ANTICIPATION MECHANISMS IN TEMPORAL EVENT-CODING?

Anne Giersch, Mitsouko van Assche, Weixin Wang and Laurence Lalanne
INSERM U666; Centre Hospitalier Régional Universitaire de Strasbourg, Dept de Psychiatrie; 1, pl de l'Hôpital ; 67091 STRASBOURG Cedex, France
giersch@alsace.u-strasbg.fr

Abstract

Results in patients with schizophrenia question the mechanisms underlying temporal event-coding. These patients are impaired at reporting an asynchrony between stimuli, but the results suggest excessive fragmentation rather than fusion of events in time. We used a simultaneity/asynchrony discrimination task and explored the impact of attention and spatial grouping by contrasting divided vs focused attention, and connected vs unconnected stimuli (squares). We replicated previous results, showing that the responses of patients and controls were biased in opposite ways on the side of the first or second square. Patients appear to be impaired at perceiving a succession between asynchronous squares, with a bias on the side of the second square decreasing instead of increasing in focused attention, when the location of squares is predictable. We will discuss the possibility of an anticipation impairment in patients, which by contrast may reveal the role of such anticipation in temporal event-coding in 'healthy' participants.

Spatial and temporal information contribute jointly to organize the perception of the environment. Synchronization can be a strong grouping cue, and spatial grouping can influence temporal judgements. The status of temporal and spatial information is not equivalent, however. Whereas the existence of specialized mechanisms for the processing of spatial information is widely recognized, mechanisms regarding the processing of temporal information are less clear. Spatial and temporal information are closely intertwined, making it difficult to disentangle the two types of mechanisms in non-clinical subjects. Here we make use of results observed in pathology, i.e. in schizophrenia, to explore the mechanisms of temporal information processing.

Schizophrenia is an invalidating pathology affecting about 1% of the population, and characterized by various clinical symptoms like delusions, hallucinations, autistic withdrawal and disorganization of thought, meaning a fragmentation of consciousness and behaviour. Many cognitive functions are also disrupted, especially memory and attention, but also visuo-perceptual abilities and time perception (review in Uhlhaas & Mishara, 2007). We used a simultaneity.asynchrony discrimination task (Elliott et al 2006), and showed repeatedly that patients judge stimuli as synchronous even for relatively large Stimulus Onset Asynchronies (SOAs) independently of a bias effect (Foucher et al., 2007; Giersch et al., 2009). However, despite the fact that synchrony perception is believed to promote grouping (see Farid, 2002 for a review), our results suggest that patients do not fuse events even when they judge them to be synchronous. On the contrary, they appear to separate events in time excessively, at least implicitly. This is consistent with the literature suggesting that patients with schizophrenia separate rather than bind information excessively (Giersch & Rhein 2008; Uhlhaas & Mishara, 2007).
In order to explore the implicit processing of asynchrony, we used response-compatibility effects ('Simon effect', Hommel et al., 2001). 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 stimulus location is irrelevant to the task (Buetti & Kerzel, 2008; Simon & Wolf, 1963). The visuomotor Simon effect is indeed believed to rely on direct activation of the manual response through visual stimulation, and reflects a tendency to press the button on the side of the stimulus without any explicit judgment. In our task, two stimuli were presented simultaneously or asynchronously. The stimuli were both on the left or right side of the screen, or one was on the left and one on the right. Subjects had to hit a left response key with the left hand when the stimuli were judged to be simultaneous and a right response key with the right hand when they were judged to be asynchronous. When the two stimuli are on the same side, subjects' responses should be biased to the side of the stimuli, thus reflecting the classical Simon effect. When the two stimuli are on opposite sides, however, no Simon effect can occur in case of two simultaneous stimuli. It is only when the two opposite stimuli are asynchronous that a Simon effect can be observed again. What we verified then was whether the responses were biased on the side of the first or second stimulus. The rationale was the following. If the first stimulus is implicitly detected as an isolated stimulus on one side of the screen, a Simon effect should be observed on the side of this first square. In contrast, if the second square is anticipated and if there is a perception of succession, the Simon effect should be observed on the side of the second square even in the absence of an explicit perception of asynchrony.

Previous results have confirmed that the responses of controls were biased to the side of the second stimulus, even for the shortest asynchronies (Lalanne et al, in press). This was also the case for patients, but only for the largest asynchronies. For the shortest asynchronies, in contrast, patients' responses were biased to the side of the first stimulus, consistent with the hypothesis that patients do not benefit from the succession of events, and rather separate events from one another.

