Attention and Masking in Schizophrenia

Laurence Lalanne, André Dufour, Olivier Després, and Anne Giersch

Background: Patients with schizophrenia are known to be impaired in masking tasks, but the mechanisms underlying their deficits are still elusive. Our study was intended to examine attentional effects, which have a known impact on masking in healthy volunteers but have only rarely been explored in relation to masking in patients.

Methods: We compared focused versus divided attention in 18 control subjects and 18 patients using forward and backward masking tasks. In the conventional masking task, subjects had to locate one target among four possible locations. Presentation of one target allows attention to be focused, in contrast with the divided attention task in which two targets were presented either in the same hemifield or different hemifields.

Results: Our results reproduce patients' deficits in forward and backward masking tasks but only when one target is presented. We show that control subjects benefit from focused attention, much more so than patients. Furthermore, patients' performance is identical to that of control subjects in backward masking when targets are presented across hemifields. This performance equalization was checked to ensure it was not due solely to the redundancy of signals (two vs. one). We achieved this by comparing performance when two targets were presented in the same vs. across hemifields, the latter yielding a greater redundancy gain.

Conclusions: From the results, it is unlikely that redundancy can account for the whole pattern of results, which suggest instead that attention deficits play a role in backward masking impairments in patients.

Key Words: Backward masking, divided attention, focused attention, forward masking, redundancy gain, schizophrenia

Patients with schizophrenia consistently display deficits in visual masking tasks (1–4). This particular deficit is related neither to intellectual deterioration (5) nor to neuroleptics (6,7). Several authors have proposed that it reflects vulnerability to schizophrenia (8,9) and has an impact on social outcome (10). These results suggest it reveals a key impairment in patients, hence the need to gain a better understanding of its underlying mechanisms and significance. The role of attention has been shown repeatedly in respect of backward masking (11), and attention impairments have been widely described in patients with schizophrenia (12,13). However, the impact of attention on masking paradigms has rarely been explored in patients. In our study, we wished to determine the extent to which patients with schizophrenia were still impaired when their attention could not be focused on a single target, and we controlled for a possible confounding factor, the redundancy gain.

In visual masking paradigms, a target (usually a letter or symbol) is presented briefly in quick succession with a mask. The subject is instructed to identify or localize the target, the visibility of which is lessened by the mask. The mask is displayed either before or after the target (forward or backward masking tasks). Mask and target are separated by a stimulus onset asynchrony (SOA), the duration of which is manipulated. Patients with schizophrenia need larger asynchronies between target and mask to reach a performance level equivalent to control subjects (1–4). Mechanisms that are proposed as an explanation for the impairment in patients are derived from theories that account for masking in healthy volunteers. Masking is a phenomenon traditionally attributed to interactions between neural visual channels known as "transient" and "sustained" channels (14–18). The transient channel responds to stimulation quickly and briefly and conveys information of low spatial and high temporal frequency, that is, transient and global information. In contrast, the sustained channel responds more slowly and to high spatial frequencies and underlies stimulus identification and fine-scale analysis. These systems correspond, respectively, to the magnocellular and parvocellular visual pathways and interact in complex ways, depending on the type of masking procedure. Backward masking in healthy volunteers is usually believed to involve both integration and interruption mechanisms. Integration is defined as a fusion between the target and the mask relying on the integration of the sustained activities elicited by both stimuli, and it occurs primarily at short SOAs (maximal between 0 and 30 msec). Interruption, on the other hand, is believed to occur at longer SOAs (maximal between 50 to 100 msec), when the transient information conveyed by the mask "interrupts" the sustained processing of the target, thus reducing its visibility (11,14).

On this basis, several hypotheses, not mutually exclusive, have been proposed to explain schizophrenia patients' impairments in backward masking. One influential hypothesis, based on studies that evaluated the detection of low versus high spatial frequency information, suggests a deficit at the level of the transient channel (6,19), which, if impaired, would mean target processing would not be interrupted as efficiently. Consequently, the first stimulus would persist longer and would be merged with the mask via integration mechanisms (20). However, this hypothesis alone may not be enough to explain the entire pattern of deficits observed in patients during masking tasks. Rassovsky *et al.* (21) used meta- and paracontrast to show that masking deficits are still observed in patients even when the mask location does not overlap with the target location, such that mask and target cannot be fused in space. Effects observed in metacontrast and paracontrast are explained by "object substitution," which might also account for the deficits observed in patients. It is a theory based on common views of visual perception, in which object identification requires not only feedfor-

From U666 (LL, AG), National Institute for Health and Medical Research; Department of Psychiatry I (LL, AG), University Hospital of Strasbourg; Mixt Unit of Research UMR7237 (AD, OD), National Center for Scientific Research, Laboratory of Imaging and Cognitive Neurosciences, University of Strasbourg, Strasbourg, France.

Address correspondence to Anne Giersch, M.D., Ph.D., INSERM U666; Centre Hospitalier Régional Universitaire de Strasbourg, Département de Psychiatrie I, Hôpital Civil, 1, Place de l'Hôpital, F-67091 Strasbourg, Cedex, France. E-mail: giersch@alsace.u-strasbg.fr.

Received May 27, 2011; revised Sep 1, 2011; accepted Sep 10, 2011.

