COMPARING TIME ONSETS: DOES IT REQUIRE TO MENTALLY GROUP ITEMS? A QUESTION DERIVED FROM RESULTS IN PATIENTS WITH SCHIZOPHRENIA.

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Abstract

Disturbed temporal event-coding has been repeatedly described in schizophrenia and may represent a core impairment in this invalidating pathology. Impairments have been observed especially when the task involves simultaneity/asynchrony discrimination. In these tasks, two bars are presented left and right from the centre of the screen and subjects decide if bars appear simultaneously or asynchronously. Patients have a difficulty to consciously detect an asynchrony between stimuli, which can be dissociated from a bias effect. Despite this, our own results and the literature suggest that patients are very sensitive to very-short duration stimuli. This suggests difficult comparison of time-onsets of separate stimuli, rather than an enlarged time window in which all events would be fused in time. This leads to the question of the relationship between spatial and temporal event-coding. We will especially discuss the possibility that comparing time-onsets requires mental grouping of the compared stimuli.

Local information belonging to the same object is initially coded by distinct neurons. A popular hypothesis states that this information is bound together in one single percept by means of synchronization of the neurons coding the different parts or attributes of the object (Engel et al., 1991; Gray et al., 1989). Since then, the relationship between synchrony and grouping has received much attention, and also the role of information synchrony, i.e. information that is displayed at the same time, which is supposed to promote grouping of information, possibly by means of neuronal synchronization (Alais et al., 1998; Fahle, 1993, but see Farid, 2002). This might be the case even if stimuli onsets are slightly asynchronous (Guttman et al., 2007). This is not surprising inasmuch stimuli are judged as synchronous even if their onset is delayed by up to 50 to 100 ms (Brecher, 1932; Elliott et al., 2006). Thus slightly asynchronous information can be perceived as synchronous, eventually leading to the perception of one single event. This has led to the concept of time window, during which all information is considered as simultaneous (Elliott et al., 2006). But does the perception of stimulus synchrony automatically lead to binding in space, as suggested by the hypothesis relating stimulus synchrony, neuronal synchronization and spatial binding? Especially in case of undetected asynchronies? And what is then required to perceive an asynchrony? Here we address these questions by contrasting results observed in normal controls and patients with schizophrenia, who show perception disruptions in both time and space domains .

Schizophrenia is an invalidating pathology affecting about 1% of the population. Patients with schizophrenia display clinical symptoms like delusions, hallucinations, autistic withdrawal and disorganization of thought, meaning a fragmentation of consciousness and behaviour. Beside clinical symptoms, many cognitive functions are disrupted, especially memory and attention, but also visuo-perceptual abilities and time perception (review in Uhlhaas &

Mishara, 2008). Regarding the perception of simultaneity, we showed repeatedly that patients are impaired at discriminating simultaneous from asynchronous stimuli, independent of a bias effect (Foucher et al., 2007; Giersch et al., 2009), thus showing that patients judge stimuli as synchronous even for relatively large Stimulus Onset Asynchronies (SOAs). However, despite the fact that synchrony perception is believed to promote grouping, the literature suggests that patients with schizophrenia separate rather than bind excessively information (Giersch & Rhein 2008; Uhlhaas & Mishara, 2008). Besides, according to previous studies, patients are sensitive to very short-duration stimuli (Herzog et al., 2004). When there is an asynchrony between successive events, the first one is perceived alone for a short duration, which should thus be detected by patients, at least sub-consciously. The question is whether this is the case even when two stimuli are perceived as synchronous. If they are fused in time, does this impede the sub-conscious detection of the first short-duration event? As will be seen here, this is not the case, suggesting that for comparing onsets of different stimuli, the detection of the first stimulus alone is not enough to perceive an asynchrony between the first and second stimuli. This leads to questions regarding the mechanisms underlying the comparison of stimulus onsets. Comparing time properties of different objects requires to select these objects together in order to make a comparison. This is close to the concept of grouping, although probably relying on attentional top-down mechanisms. If this is impaired in patients, as suggested previously (Giersch & Rhein, 2008) this might explain the patients' difficulty to detect asynchronies.