At this stage, several impairments were possibly explaining the results observed in patients. First, their tendency to segregate events in space may have impeded them from comparing the temporal properties of the different stimuli and thus perceiving a succession of events. This would mean that the fragmentation in space originates the fragmentation in time. Indeed in the previous study, there were four possible locations for the stimuli, which implied that after the display of the first square, there were still 2 possible locations for the second stimulus. This may have impeded patients from anticipating the second stimulus. Again it would mean that difficult temporal event coding is due to spatial impairments. Conversely, patients may have a basic temporal coding deficit, independent of their spatial impairments.

Here we checked these possibilities by comparing performance in case of two vs. four possible locations for the stimuli (Figure 1). If the bias to the side of the first stimulus is due to uncertainty regarding the second stimulus location, then performance should be normalized in case of two stimuli, when the second stimulus location in 100% predictable. In addition we manipulated spatial grouping by drawing connectors between stimuli. This way, the two target squares were either connected and automatically grouped, or unconnected and segregated. If the bias to the side of the first stimulus is due to excessive spatial segregation in patients, then the bias should disappear when the stimuli are grouped. This should be all the more the case that grouping should promote synchrony perception. Hence, when stimuli are grouped, no Simon effect should be observed. Alternatively, if the impairments observed in patients are not the consequence of spatial segregation, then the bias to the side of the first stimulus should persist in case of two stimulus locations, and maybe even in case of connected stimuli. This would argue in favor of the existence of mechanisms specifically dedicated toward time processing.

Method

Patients with schizophrenia (19 and 18 for respectively 4 and 2 locations, mean age = 38,2 years old, SD = 6.1; mean level of education = 11.9 years, SD = 1.9) were diagnosed according to the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (American Psychiatric Association, 1994). The control group (17 in both experiments; mean age = 40,5, SD = 8; mean level of education = 12.5, SD = 2.2) matched the patients' group on the basis of gender, age and education level (Fs < 1). It should be noted that 6 more patients and 1 more control had initially been included. Their results had to be rejected, however, due to a difficulty to do the task properly: in half cases, performance did not vary across SOAs, and in half cases, responses were strongly biased by the presence of connectors or by the location of the target squares.

