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Visuo-perceptual organization and working memory in patients with schizophrenia

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ABSTRACT

We explore the mechanisms sub-tending the re-organization and memorization of visual information by studying how these mechanisms fail in patients with schizophrenia. Several studies have suggested that patients have difficulties in organizing information in perception and memory. We explore to what extent prompting patients to group items influences memory performance. We distinguish automatic grouping from top-down grouping processes, which are especially involved in re-organizing information. The main task was to memorize pairs of figures. Following manipulation of proximity, pairs of figures were part of the same perceptual group (within-group pair, formed on the basis of automatic grouping) or belonged to different groups (between-group pairs, re-grouped through top-down processes). Prior to the memory task, subjects ran a perception task prompting them to prioritize either within-group or between-group pairs. Unlike patients, controls globally benefited from grouping by proximity in the memory task. In addition, the results showed that prioritizing between-group pairs had a deleterious effect in patients, but with a large decrement in memory performance in the case of within-group rather than between-group figures. This occurred despite preserved focalization on within-group figures, as shown by eye-movement recordings. The suggestion is that when patients are prompted to re-group separate items, they can do so, but the benefit derived from automatic grouping is then not only lost but also reversed. This suggests re-organizing visual information not only involves re-grouping separate items but also integrating these new groups in a unified representation, which is impaired in patients with schizophrenia.

1. Introduction

Our perception and memorization of our environment involve conflicting abilities, maintaining a perceptual stability while still being able to navigate flexibly between elements and mentally create new links between items. We explore these abilities by studying how they are disrupted in pathologies like schizophrenia. We test for two possibilities in patients: an impaired ability to create links between items-to-be-remembered, or an impaired ability to integrate new links in a unified representation. We argue that the latter might result in a loss of perceptual stability by disrupting representations stemming from automatic grouping.

Patients with schizophrenia are known to display an impaired organization of information, in both visual perception (Giersch & Rhein, 2008; Silverstein et al., 2006; Uhlhaas, Phillips, & Silverstein, 2005; van Assche & Giersch, in press) and memory (Burglen et al., 2004; Danion, Huron, Vidailhet, & Berna, 2007; Danion, Rizzo, & Bruant, 1999; Diaz-Asper, Malley, Genderson, Apud, & Elvevåg, 2008; Elvevåg, Fisher, Weickert, Weinberger, & Goldberg, 2004; Huron et al., 1995; Lepage et al., 2006; Luck, Buchy, Lepage, & Danion, 2009; Luck, Montoya, et al., 2009; Rizzo, Danion, van der Linden, & Grangé, 1996a; Rizzo, Danion, van der Linden, Grangé, & Rohmer, 1996b; Waters, Maybery, Badcock, & Michie, 2004). However, these impairments might be due to different types of mechanisms, since organizing information involves both automatic and controlled processes, the latter being based on attentional top-down mechanisms (Beck & Palmer, 2002; Palmer & Beck, 2007). What is more, both types of grouping are required all the time, even though they are not accessible to introspection. To illustrate their roles, let us consider the task of grocery shopping. In a store, identical items are usually arranged in stacks or piles. These items are thus grouped and segregated automatically, according to both proximity and similarity. When customers want to choose between different piles of the same fruit (e.g. tangerines of different origins), they have to select single items from each pile to compare them and decide which suits them best. At the same time, the customer is still able to

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perceive each individual item as being part of its pile. Local/global processing alone cannot account for this ability. Local processing allows single items to be considered individually while, at the same time, global processing provides the means to consider piles of fruit. Mentally re-grouping two items from different piles occurs at an intermediate level of processing, between local and global processing. It enables individuals to segregate items at the same time as re-grouping them, and apparently effortlessly. The question is how this conflict is resolved. Do subjects oscillate between two conflicting representations or do they build a representation including both types of grouping? If they oscillate between different, conflicting representations, it would mean that when their attention is focused on one kind of grouping, the conflicting representation is suppressed. While this clearly does happen in some instances, like with the Necker cube (Bruno, 2005), such perceptual multistability is not usually experienced in occasions like the one described above. The rarity of multistable experiences suggests that newly formed groups coexist with those deriving from automatic grouping, at least in healthy subjects, e.g. the two independent piles would coexist along with the pairs of items belonging to different piles. It would mean that access to groups deriving from automatic grouping should be preserved in all cases. This could be important, since this kind of grouping makes it possible to access the identity of the objects in our environment. Preserved access to groups resulting from automatic grouping would then help with maintaining a sense of perceptual stability. In patients with schizophrenia, on the other hand, the experience of stability appears to be disrupted. Patients frequently describe a fragmented visual environment: 'Everything I see is split up. It's like a photograph that's torn in bits and put together again' (Chapman, 1966). Several explanations have been put forward to explain these impairments. Here we explore the hypothesis that patients have a difficulty integrating different types of grouping in a coherent and stable perception.

