The distortion of reality perception in schizophrenia patients, as measured in Virtual Reality

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Abstract. **Background**: Virtual Reality is an interactive three-dimensional computer generated environment. Providing a complex and multi-modal environment, VR can be particularly useful for the study of complex cognitive functions and brain disorders. Here we used a VR world to measure the distortion in reality perception in schizophrenia patients. **Methods**: 43 schizophrenia patients and 29 healthy controls navigated in a VR environment and were asked to detect incoherencies, such as a cat barking or a tree with red leaves. **Results**: Whereas the healthy participants reliably detected incoherencies in the virtual experience, 88% of the patients failed in this task. The patients group had specific difficulty in the detection of audio-visual incoherencies; this was significantly correlated with the hallucinations score of the PANSS. **Conclusions**: By measuring the distortion in reality perception in schizophrenia patients, we demonstrated that Virtual Reality can serve as a powerful experimental tool to study complex cognitive processes.

Keywords. Schizophrenia, reality perception, audio-visual incoherency

Introduction

The term Virtual Reality describes systems in which the user becomes fully immersed in an artificial, three-dimensional world generated by a computer. The sensation of presence is typically achieved through the use of a head-mounted display (HMD). A motion tracker continuously measures the position and orientation of the user's head and allows the image-generating computer to adjust the scene representation to the current view. As a result, the viewer can look around and walk through the surrounding virtual environment in a similar fashion to the real world.

As the main motivation for this study, we hypothesize that by using VR technology, one will be able to design complex interactive tasks that will challenge multiple modalities simultaneously in a natural way. In this way VR may become a particularly useful tool for the study of complex disorders such as schizophrenia. Specifically, we chose in this study to measure the distortion in one's reality perception in a complex realistic VR Environment, because this deficiency is a common serious manifestation of schizophrenia [1]. Though it is difficult to find any cognitive task that schizophrenia patients perform adequately as a group [2-4], there are always individuals that fall within the normal range. Therefore we were particularly interested in seeing how many patients will demonstrate impairment and what fraction will perform normally.

We used a detection paradigm in order to measure abnormal reality perception. A subject is required to detect various incoherent events inserted into a normal virtual environment. Everything is possible: a guitar may sound like a trumpet, causing an audio-visual incoherency; a passing lane may be pink and a house may stand on its roof, resulting in visual-visual incoherencies of color and location respectively (see Figure 1).

1. Methods

1.1. Subjects

43 schizophrenia patients (23 in-patients and 20 out-patients) and 29 healthy controls matched by age, education level and gender were recruited for the study. Mean age was 32.6 (SD=8.5), with an average of 11.1 (SD=1.8) years of schooling; 19% were females.

All patients underwent a psychiatric interview with a senior psychiatrist (author AP). The diagnosis of schizophrenia was established according to the DSM-IV-TR criteria, and symptoms severity was assessed using the Positive and Negative Syndromes Scale (PANSS) [5]. The study was approved by the Sha'ar Menashe Mental Health Center Review Board, and informed consent was obtained from all participants after the nature of the study was fully explained to them. All subjects volunteered and received payment.

1.2. Experimental Design and Procedure

Subjects sat comfortably in a reclining chair, wearing a Head Mounted Display (HMD) containing the audio and visual devices and a position tracker. Subjects navigated along a predetermined path through a residential neighborhood, shopping centers and a street market. Apart from the incoherencies which were deliberately planted, the virtual environment was designed to resemble the real world as closely as possible.

Whenever the path traversed an incoherent event, progress was halted and a one minute timer appeared, during which the subject had to detect the incoherency. Response included marking the whereabouts of the incoherent event by a mouse click, and an accompanying verbal explanation to be recorded. A number of external observers, blind to the purpose of the experiment and the assignment to patient vs. control group, determined correctness of an explanation. We gave no examples before the test as guidelines, and no feedback indicating correct or incorrect response. (See http://www.cs.huji.ac.il/~daphna/movies/vr_inconsistencies/Demo_best.swf - a movie demonstration of the virtual world.)