We tested this hypothesis by exploring how short isolated events, i.e. the first stimulus appearing on one side of the screen, elicits a manual response on the same side, by means of response-compatibility effects ('Simon effect', Hommel et al., 2001). If patients separate events and are sensitive to short-duration events, their response should be biased by the first square appearing on the screen. On the other hand, if synchrony perception elicits grouping and information fusion, as might be expected if there is an equivalence between synchrony perception, neuronal synchronization and grouping, then the first short-duration stimulus should not be detectable, even sub-consciously, and no Simon effect should be observed. Finally, if attention is drawn to the task at hand and thus to the pair of squares, this should lead to both expectancy regarding the second square and a sense of direction. As a result, the response should be biased on the side of the second square. Inasmuch this expectation differs from low-level grouping, it should not impede the detection of the first short-duration stimulus, making it possible to observe a Simon effect even below threshold.

Method

Eighteen patients with schizophrenia (mean age = 36, SD = 6; mean level of education = 12, SD = 2) took part in the study. They were diagnosed according to the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (American Psychiatric Association, 1994). The control group (mean age = 34, SD = 6.5; mean level of study = 12.5, SD = 1.7) matched the patients' group on the basis of gender, age and education level (Fs < 1).

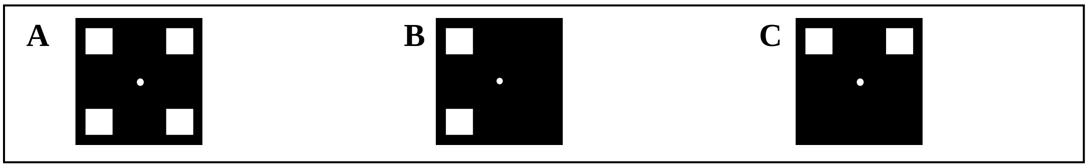

Fig. 1. Illustration of the possible locations of the squares in A, of a left intra-hemifield presentation in B, and of a top inter-hemifield presentation in C.

Stimuli were 2 squares (0.8° x 0.8°) displayed on one side of a virtual square (5.5° x 5.5°). To avoid magno-cellular pathway activation, squares increased progressively in luminance from 0.02 to 12 cd/m², within intervals of 75 ms. Continuous eye tracking ensured that subjects fixated the central fixation point and that stimuli were presented in the same hemifield in case of right or left localization, and across hemifields in case of top or bottom localization (Figure 1). Subjects decided if squares appeared synchronously or not. They pressed on a left response key in case of simultaneity and a right response key in case of asynchrony. Squares stayed on the screen till the response of the subjects. SOAs varied between 0 and 96 ms, by steps of 8.3 ms. The threshold for asynchrony detection is defined by the SOA corresponding to 50% 'synchronous' responses (for more details see Giersch et al., 2009).

Results and discussion

Patients showed a higher threshold for asynchrony detection than controls (50.1 ms in patients vs 41.7 ms in controls, F(1, 34) = 4.8; p<.05). There was no interaction between presentation (within or across hemifields) and group, (F<1). The difference in threshold between groups represents an increase of about 20% in patients relative to controls and replicates previous results (Foucher et al., 2007; Giersch et al., 2009).

What we wanted to know is whether this disturbance is accompanied, or not, by spatial grouping of the stimulus perceived as being simultaneous.

To that aim we calculated the Simon effect. The Simon effect refers to the finding that performance is faster and more accurate when the stimulus appears on the same side as the responding hand, even if the stimulus location is irrelevant to the task. We first checked the Simon effect when stimuli were both on the same side of the fixation point. As subjects have to press a left response key when stimuli are simultaneous, the Simon effect is expected to result in a higher percent of 'simultaneous' responses when both stimuli are displayed in the left rather than in the right hemi-field. The results (averaged over groups) showed that the percent of 'simultaneous' responses is indeed higher by 7% in case of two left rather than two right squares (F[1, 34]=10.6, p<.005). This Simon effect did not differ significantly between patients and controls, suggesting that subsequent differences between patients and controls cannot be attributed to an general impairment in the Simon effect (F<1).

The critical analysis, though, concerned the Simon effect in case of squares displayed in two different hemi-fields (1st square on the left, 2d on the right, or the reverse). This analysis is similar to the previous one but this time it is possible to distinguish between a Simon effect elicited by the first or the second square. Since the threshold varies between subjects, we distinguished the percent of 'simultaneous' responses for SOAs below and above individual thresholds. There was a significant interaction between group, SOAs (sub- vs supra-threshold) and presentation sides (F[1, 34]=5.5, p<.05). Regarding SOAs below threshold, patients made more 'simultaneous' responses, i.e. responses on the left response key, when the first square was on the left and the second one on the right, than when the locations were reversed (by 4.1%, F[1, 17]=6.9, p<.05). This indicates that, below threshold, the response of patients is influenced by the first displayed square. This pattern of results is reversed in controls, whose responses appear to be influenced by the second rather than the first square, even below threshold. Below threshold, controls made more responses on the left response key when the second square was on the left than when it was on the right, by 4.8%, (F[1, 17]=4.8, p<.05).

