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Low time resolution in schizophrenia Lengthened windows of simultaneity for visual, auditory and bimodal stimuli

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Abstract

The guarantee of perceptual coherence for events through everyday life situations depends upon the capacity to correctly integrate series of multi-sensory experiences. Patients with schizophrenia have been shown to reveal a deficit in integrating, i.e., "binding", perceptual information together. However, results in the literature have also suggested the reverse effect. Indeed, in certain paradigms patients have revealed more binding phenomenon than healthy controls and reported experiencing two distinct events as occurring "together". This finding suggests that patients may require longer time intervals between two distinct events before being able to perceive them as "one-after-the-other". The question here was to test whether this perceptual binding abnormality in schizophrenia is confined to events within the same modality or whether it is also present across sensory modalities.

Thirty patients with schizophrenia were compared with 33 normal controls using a simultaneity judgement paradigm. There were two uni-modal conditions in which stimuli were presented in the same modality (visual or auditory) and one bimodal condition (audio-visual). Participants were presented with stimuli varying across a range of inter-stimulus intervals (ISI). They were required to judge whether they experienced two stimuli as occurring "together" or "one-after-the-other".

Compared to controls and in all conditions, patients needed larger ISI to experience two stimuli as "one-after-the-other" (all ISI × Group interactions $p < 5 \cdot 10^{-5}$). These abnormalities correlated with the disorganization dimension but not with the dosage of chlorpromazine equivalent.

The increase of the time interval needed to perceive two stimuli as "one-after-the-other", reflect an abnormally low time resolution in patients with schizophrenia. We discuss the possible involvement of anatomical disconnectivity in schizophrenia which would specifically affect the time integration properties of neural assemblies.

Keywords: Schizophrenia; Integration; Time; Synchrony; Multi-modality; Disconnectivity

1. Introduction

Humans evolve in a multi-sensory context, which confers a general information-processing advantage. Indeed, through this mechanism, information from one sense can complete missing information from another

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(Stein et al., 2004). As such, multi-sensory integration should not be conceived as a mere juxtaposition of two or more representations, but rather as the integration or "binding" of sensory data to form a completely new percept. A classical example of this is the "McGurk effect" for which a subject hearing /*ba*/ while looking at a face articulating /*ga*/, will actually perceive /*da*/ (McGurk and MacDonald, 1976). In this case, integration of visual and auditory information provides the means to construct a coherent representation, i.e. a parametric fusion of each contributive sense.

Because our perceptual field comprises a number of independent sources of information, one pre-requisite of such a fusion ability is that only those stimuli belonging to a given event are integrated together. Perception operates in real time and thus, it must be dynamic in nature. Perhaps because of this, our brain tends to integrate events that co-occur within short intervals of time. This phenomenon has often been referred to in the literature as the "windows of simultaneity", i.e. the time window within which two stimuli are perceived as occurring together (see, e.g., Bertelson and de Gelder, 2004; Elliott et al., 2006; Exner, 1875; Poppel, 2004). This form of temporal integration has been shown to be automatic, unconscious and unmodified by attention (Bertelson and de Gelder, 2004).

Schizophrenia is generally held to include a problem of cognitive integration (Tononi and Edelman, 2000). Evidence has been found by examining the patients' susceptibility to the McGurk effect. For example, using synchronized audio and visual cues, de Gelder et al., 2003, 2005) found in patients with schizophrenia a reduction in the bias induced by the visual cues leading to less frequent perception of the multimodal (and illusory) phoneme /*da*/. This was interpreted as being caused by a deficit in integrating visual and auditory stimuli, maybe because of faulty synchronization mechanism of simultaneous cues. Conversely, studies exploring an "ownership illusion" based on the integration of proprioceptive and visual cues reported a reversed pattern of effects in patients when the two sources of information were presented slightly asynchronously, i.e. one after the other. In this case, patients made abnormal over-attribution of a hand to themselves when this hand was viewed though a mock TV screen and when it more or less imitated their true movements (Daprati et al., 1997, Franck et al., 2001). Interpreted in the framework of multimodal integration, the perception of visual and proprioceptive information as occurring together bring about an incorrect integration of invalid cues within a single, coherent perceptual event. Similarly a feeling of ownership for an artificial rubber hand was shown to appear when the hand was stimulated together with the subjects true hand (Botvinick and Cohen, 1998). Here, the "rubber hand" illusion was shown to be stronger and to occur more rapidly in patients than in controls (Peled et al., 2000, 2003).

We propose that the seemingly contradiction in the literature for evidence of abnormal multi-sensory integration in schizophrenia results from a combination of two factors. First, the integration process itself may be faulty and prone to non-systematic errors (Tononi and Edelman, 2000; de Gelder et al., 2003, 2005). Second, windows of simultaneity may be lengthened in patients. If this latter possibility were true, in spite of relatively long intervals between two stimulus events, patients would continue to bind those events and thus, should perceive two stimuli as occurring together. In contrast, at similarly time intervals control participants should no longer perceive the simultaneity but should judge stimuli as appearing one after the other.

The problem of time has already been raised as a key issue in studies conducted in patients with schizophrenia. But this has especially been the focus of the action literature interested for gaining a better understanding of the fluency deficits in schizophrenia, e.g. for the coordination of movement and thought (Andreasen, 1999). When considering sensory processing, timing abnormalities have been described for example using either "span of apprehension" or "backward masking" paradigms (Nuechterlein and Dawson, 1984; Saccuzzo and Schubert, 1981). In these tasks, subjects are asked to locate, detect or identify a first stimulus, which is followed after a varying delay by a second meaningless stimulus — the mask. Patients with schizophrenia were shown to need typically a longer time interval than controls between target and mask in order to perform the task successfully (Braff, 1981; Butler et al., 1996; Rund et al., 1993). This could be due to the fusion of the first stimulus with the mask when both fall within the same (lengthened) window of simultaneity.

The study described here was designed to answer two related questions. First, we wanted to assess whether simultaneity thresholds are larger in patients with schizophrenia when stimuli are presented in two different modalities. The simultaneity threshold is defined as the time interval separating two stimuli, below which the subject perceive the stimuli as occurring together in more than half of the trials. If this was the case, the threshold's increase could account for the results of increased binding in multi-sensory integration experiments. To test this idea we used a temporal discrimination paradigm, i.e. asking subjects to judge whether they perceive two stimuli as occurring