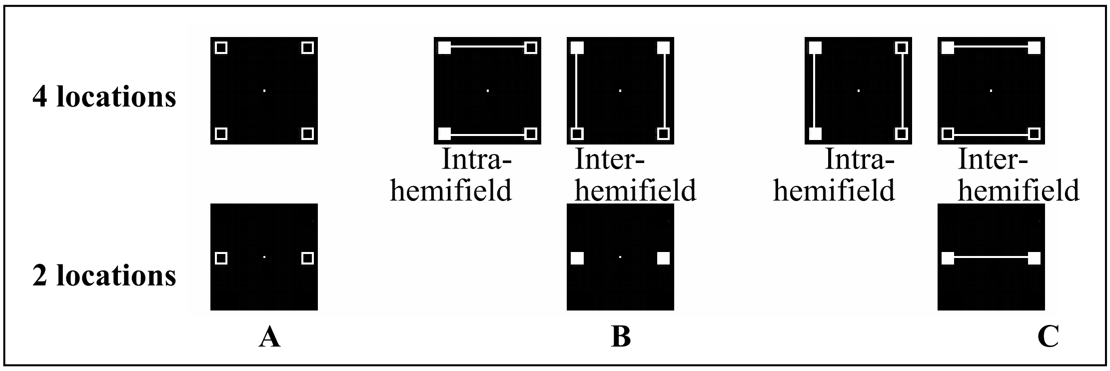


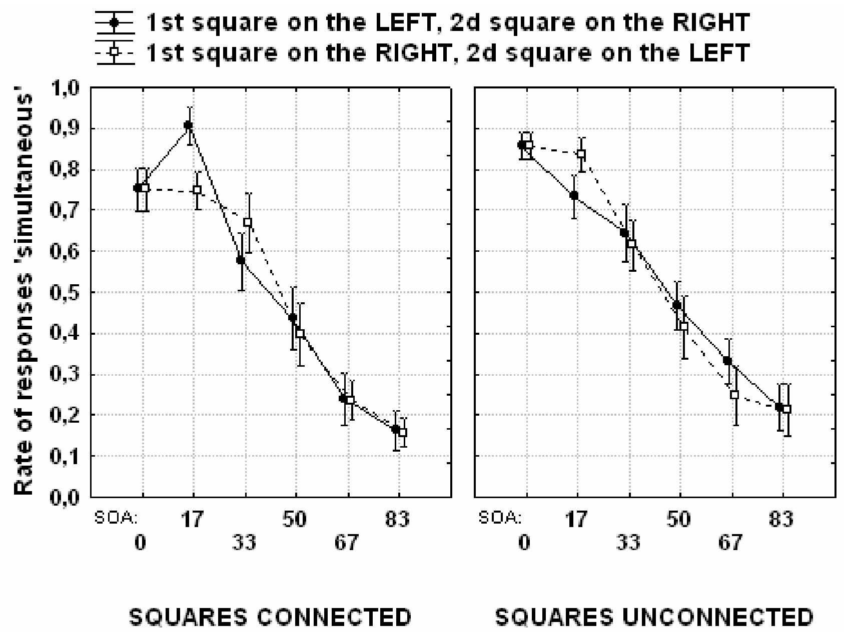
Fig. 1. Illustration of the possible locations of the squares in A, of unconnected stimuli in B (targets squares are filled), and of connected stimuli in C. Two or four empty squares (0.8° x 0.8°) with or without connectors were first displayed for 500 ms, at a distance of 2.5° from the fixation point. After that delay, 2 squares were filled with white. To avoid magno-cellular pathway activation, squares were filled progressively (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 in case of four stimuli, and by steps of 16.7 ms in case of 2 stimuli (for more details see Giersch et al., 2009; Lalanne et al., in press).

Results and discussion

Our main aim was to evaluate how the Simon effect varies as a function of the experimental conditions, and we focus on these results here. We first checked the Simon effect when stimuli were both on the same side of the fixation point (in case of 4 squares). As subjects have to press a left response key when stimuli are judged to be 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 5% in case of two left rather than two right squares ($F[1, 34]=19.6$, $p<.001$). This Simon effect did not differ significantly between patients and controls, suggesting that subsequent differences between patients and controls cannot be attributed to a general impairment in the Simon effect ($F[1, 34]=2$, *ns*).

The critical analysis 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. In order to compare the results observed in case of 2 and 4 possible locations, we considered only SOAs used in both experiments.

PATIENTS



CONTROLS

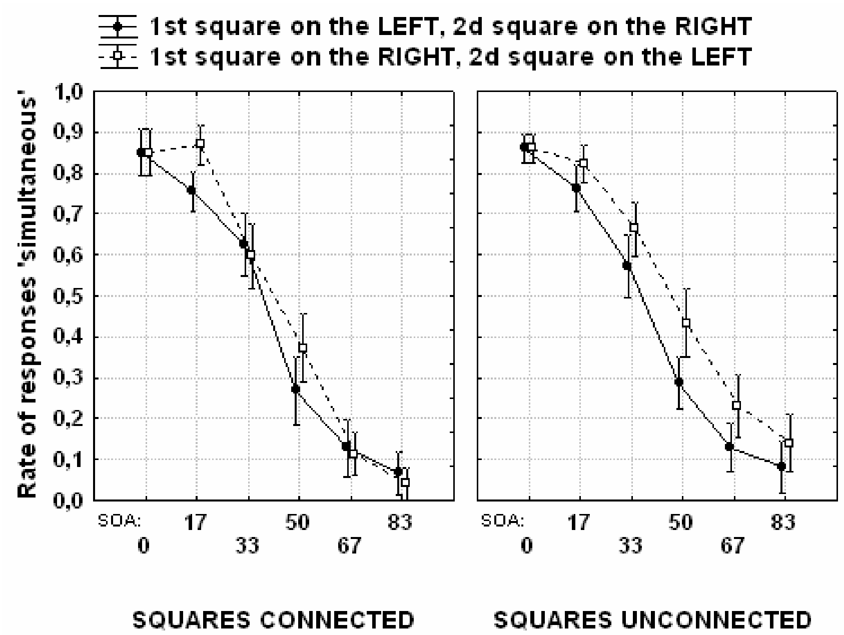


Fig 2: Rate of responses ‘simultaneous’ as a function of SOAs and stimulus sides when squares are presented in two possible locations, in controls (lower panel) and patients (upper panel). Patients differ from controls both on the amplitude of the bias on the side of the 2d stimulus when squares are unconnected, and on the Simon effect observed at short SOAs when squares are connected.

