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Disruption of information processing in schizophrenia: The time perspective

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ABSTRACT

We review studies suggesting time disorders on both automatic and subjective levels in patients with schizophrenia. Patients have difficulty explicitly discriminating between simultaneous and asynchronous events, and ordering events in time. We discuss the relationship between these difficulties and impairments on a more elementary level. We showed that for undetectable stimulus onset asynchronies below 20 ms, neither patients nor controls merge events in time, as previously believed. On the contrary, subjects implicitly distinguish between events even when evaluating them to be simultaneous. Furthermore, controls privilege the last stimulus, whereas patients seem to stay stuck on the first stimulus when asynchronies are sub-threshold. Combining previous results shows this to be true for patients even for asynchronies as short as 8 ms. Moreover, this peculiarity predicts difficulties with detecting asynchronies longer than 50 ms, suggesting an impact on the conscious ability to time events. Difficulties on the subjective level are also correlated with clinical disorganization. The results are interpreted within the framework of predictive coding which can account for an implicit ability to update events. These results complement a range of other results, by suggesting a difficulty with binding information in time as well as space, and by showing that information processing lacks continuity and stability in patients. The time perspective may help bridge the gap between cognitive impairments and clinical symptoms, by showing how the innermost structure of thought and experience is disrupted.

1. Introduction

We review here recent investigations regarding the visual perception of events in time in patients with schizophrenia. We examined the coding of the succession of distinct events in time, i.e. the ability to predict and follow the events flow. This ability is an integral part of our inner experience and our ability to interact with the outer world. We argue that these abilities are rooted in elementary mechanisms that allow us to distinguish and follow events in time on an unconscious level (<20 ms), and which are impaired in patients with schizophrenia (Lalanne et al., 2012a,b). Here we shall examine relationships between such elementary mechanisms and conscious experience, based on previous studies.

1.1. Time and predictive coding

Coding events efficiently in time is necessary in order to be connected with the outer world. It is necessary for encoding both predictable and new events. Predictive coding provides a theoretical framework to account for these abilities (Friston, 2008), by proposing that the brain triggers expectations about future sensory inputs. These can then be used to check whether actual sensory signals match expectations. If a match is found, sensory signals can be suppressed, whereas sensory information contrary to predictions will be relatively enhanced (Garrido et al., 2009). Predictable events thus bring about a suppression of information, whereas new events are detected by means of continuous updating of information. Here we focus on the regularity of this updating in time, on both unconscious and conscious levels. We also question how automatic updates are used and integrated into conscious, subjective experiences. It is not straightforward that the updating frequency is the same on automatic and subjective levels. In everyday life, new events can be both numerous and close in time, and the successive processing of events based on automatic updating could be misleading. For example, objects or people move behind information in the foreground or come out from side streets, windows are

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opened or closed, lights are switched on or off. Such events are successive, without, however, necessarily being logically related in time. A light might be switched on between successive appearances of the same moving object. If subjective perception were directly impacted by temporal updating mechanisms, the light would interrupt perception of the moving object, but this is not what happens. Furthermore, experimental evidence shows that our sensory system is not sensitive enough to capture the location of the moving object at exactly the same time as the light, resulting in the flash-lag effect, where the moving objet is perceived ahead of time in relation to the light (reviews in Hubbard, 2014; Shimojo, 2014). This suggests that the updating of information may not be totally accurate in time, and that additional processing affects our subjective perception. It thus raises questions about the relationship between the updating of information on an elementary and subjective levels. This is of particular relevance with respect to patients with schizophrenia, insofar as it has been proposed that they suffer from predictive coding impairments (Fogelson et al., 2014; Ford et al., 2014; NotreDame et al., 2014). It is true that they display connectivity disorders (Friston, 1996; Uhlhaas and Singer, 2010), which might account for disturbances in recurrent loops subtending the constant updating of information processing and the detection of prediction errors (Fogelson et al., 2014). Patients with schizophrenia display a disturbed ability to detect deviants, e.g. a new and unexpected stimulus, and the amplitude of the EEG response to deviants is reduced (Umbricht and Krljes, 2005, for a review see Nagai et al., 2013). This would induce difficulties distinguishing between relevant and irrelevant information, and would cause patients to assign the wrong salience to events (Kapur, 2003; Nelson et al., 2013), possibly resulting in delusional beliefs (Schmack et al., 2013).

These difficulties may be explained in the context of predictive coding (Garrido et al., 2009). Several studies have suggested that some prediction aspects are impaired in patients (Ford et al., 2014; Franck et al., 2001; Frith, 2005; Neuhaus et al., 2013). However, the temporal dimension of this prediction has not been explored in patients (but see Schwartze et al., 2011 for evidence in healthy volunteers).

