theory the self attribution of action is essentially assured by the forward motor model, which predicts the motor and sensory consequences of the action. This model of control of action can be directly applied to the problem of action recognition. Action recognition can rely on the concordance between a desired action and its sensory consequences.

If patients with schizophrenia perform a test repetitively in which they are agents, and perceive themselves being an actor, adjusting their actions to match the feedback they perceive (perception-action loop), it might help restructuring the integrity of their body in action. That is the reason why we propose a task in which the subject has a visual perception of her/his body performing the action as if he were facing a mirror.

2.3 *Hypothesis*

In this paper we hypothesize that the exercises we propose are sensitive enough to observe a difference when we alter the image of the user. If this is the case, it would underline the importance for the subject to use a visual perception of his body in action to increase the performances.

3. METHOD – VALIDATION IN A CONTROL GROUP

3.1 Participants

We recruited a total of twenty two controls in this study who were evaluated by the Mini International Neuropsychiatric Interview (Lecrubier et al. 1997). Participants were nine males and thirteen females ranging in age from 18 to 35 years old, with an average age of 23,87. The exclusion criteria were the following: familial antecedents of schizophrenia and bipolar disorder, neurological history, stroke.

3.2 Material

We use Augmented Reality tests: the subject's image and his surrounding are projected by a web cam in a virtual world; therefore there is an association between the real and the virtual world by using the integration of real images (RI) with virtual entities (VE). The user interacts with this virtual world by means of his movements. In Eye Toy, the RI and VE are displayed simultaneously on the same screen (latency less than 100 ms).

One of the most important characteristics in using augmented reality is the way it makes a transformation of the locus of interaction possible. The interactive system is no more understood as a face-to-screen exchange, but dissolves itself in the surrounding space and objects. Those tests are on line with our problematic on agency because the user is not only an agent, but also sees himself being the actor. Two virtual environments were used in this system:

Wishi Washi: the user faces a virtual window which is covert by soap. The task is to wash each window by the means of the movements of the arms and body as fast as possible. Each time a window is washed, a new one is presented to the subject. The total time for each test is two minutes (Fig. 1).



Figure 1. A subject performing the Wishi Washi task.



Figure 2. A subject performing the Mirror test (with horizontal and vertical inversion).



In the Mirror test the subject is facing a virtual mirror which contains a bonus or a malus in each corner. Sometimes the mirror is horizontally or vertically inverted. Each subject has to catch the bonus and disposes of three minutes for each test. If the subject touches more than three malus, the test ends straight away (Fig 2).

3.3 Procedure

All subjects start with the Wishi Washi test – which does not involve any distortions of the visual feedback – and then do the Mirror test – which includes distortions. Three practice trials were given at the beginning of both tests to train subjects to the sessions.

In each test we alternated between two conditions: a control condition and a second one in which we hide the central part of the body by means of a rectangular object placed in front of the projector, so that the subject only sees his arms moving but has no visual feedback of the other parts of his body. We call this condition the “mask” condition.

Therefore half of the subjects did the following sequence:

- 3 tests of familiarisation
- 2 control tests – 2 tests with alteration of the body image (“mask” condition) – 2 control tests – 2 “mask” tests
- The other half:
- 3 tests of familiarisation
- 2 “mask” tests – 2 control tests – 2 “mask” test – 2 control tests

The performances of each test were recorded and analysed using SPSS. In Wishi Washi, the score represents the number of windows washed and the bonuses obtained; in Mirror it is the number of balls caught. In both tests the dependant variable is the total score obtained.

4. RESULTS

In both tests and in each condition, the distribution of the total score among the subjects is globally Gaussian, as shown by the following graphics:

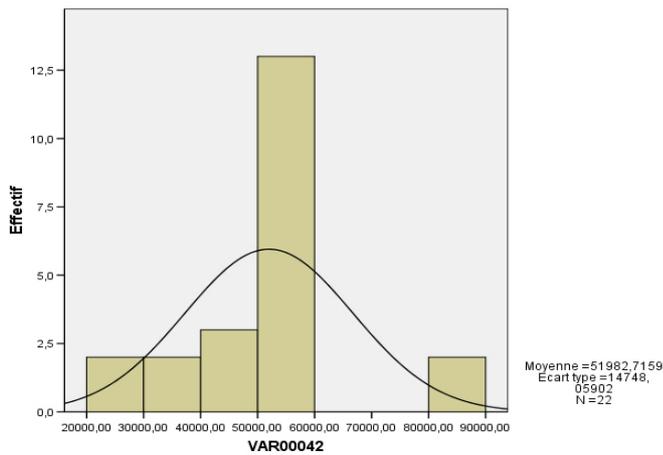


Figure 3. “Wishi Washi”:
Distribution of the averages of the total score.
Control condition.