We created three categories of incoherent events: sound (Figure 1A), color (Figure 1B) and location (Figure 1C). The virtual world contained 50 incoherencies: 16 involving color, 18 concerning location and 16 related to sound. Three incoherencies were excluded from the final analysis: two due to the high miss rate (≥25%) among the control subjects, and one due to repeated reports of its being confusing. This resulted in 14 incoherencies of color, 17 - location, 16 – sound, for a total of 47.

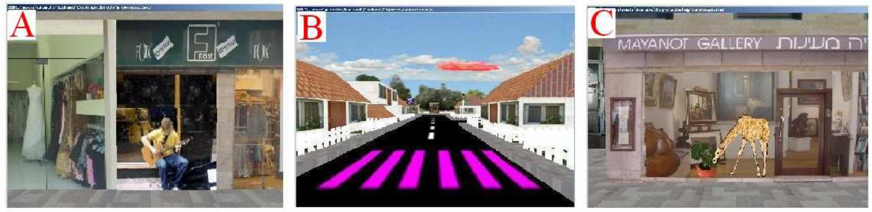

Figure 1. Examples from the virtual world used in the experiment, illustrating the 3 types of incoherencies.
A. incoherent sound: a guitar emitting trumpet sounds; B. incoherent color: pink crossing and a red cloud; C. incoherent location – a giraffe grazing in a local store.

2. Results

2.1. Detection Rates

The histogram of detection rates is shown in Figure 2A. The control subjects detected incoherencies very well, with an accuracy level of 96% on average (SD=4) (left panel). In general, the patient group (right panel) differed significantly from the controls. Normal detection rates (defined as the mean of the control group ±2.5 SD, including roughly 99% of the normal population) are shown in red for each category, whereas blue bars indicate the number of subjects that performed below normal. For example, the normal range for total detection rates is 87-100%. The upper plot shows that all but one of the control subjects performed in this range. Among the patients only 6 subjects (red bars) performed in the normal range, whereas 37 subjects (blue bars) had lower detection rates. The patients group exhibited the most difficulty in the sound category: 30 patients performed below the normal range, and 19 had detection rates below 50%, compared to the location category, where only 10 patients detected less than 50% of the incoherencies.

2.2. The 'Gap' Phenomenon

While analyzing the data, we noticed that many patients exhibited specific categorical deficiencies unlike the control group, which showed similar detection rates in all three categories (Figure 2B, left plot). We therefore defined and quantified the notion of *gap*, which indicates whether the subject's detection rate in one category has differed significantly from his/her best category (a significant difference is a difference exceeding the mean±2.5SD of the control group). Thus a *gap* is measured relative to individual performance levels. Almost half of the patients (20 out of 43) demonstrated this phenomenon, showing specific difficultly in one or two categories (see Figure 2B).