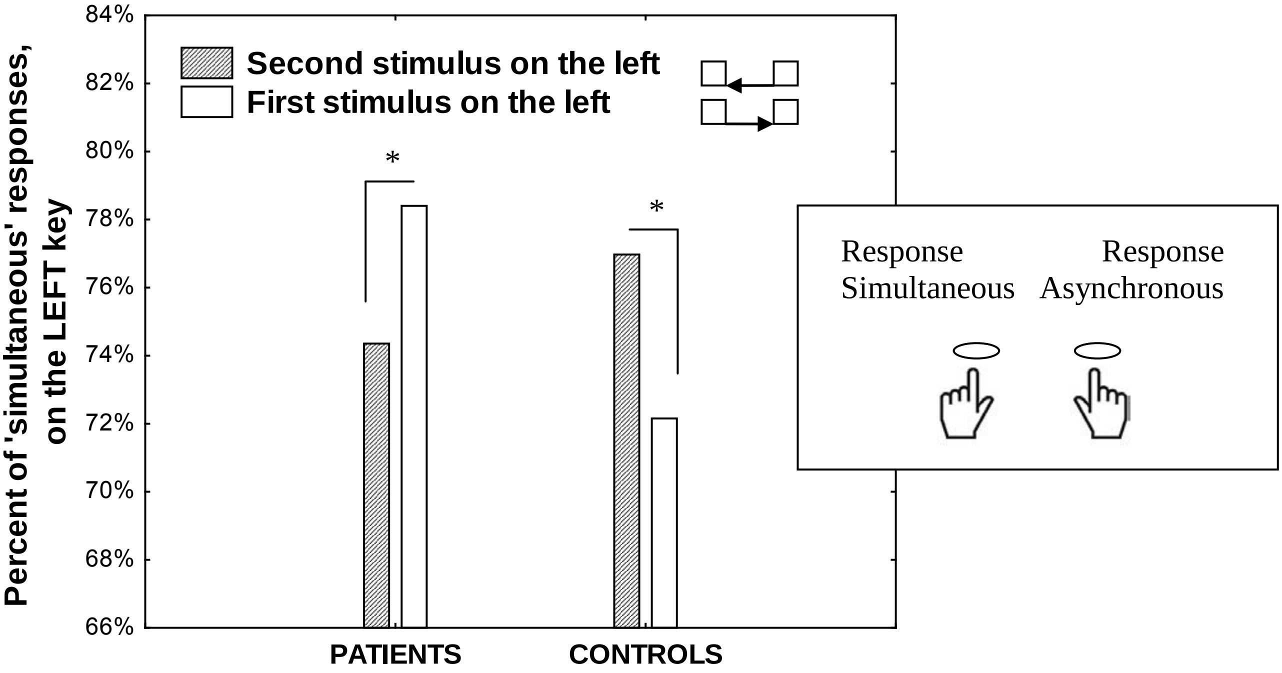

Fig.2. Simon effects in patients (on the left) and in controls (on the right), for SOAs below threshold. Patients are biased to give a response on the side of the 1^{st} stimulus (by 4% SEM 1,5%) and controls on the side of the 2^{d} stimulus (by 4,8%, SEM 2,2%).

The profile was similar in both groups for SOAs above threshold, with an influence of the side of the second square. There was a higher percent of responses on the left response key (‘simultaneous’ responses) when the second square was on the left rather than on the right (by 6% in patients, F[1, 17]=7.4, p<.05, and by 7 % in controls, F[1, 17]=11.4, p<.005). In patients the inverse profile below and above threshold resulted in a significant interaction between SOA (below vs supra-threshold) and the side of the second square, F[1, 17]=17.6, p<.001.