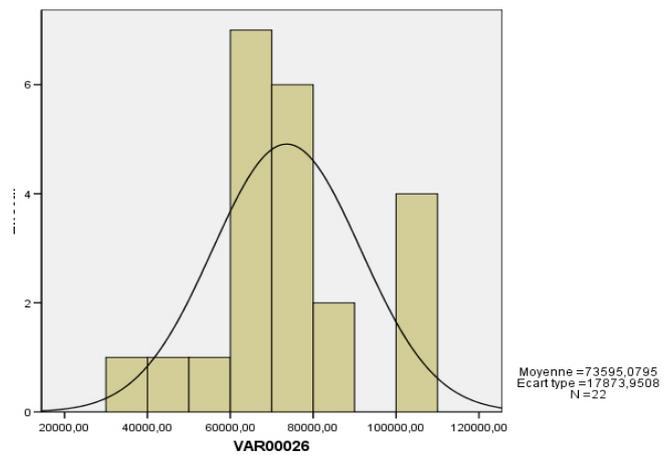


Figure 4. “Wishi Washi”:
Distribution of the averages of the total score.
“Mask” condition.

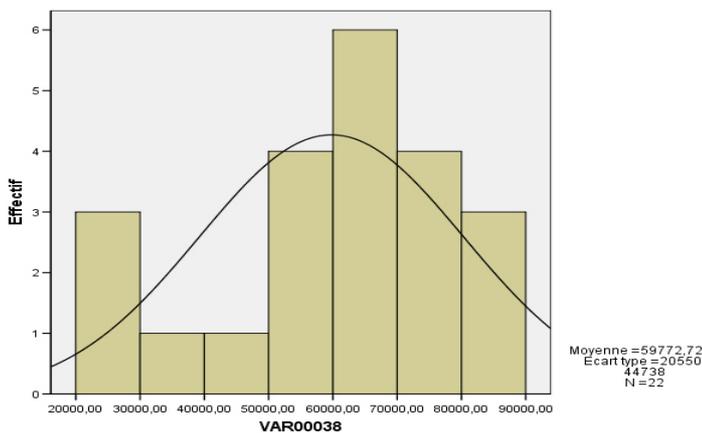


Figure 5. “Mirror”:
Distribution of the averages of the score.
Control condition.

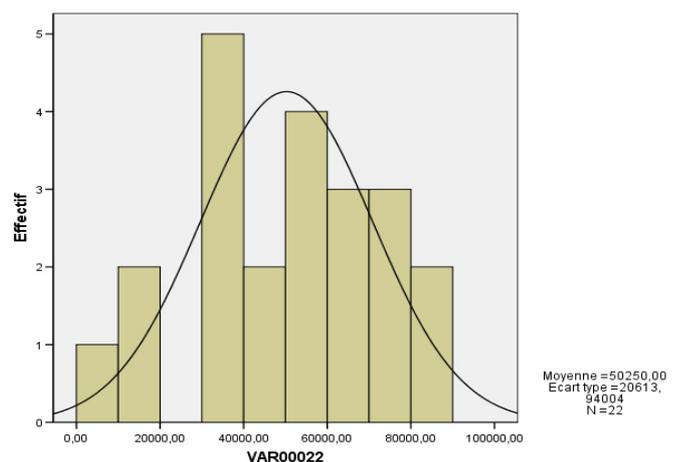


Figure 6. “Mirror”:
Distribution of the averages of the score.
“Mask” condition.

Results show that the presence of the “mask” provokes significant changes in the performances; subjects do better in the Wishi-Washi ($p < 0.0001$) test and worse in Mirror ($p < 0.0001$).

Table 1. Wishi Washi.