The Simon effect varied according to the group, the presence of connectors, and the number of possible locations (F[1, 63]=6.3, p<.05). In case of 4 possible locations, there was a clear and significant bias to the side of the second square only in patients and only when there was no connector: there were 5% more synchronous responses (left response key) when the second square was on the left than when it was on the right, F[1, 18]=13.6, p<.005). At first sight, this might suggest a perception of succession and a correct anticipation of the second stimulus. However, this interpretation is contradicted by the fact that the Simon effect disappeared in case of 2 possible locations (F<1), and differed significantly from the one observed in case of 4 possible locations: F[1, 33]=5.2, p<.05. In case of 2 squares, the second square's location is predictable. Besides, the perception of a succession between squares should be facilitated by the fact that squares are isolated instead of embedded in a complex structure (Nicol & Shore, 2007). It should thus result in a larger bias to the side of the second square. This is indeed the case in controls, who showed a clear and significant bias to the side of the second square in case of 2 unconnected squares: controls made 7.6% more 'synchronous' responses (left response key) when the second square was on the left than when it was on the right (F[1, 14]=8.4, p<.05; Figure 2). This effect was significantly larger than the one observed in case of 4 possible locations: F[1, 30]=5.9, p<.05. All in all, the results of the controls are consistent with a relationship between the bias and the perception of succession. This is not the case for patients, however, who show a reversed pattern of results.

In addition, abnormal Simon effects were also observed in case of connected squares (Figure 2). These abnormalities were observed only for the shortest SOAs and only for connected squares, resulting in a significant interaction between the group, the presence of connectors, the Simon effect and SOAs (F[5, 315]=3.3, p<.01). When the SOA was of 16.7 ms, the response of the patients was biased to the side of the first square by 8.3% (F[1, 36]=10.1, p<.005). This effect differed from the one observed when squares were unconnected (F[1, 34]=9.4, p<.005) and from the effect observed in controls (F[1, 63]=12.3, p<.001).
Most importantly, patients' reversal of the Simon effect tended to be significantly larger (F[1, 35]=4, p=0.52) in the case of 2 possible locations, when the 2d stimulus location was predictable (effect of 15.2% in case of 2 locations, F[1, 17]=9.9, p<.006) than in the case of 4 locations (effect of 4%, F[1, 18]=1.6, *ns*).

The results replicate the effects observed in our previous study, with a global bias on the side of the second square in both groups, and with a reversed bias occurring only in patients for the shortest SOAs. What the present results show in addition is the influence of the predictability of the stimulus locations, and of spatial grouping. Both factors affect the results in patients and controls, but not in the same way. In controls, the results might be explained by an anticipation of the second stimulus, i.e. a prediction, and/or a perception of succession, i.e. a post-diction. In both cases, spatial organization appears to drive the results. Indeed, in case of two stimuli, the location of the second stimulus is predictable. Second, if it is the sense of succession that originates the bias to the side of the second stimulus, it is again the spatial setup of the stimulus that might facilitate the perception of succession in case of two separate stimuli. The role of spatial attributes is thus difficult to disentangle from the role of temporal attributes in controls. In patients, however, the results can hardly be attributed to spatial effects. The bias for the first stimulus suggests a fragmentation of events, inasmuch the patients appear to be influenced by the stimulus which is displayed alone for a short time, rather than by the stimulus appearing last. This bias to the side of the first stimulus is the largest when the two successive events are grouped in space, and when the second stimulus' location is 100% predictable. In other words, the bias is the largest when the spatial difficulties are erased, suggesting that the origin of the paradoxical Simon effect is temporal rather than spatial. Temporal difficulties might concern implicit prediction or post-diction, i.e. a difficulty to anticipate the second stimulus, or to perceive a succession between the two squares' onsets. Since the patients' bias is observed when even controls have a difficulty to perceive a succession (connected squares), the results rather suggest a difficulty to anticipate the upcoming event in time.

It should be noted that the results of both groups are nonetheless influenced by spatial factors. In patients, this influence might be related with their spatial difficulties, occurring when stimuli are separated and belong to different groups (van Assche & Giersch, in press). The difficulties and reorganization that follows might explain the large bias on the side of the second square observed in patients at large SOAs.

All in all, the peculiar deficits observed here might represent a way both to better understand the pathophysiology of schizophrenia and to isolate selective temporal anticipation mechanisms.

Acknowledgements

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