1.1. Visual perception, attention, and schizophrenia

Some studies have suggested that automatic grouping is impaired in patients (Kéri, Kelemen, & Benedek, 2009; Kurylo, Pasternak, Silipo, Javitt, & Butler, 2007). However, when information organization is unambiguous, patients usually benefit from grouping to a similar degree as controls (Carr, Dewis, & Lewin, 1998; Chey & Holzman, 1997; Gabrovska, Laws, Sinclair, & McKenna, 2002; Giersch & Rhein, 2008; Herzog, Kopmann, & Brand, 2004; Uhlhaas, Phillips, & Silverstein, 2005; van Assche & Giersch, in press). In particular, we used a task in which subjects had to search for a pair of two identical targets among distracters. Proximity or the presence of connectors defined pairs of objects (Fig. 1A), and the target pair was either within the same group (Fig. 1, A2) or in different groups (Fig. 1, A3). In this task, stabilized patients benefited to the same extent as controls from grouping by both proximity and connectors (Giersch & Rhein, 2008; van Assche & Giersch, in press). Furthermore, they were able to focus on groups derived from automatic grouping when the task prompted them to do so. Patients performance was impaired, however, in the case of targets that were not part of the same group insofar as, unlike controls, they were unable to focus selectively on separate object. We suggested that patients failed to build an internal representation of unrelated figures. It is unclear, however, to what extent patients can build such representations when the task forces them to do so, and what happens if they do. If patients can mentally bind separate items together, are they able to maintain this link together with the groups resulting from automatic grouping? If not, what happens to the groups that stem from automatic grouping? Do the patients replace the representations deriving from automatic grouping (the piles) with those deriving from top-down grouping (the pair of tangerines)? This would entail an unusual suppression of representations stemming from automatic grouping, and would mean the visual environment lacked stability. In the present study, we tested this hypothesis with the help of a memory task that involved memorizing two types of pairs of figures, namely pairs resulting from automatic grouping, and pairs composed of separate figures. In memory, as in perception, grouping is expected to improve performance (Campo et al., 2010; Luck, Foucher, Offerlin-Meyer, Lepage, & Danion, 2008; Luck & Vogel, 1997; Olson & Jiang, 2002; Prabhakaran, Narayanan, Zhao, & Gabrieli, 2000; Wu, Chen, Li, Han, & Zhang, 2007). We wanted to know whether patients (1) benefit from automatic grouping, (2) are able to memorize pairs of unrelated figures, and, if so, (3) whether or not the advantage usually brought by automatic grouping is then lost or reversed.

1.2. The paradigm and the predictions

One originality of the paradigm is to measure grouping both in visual perception and in memory. In the visual perception task, subjects have to detect a pair of identical figures among distracters, with the figures part (or not) of the same group. It is typically easier to detect the pair of target figures when they are part of the same group rather than belonging to different groups. Automatic grouping thus yields a response time and accuracy advantage in the task, and grouping is evaluated by measuring the performance difference observed when target figures belong to the same group, as compared to when they belong to different groups (Beck & Palmer, 2002). In the present study, we use grouping by proximity. The same figures are used in both the perception and memory tasks, and there is the same manipulation of proximity. In the memory task subjects have to memorize the relative spatial position of three figures, which requires them to retain two types of pairs, one resulting from automatic grouping (two figures that belong to the same pair) and the other one based on top-down grouping (two figures belonging to different pairs) (Fig. 1B). In addition, manipulation of attention demands during the visual perception blocks provides the means of prompting subjects to focus on either pairs of objects grouped by proximity or, on the contrary, ungrouped objects. So that the impact of this incentive on memorization can be assessed, each perception block is followed by a memory block (Fig. 1C).

We expected that a focalization on either objects grouped by proximity or on separate objects during perception would be carried forward to the following memory block. Since the memory blocks are all equivalent to each other in terms of attention conditions, a difference in performance across memory blocks can only be attributed to the prioritization bias induced during the visual perception blocks.

If patients mainly have difficulty establishing links between separate items (i.e. top-down grouping), then memory performance should be selectively impaired in this type of trials. If, however, patients are able to build representations of separate figures but have difficulty maintaining newly formed links together with links derived from automatic grouping, then the benefit of automatic grouping would not only be lost but even be reversed.

2. Methods

2.1. Subjects

Participants were the same as in Giersch and Rhein (2008): for the sake of simplicity, the perception task results have been reported separately from the memory results. Three patients and their matched controls were taken out of the analysis, because their performance in the memory task failed to exceed chance level. The 27 remaining outpatients were 9 women and 18 men (mean age 34.4 years SD 8.8; mean level of education 11.7 SD 1.8). Controls were individually matched with patients on gender, level of education, and age, and in respect of these characteristics did not differ from patients (9 women and 18 men, mean age 33.8 years SD 8, mean level of education 11.9 SD 1.8, $Fs < 1$). The project had the approval of local ethics committee. Informed written consent was obtained from each patient and control