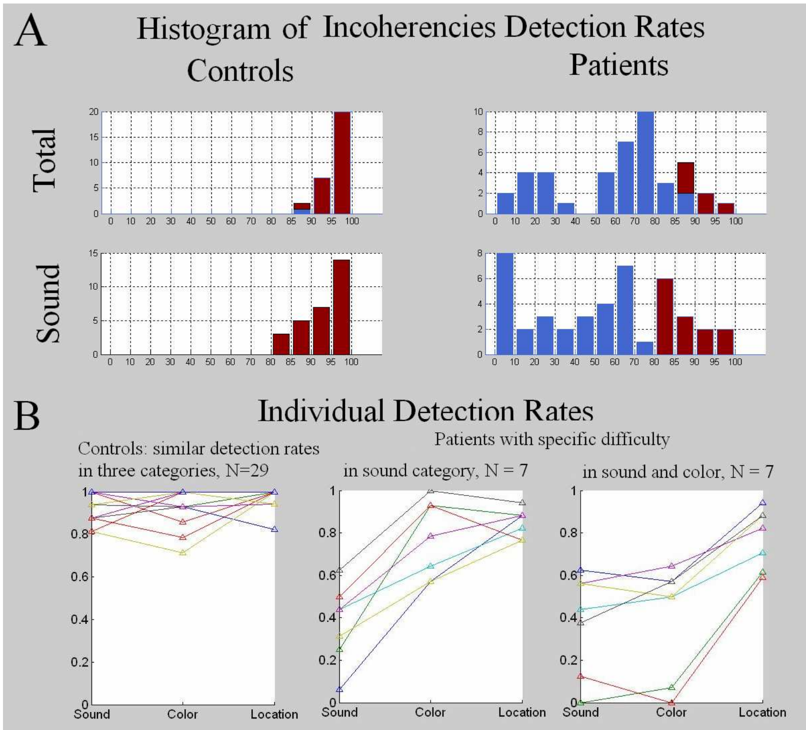

Figure 2. Histogram of detection rates among the control and patient groups.

A. The horizontal axis represents detection rates, while the vertical axis shows the number of subjects obtaining each score. The red bars indicate performance in the normal range (defined as the mean of the control group ±2.5 SD), and the blue bars – performance outside the normal range. **B**. Comparison of individual detection rates among sound, color and location categories. Left: controls, middle: patients with gap in the sound category only, right: patients with gap in the sound and color categories.

2.3. Various divisions of the patient group

Based on the similarity in detection rates the patient group could be divided into two major sub-groups: (1) The *uniform* group (23 subjects) – patients whose detection rates in all three categories were similar. (2) *Gap* (20 subjects) – the group of patients having specific difficulty in one or two categories.

The *uniform* group could be further divided into: i) *uniform normal*: patients performing at normal levels (N=5 subjects); ii) *uniform fair*: patients with good detection rates (50-87%) but below the normal range (N=10 subjects); and finally iii) *uniform poor*: patients with poor uniform performance below 50% (N=8 subjects).

In the *gap* group the majority of patients had a difficulty in the sound category. 16 patients (37%) had a specific difficulty in detecting audio-visual incoherencies: 7 patients had difficulty in the sound category only (Figure 2B, middle plot), 7 patients had difficulty in the sound and color categories as compared to the location category (Figure 2B, right plot), and two patients had difficulty in the sound and location categories. Four additional patients exhibited other specific difficulties. In contrast, only one of the control subjects exhibited a *gap* in the sound category.

The detection rates discriminate well between the control and patient populations. Nearly all control subjects, 96.5% (28 out of 29), belong to the *uniform normal* group. In contrast, while 5 patients belong to the *uniform normal* group and thus cannot be distinguished from the control group, the remaining 88% of the patients show a significantly different detection profile.

2.4. Symptom Analysis

We found a number of significant correlations (Spearman's $r \geq 0.3$, $t \geq 2.02$, $df=41$, $p<0.05$) between the detection rates and the PANSS scores in the patient group: i) The 'hallucinations' score was correlated with low total and sound detection rates. ii) 'Difficulty in abstract thinking' showed correlation with low total, sound and color detection rates (correlation: Spearman's $r \geq 0.3885$, $t \geq 2.7$, $df=41$, $p<0.01$). In addition, reaction time showed negative correlation with age.

3. Summary and Discussion

Our results show that Virtual Reality can be readily used with schizophrenia patients, allowing for the measurement of some complex deficiencies that they experience. Thus the Virtual Reality experimental environment promises to become a particularly beneficial tool for the characterization of complex brain disorders such as schizophrenia, where the complex nature of the syndrome may manifest itself differently in different complex multi-modal tasks.