Conditions	Score	SD	t-test	p
Control	13 635	384.76	35.44	<0.0001
Mask	17 875	384.76	46.46	<0.0001

Table 2. Mirror.

Conditions	Score	SD	t-test	p
Control	62 186	2669.08	23.30	<0.0001
Mask	51 077	2669.08	19.14	<0.0001

5. DISCUSSION AND PERSPECTIVES

5.1 *Different levels of action*

Our work is a validation of a paradigm to use VR and multimedia technologies in schizophrenia patients as a way to rehabilitate the self in action. In this present paper, we gathered the scores in a population of controls in order to further compare them to schizophrenia in a further study. In both tests the twenty two controls presented homogeneous performances. Each test corresponds to a different level of action: one requires sensory-motor ability (Wishi-Washi) whereas Mirror corresponds to a higher level of action accompanied with a better control of the body movements.

According to the literature, there are three distinctive levels of action: the first one is sensory-motor, the second is contextual; the last level of action is the episodic memory (Koechlin, 2003). According to several studies, the contextual condition is defective in schizophrenia but not the sensory-motor stage (Green, 2005). We therefore believe that schizophrenia subjects would have performances in the average range in the Wishi Washi test, but be particularly impaired in the other test. Furthermore they would do worse in Mirror with the mask, whereas the performances would be the same with the mask.

5.2 *Body ownership and agency*

In those tests the matching of visual and proprioceptive signals contributes to the inter-modal sensory image of the body. Experimental data show the prevalence of vision over the other senses in self recognition: we feel our hand where we see it, and not the opposite. The sense of the position is recalibrated in order to be conformed to the visual information (especially in the Mirror test, with inversion of the image).

Botvinick and Cohen (1998) placed a plastic hand in front of subjects, which was hidden by a screen. A tactile simulation was applied simultaneously to the real hand and to the plastic one. After a while subjects had the illusion that they felt touched whereas it was the plastic hand – which they were seeing. In other words, the subject had a sense of ownership of the plastic hand just by seeing it.

Therefore watching ourselves performing an action, like in the tests presented, may contribute to our sense of body ownership. If one sees an image in front of him/her which moves when she/he moves and that the two movements are congruent, then the image seen must own to him/her. The position sense is recalibrated to conform to the visual information. The visual feedback of the body in action is also a way for individuals who experience a syndrome of influence to feel that they are the cause of the action (feeling of agency), since there is a correlation between the expected actions and the result (Frith, 1992).

5.3 *Seeing oneself in action*

The purpose of hiding the central part of the body (the mask condition) is to make a switch between the first and third person perspective as it changes the visual presence of the self. Indeed with the “mask” the user needs to make abstraction of a part of himself. In this condition, the integrity of the body is parcelled out and the subject does not adjust his actions to the perception of his body in action any more, but only to his arms, isolated from his body.

On the one hand, in the test without distortion (Wishi-Washi), subjects don’t need a higher cognitive ability to perform it because it is a simple motor test. The “mask” does not disrupt the performance in this task.

On the other hand the Mirror task -with a distortion of the visual feedback- requires a higher cognitive ability and various mental rotation levels. Indeed it is necessary for the subject to have a mental representation of his body in space. The “mask” presents a real handicap because it alters the inhibition

ability of the user to accomplish the task. We believe that schizophrenia patients could benefit from seeing themselves in action in order to participate in the restructuring of their self and body-in-space representation.

In our study we have presented that the combination of virtual and multimedia technologies are applicable to a group of controls and have a noticeable sensitivity. We have tested two schizophrenia subjects using our paradigm to measure the feasibility of this study. We intend to apply this paradigm to a group of schizophrenia patients.

6. CONCLUSION

The finality of Virtual Reality combined with multimedia technologies is to allow sensory-motor activities with a visual feedback of the user's body in action. The process of body perception and the creation of one's own body based on multiple stimuli (proprioceptive and visual) is a prerequisite for rapid and effective action with our surroundings and an awareness of being the agent. The objective of the present study was to validate a paradigm for agency rehabilitation in schizophrenia. In the future we would like to demonstrate that repetitive practice of the models presented can help restructuring the perception-action loop and thus give access to a rehabilitation of the feeling of agency in schizophrenia.

7. REFERENCES

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