The analysis on RTs confirms the fact that patients are sensitive to the first stimulus when it is presented alone for a short duration. Patients increased significantly their RTs between 0 and 8 ms, by 27 ms (F[1, 17]=5.4, p<.05). This increase was even more marked between 0 and 16.7 ms (by 47 ms, F[1, 17]=8.6, p<.01) and 0 and 25 ms (by 54 ms, F[1, 17]=9.6, p<.01). In all these cases controls’ RTs remained stable (Fs<1), leading to a significant interaction between SOAs and group (F[11, 374]=3.3, p<.001).

In summary, above threshold, both patients and controls are biased toward responses on the side of the 2d square, showing that both controls and patients waited for the second stimulus before making a decision. It shows that the patients performed the task as instructed.

However, in patients, results below threshold show a Simon effect elicited by the 1st square. This suggests that neuronal structures allowing to detect short-duration stimuli are preserved in patients, confirming earlier work by Herzog et al. (2004). One would have expected that if synchrony perception elicits the fusion of information in one single event, it should make it difficult to individualize stimuli, especially on temporal properties. This is clearly not the case in patients. The perception of synchrony does not impede the sub-conscious detection of the first short-duration event. The fact that this sensitivity relies on sub-conscious processing is confirmed in patients by the reversal of the Simon effect when the asynchrony between the two successive stimuli becomes conscious. Patients then become sensitive to the second stimulus onset. It might be argued that the Simon effect observed below threshold differs in patients and controls because controls have a lower threshold. However, the Simon effect was evaluated as a function of individual thresholds, and it is unlikely that healthy volunteers consciously perceived the asynchrony below thresholds. Their threshold are similar to those observed in previous studies, and, contrary to patients, the RTs in healthy volunteers remained stable for short SOAs. RTs increased only around threshold, thus confirming the validity of the measure (maximal peak RT at 37 ms in controls vs 52 ms in patients). It seems thus that patients process information differently from controls in case of synchrony perception, making them sensitive to short-duration events. In controls, the bias on the side of the 2d square suggests that the visual system of the controls is prepared to expect the second stimulus of a pair. This kind of expectation reveals that controls' attentional system is directed toward the pair of stimuli rather than to each stimulus in turn. In contrast, patients appear to be influenced by the second square only when they consciously perceive it as appearing after the first one. Else, they neither appear to anticipate the second square, nor do they fuse the first with the second square. It is as if patients consider the two stimuli separately, making it possible for their visual system to be sensitive to the first stimulus of a pair.

The results observed in patients cannot be generalized to healthy volunteers and do not allow to reject the hypothesis that information synchrony elicits grouping. As emphasized above, the perception of synchrony may not rely on the same mechanisms in patients and controls.

The results nonetheless suggest that the relationship between synchrony detection and grouping might be bi-directional, with synchrony inducing grouping, but also top-down expectation helping to consider the pair of stimulus instead of each stimulus in turn, thus facilitating the discrimination of synchronous from asynchronous events. It has been suggested several times that effects of stimulus synchrony can come about only through feedback connections. Indeed, in case of stimuli far apart from each other, receptor fields in V1 and V2 are too small to encode stimulus synchrony in a bottom-up manner. It requires either lateral connectivity or most probably feedback connections from areas with larger receptive field neurons (Caplovitz et al., 2008; Conci et al., 2004; Roelfsema & Singer, 1998). It is thus not surprising that simultaneity-asynchrony discrimination is affected by top-down mechanisms. Top-down processes might be especially used to select both stimulus together and refine the detection of asynchrony, thus avoiding to fuse distinct events together.

Thus, a 'simultaneous' response in patients might be due to a difficulty to detect asynchrony rather than to a true perception of synchrony. This might explain why synchrony perception does not induce grouping in patients. It remains to be understood, however, how asynchrony detection impairments, spatial grouping alterations and sensitivity to short-duration stimuli are articulated with one another in patients. This is all the more difficult that multiple compensation mechanisms take place as the pathology progresses. First, it might be possible that grouping impairments make it difficult to consider two separate stimuli together and to compare them. This would explain the sensitivity to the first stimulus and the difficulty to detect asynchronous elements. A second hypothesis is based on the observation that, whatever its mechanisms, patients appear to have a real difficulty to consciously perceive an asynchrony between different stimuli. If this tends to result in a fusion of events in one single percept (this hypothesis has not been excluded in controls), then both separating events in space and sensitivity to short-duration events might represent compensation strategies. Unravelling these questions might help to better understand both the pathophysiology of schizophrenia, and the relationships between these different mechanisms in healthy controls.

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