0006-3223/$36.00
doi:10.1016/j.biopsych.2011.09.018

ward processing but also feedback connections to overcome any ambiguity between the different interpretations that may be derived from the initial feedforward processing (22). With masking, both the target and the mask would elicit feedforward and feedback processing in turn. However, the target and the mask are presented in close spatiotemporal proximity. This means a possible mismatch between feedforward and feedback processing. For example, in backward masking, when the target has disappeared and the mask is displayed, the feedforward processing would correspond to the mask, whereas the feedback would correspond to the target. It would lead to the target being substituted by the mask, before all ambiguities about the target have been overcome. It might account for patients' deficits if the target processing is too weak or the mask too strong. However, like the hypothesis with respect to excessive integration, this theory must also account for results in implicit tasks that show patients are very sensitive to short duration information, even when efficiently masked. Herzog *et al.* (23) explored the incidental influence of short-duration stimuli on performance in a masking task. They used a 20-msec prime and found that patients were as sensitive to such short-duration stimuli as control subjects. Del Cul *et al.* (24) also showed that the implicit processing of the target was preserved. On the whole, the results of the latter studies show the typical increase in backward masking in patients, which, however, does not seem to be systematically associated with the target and the mask fusing at an early level of processing and still allows the target to be processed efficiently.

As proposed in several models (25), attention is important for enabling information to reach consciousness. Furthermore, the latest "object-substitution" theory stresses the importance of feedback connections that may be reinforced through attention. In fact, studies on object substitution have been particularly helpful in highlighting how attention influences metacontrast (26,27) and even backward masking (28). In addition, attention effects have frequently been described in patients with schizophrenia (29–31), especially with respect to visual perception (13,32), although few studies have confirmed its role in masking deficits in patients with schizophrenia. Granholm *et al.* (33) assessed how attentional resources are allocated during backward masking tasks by measuring pupil dilation. They suggested that patients either failed to allocate sufficient resources or that they mistakenly allocated them toward the mask instead of the target. This would be consistent with the literature suggesting selection control deficits (34). Rassovsky *et al.* (35) manipulated attention by warning subjects before a subset of trials that they would receive a monetary reward for a good response. Although this manipulation improved patient performance, the effect was fairly modest. In all experiments, patients remained impaired in relation to control subjects in all conditions. The hypothesis that attention influences backward masking in patients warrants further examination. We made no attempt in our study to improve masking performance by manipulating attention or to measure attention alongside the masking task. Rather, we tried to minimize the impact of attention in the masking procedure to see whether the performance of patients and control subjects would then be equated. We reasoned that attention allocation should be efficient, at least in healthy control subjects, when focused on a single target but not when divided between two locations. If attention has a role to play in the masking deficit found in patients, their performance should be more similar to that of control subjects when attention is divided. We therefore checked the impact of attention by comparing performance when attention is focused on a single target versus when it is divided between two targets. In the divided-attention condition, two targets were presented, which means a possible redundancy gain in which detection is facilitated by comparison of two identical stimuli with a single one (36,37). Despite this, attention focalization predicted better performance when there was only one target. We predicted less attention focalization efficiency in patients, with similar performance for one versus two targets. However, another explanation for this could be an effect on the redundancy gain, and we wanted to determine whether this gain was affected in patients. Our approach was based on recent studies suggesting that the redundancy gain might be affected in a paradoxical way in presentation across hemifields. Indeed, several studies have demonstrated that the redundancy gain is greater in detection tasks when signals are displayed across hemispheres than when the same number of signals is displayed within hemifields (38,39). Underlying this at least in part is the fact that bilateral stimuli activate both hemispheres in parallel: bilateral activation would help detection and motor response more than unilateral activation (38). This means that in addition to the redundancy gain due to the presentation of two targets instead of only one, the presentation of the two targets in different hemifields should result in even further detection facilitation (38, 39). This effect might be paradoxically enlarged in patients with schizophrenia because of interhemispheric transfer disturbances. When interhemispheric transfer is disturbed, as in cases of commissurotomy or callosal agenesis (40,41), redundancy gain is increased. This is also the case in schizophrenia (42).

This might have a number of implications for the masking paradigm because in the typical paradigm, the mask includes information displayed in both hemifields, implying the activation of both hemispheres. If the redundancy gain was increased in patients, it would mean a higher impact for the mask in patients than in control subjects. However, the presentation of two rather than one target should help patients more than control subjects. This should be especially when the two targets are presented in different hemifields. To confirm this, we contrasted a condition in which both targets are presented in the same hemifield with one in which they are displayed in different hemifields. If the redundancy gain is higher in patients than control subjects and accounts for performance variations across tasks, patients' performance should improve more than that of control subjects when targets are presented across hemifields rather than within the same hemifield.

Our predictions were as follows. First, in healthy control subjects, the possibility of focusing attention in the single target presentation should lead to better performance than when there are two targets. Focused attention may help to amplify the signal conveyed by the target, thus helping to avoid substitution or interruption of target processing by the mask. Inasmuch as these effects have been observed mainly in metacontrast and backward masking, we expected them to be less pronounced in forward masking (11,28). If patients have difficulty related to focused attention, the advantage of having a single target should be lessened, especially with backward masking. Furthermore, by comparing performance as a function of within-hemifield and between-hemifield presentation, we were also able to check the advantage provided by the redundancy of signals across hemifields and to establish whether there was a differential effect of mask and target redundancy between groups. If patients benefit from an increased redundancy effect, their performance should improve more than that of controls when targets are presented in different hemifields as opposed to the same hemifield. This should be true in both backward and forward masking.

Methods and Materials

Demographic characteristics of the 18 patients and 18 control subjects are displayed Table 1. It should be noted that the patients'