Since predictive coding is based on the continuous updating of information, any disturbance in how information is updated in time should impact predictive coding. Our results suggest not only that the frequency of updating is higher than previously believed in both controls and patients with schizophrenia, but also that the updating mechanisms are qualitatively impaired in patients.

2. Time events structure coding and schizophrenia

Distinguishing between two events in time requires that each event be considered to be ‘new’. If the second event is not detected as being new, it is either ignored or merged in time with the first, with the two events considered to be simultaneous. In the context of predictive coding, this means that an information update is needed to distinguish between events in time. Conversely, it means that our ability to distinguish between events in time might index the frequency of the updating mechanisms.

Many studies revealed a lower margin in our ability to distinguish subjectively between events in time, estimated at between 30 and 50 ms, irrespective of the sensory source. These results produced the concept of windows of time, or perceptual moments, within which all events are processed simultaneously (reviewed in Elliott et al., 2006, 2007; van Wassenhove, 2009; Wittmann, 2011). In the context of predictive coding, this means that information processing is updated every 50 ms. Interestingly, this time window is longer in patients, which suggests that updating is slower in patients with schizophrenia (Foucher et al., 2007; Giersch et al., 2009; Lalanne et al., 2012a; Schmidt et al., 2011). The time window is assessed using a simple paradigm involving two visual stimuli (e.g. two squares) shown on a computer screen[1]. They appear simultaneously or with a short stimulus onset asynchrony (usually between 0 and 100 ms) and participants judge whether the two stimuli are simultaneous or asynchronous. They respond by pressing a left response key for simultaneity and a right response key for asynchrony. Patients systematically require greater asynchronies than healthy participants before reporting that two stimuli are separated in time (Foucher et al., 2007; Giersch et al., 2009; Lalanne et al., 2012a; Schmidt et al., 2011). They have even more difficulty when they have to code the temporal order of the stimuli (Capa et al., 2014). Temporal order judgments were explored using exactly the same protocol as for asynchrony detection, but participants had to press the key on the same side of the second stimulus instead of deciding whether the stimuli are simultaneous or asynchronous. Control experiments have enabled us to rule out possible confounding factors like bias effects, eye movements, inter-hemispheric transfer or subjective judgments (review in Giersch et al., 2013).

However, our recent results challenge the assumption that all events are merged in time within 50 ms elementary time windows. They suggest, on the contrary, that events can be processed automatically as separate in time in the case of short delays of less than 20 ms, i.e. even when they are subjectively judged as being simultaneous. In the context of predictive coding, this suggests that updating mechanisms have a higher temporal resolution on the automatic level than on the subjective level. Below, we review evidence of such automatic mechanisms and their distortion in patients with schizophrenia.

3. Automatic updating of information within temporal windows

The exploration of implicit timing mechanisms was motivated by the mismatch between the mild clinical state of the patients involved, and their considerable impairments as regards subjectively distinguishing events in time. In some studies (with distractors, Giersch et al, 2009, or with multisensory information, Martin et al, 2013) patients with schizophrenia needed asynchronies of more than 100 to 200 ms to detect the stimuli were not simultaneous. We reasoned that if this were true in everyday life, it would cause major difficulties, which was not consistent with the mild clinical state of our outpatients. In our experiments, the instructions given included a direct, explicit question about the presence or absence of asynchrony. We wondered whether automatic processing in patients was more accurate than explicit responses suggested (Del Cul et al., 2006) and consequently used the Simon effect to investigate patients' ability to code events in time independently of an explicit response. The Simon effect refers to the fact that responses are faster and more accurate when a visual stimulus is presented within the same perceptual hemifield as the responding hand (Hommel, 2011a,b; van der Lubbe and Abrahamse, 2011). This effect was used to measure the implicit processing of events in time while avoiding the need for explicit instructions. As described above, two stimuli were displayed on the screen, one to the left and one to the right, and participants responded (‘simultaneity’ or ‘asynchrony’) by pressing the left or right response key, respectively. When both stimuli are displayed simultaneously, a Simon effect cannot occur, because the information displayed is equivalent on both sides of the screen, and participants cannot be biased to respond on any one side. Asymmetry only occurs when the stimuli are asynchronous, and in these conditions a Simon effect was

[1] To facilitate replication studies, it should be emphasized that care must be taken to achieve accurate time presentation on the screen. We only used CRT screens (120 Hz to achieve presentations lasting 8.3 ms; otherwise, the usual 60 Hz screen allows for 17 ms presentations). In the first studies we used a dedicated ViSaGe stimuli generator (Cambridge Research System) with a 50 Hz video eyetracker to control time accuracy and check that subjects were focusing on the center of the screen. More recent studies were programmed on dedicated (not connected to internet) computers with Matlab (no-java) and Psychtoolbox. All these softwares include programming routines designed to avoid interference during stimuli presentations, i.e., to devote CPU time to the program, even in a Windows environment. Timing accuracy was checked with photo cells. This should be done systematically.