In this experiment we designed an environment in which we can challenge one's reality perception, using a detection task of incoherent visual and audio-visual stimuli. This very simple task distinguished very well between the control and patient populations: 88% of the patients differed significantly from the control group. The patient group showed the greatest difficulty in detecting audio-visual incoherencies, where poor performance correlated with the presence of hallucinations. Interestingly, we observed that most effective were events involving auditory stimuli, where the object and sound matched overall but were used under the wrong circumstances, as in adults laughing like babies or a civilian airplane emitting bombing sounds.

The task has additional advantages: it is short - taking only half an hour, and it can be self-administrated requiring only minimal non-professional assistance. The analysis of individual incoherencies revealed that some incoherencies present greater difficulty for the patient group but not for the controls. Therefore, the set of incoherencies may be further improved to shorten the duration of the test, and to increase the discriminability of the patient population.

It would be interesting to compare the performance of schizophrenia patients in this incoherencies detection task with standard cognitive tests. Previous studies show that in some tests less than 40% of schizophrenia patients are impaired [6, 7], while in others only 11%-55% of the schizophrenia patients perform in the normal range [8-10]. In an extensive study Palmer et al. [3] aimed to explore the prevalence of neuropsychological (NP) normal subjects among the schizophrenia population. In their study, the proportion of impaired patients in different cognitive dimensions varied in the range 9%-67%. In comparison, our results in the incoherencies detection task seem very promising, with 88% of the patients demonstrating impairment. These results should be replicated with a larger group of patients and controls and confirmed with additional comparison groups, including groups consisting of patients with different mental disorders.

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References

[1] David AS., 2004. The cognitive neuropsychiatry of auditory verbal hallucinations: an overview. Cognit Neuropsychiatry. Feb-May;9(1-2):107-23.

[2] MATRICS: Measurement and Treatment Research to Improve Cognition in Schizophrenia. 2004. MATRICS: Provisional Consensus Cognitive Battery. Available at: http://www.matrics.ucla.edu/provisional-MATRICS-battery.shtml. Accessed Oct 22, 2006.

[3] Palmer, B.W., Heaton, R.K., Paulsen, J.S., Kuck, J., Braff, D., Harris, M.J., Zisook, S. and Jeste, D.V., 1997. Is it possible to be schizophrenic yet neuropsychologically normal?. Neuropsychology 11, pp. 437–446.

[4] Green Michel F., 2006. “Cognitive Impairment and Functional Outcome in Schizophrenia and Bipolar Disorder” . J Clin Psychology 67 (suppl 9):3-8.

[5] Kay, S.R., Fiszbein, A. and Opler, L.A., 1987, The Positive and Negative Syndrome Scale (PANSS) for schizophrenia. Schizophr. Bull. 13, 261-276.

[6] Goldberg, T.E. and Gold, J.M., 1995. Neurocognitive functioning in patients with schizophrenia. In: Bloom, F.E. and Kupfer, D.J., Editors, 1995. Psychopharmacology: The Fourth Generation of Progress, Raven Press, New York, pp. 1245–1257.

[7] Braff DL, Heaton R, Kuck J, Cullum M, Moranville J, Grant I, Zisook S., 1991. The generalized pattern of neuropsychological deficits in outpatients with chronic schizophrenia with heterogeneous Wisconsin Card Sorting Test results. Arch Gen Psychiatry 48:891–898.

[8] Torrey, E. E, Bowler, A. E., Taylor, E. H., & Gottesman, I. I., 1994. Schizophrenia and manic-depressive disorder. New York: Basic Books.

[9] Strauss, B. S., & Silverstein, M. L., 1986. Luria-Nebraska measures in neuropsychologically nonimpaired schizophrenics: A comparison with normal subjects. International Journal of Clinical Neuropsychology, 8, 35-38.

[10] Bryson, G. J., Silverstein, M. L., Nathan, A., & Stephen, L.,1993. Differential rate of neuropsychological dysfunction in psychiatric disorders: Comparison between alstead-Reitan and Luria-Nebraska batteries. Perceptual and Motor Skills, 76, 305-306.