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Highlights

Acta Psychologica xxx (2013) xxx–xxx

Memory for symmetry and perceptual binding in patients with schizophrenia

Vincenzo Cestari [a,b], Daniele Saraulli [a,b], Pietro Spataro [a], Alessandro Lega [c], Antonio Sciarretta [c], Valéria Rezende Marques [a,d], Clelia Rossi-Arnaud [a,*]

[a] Department of Psychology, Sapienza University of Rome, Via deiMarsi 78, 00185 Rome, Italy
[b] Cell Biology and Neurobiology Institute, C.N.R. National Research Council of Italy, Via del Fosso di Fiorano 64/65, 00143 Rome, Italy
[c] Acute Psychiatric Care Unit, Department of Mental Health RM-G, San Giovanni Evangelista Hospital, Via Antonio Parrozzani 3, 00019 Tivoli, Italy
[d] CAPES Foundation, Ministry of Education of Brazil, Setor Bancário Norte, Quadra 2, Bloco L, Lote 06, CEP 70040-020 Brasília, DF,Brazil

- We examined perceptual binding in schizophrenic patients.
- Participants recalled symmetrical and asymmetrical patterns of increasing length.
- Binding deficits in patients could not be ascribed to lower visuospatial ability.
- Impairment in patients was magnified with supercapacity patterns.
- Patients were more likely to recall symmetrical patterns as asymmetrical.

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Memory for symmetry and perceptual binding in patients with schizophrenia

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[a] Department of Psychology, Sapienza University of Rome, Via deiMarsi 78, 00185 Rome, Italy
[b] Cell Biology and Neurobiology Institute, C.N.R. National Research Council of Italy, Via del Fosso di Fiorano 64/65, 00143 Rome, Italy
[c] Acute Psychiatric Care Unit, Department of Mental Health RM-G, San Giovanni Evangelista Hospital, Via Antonio Parrozzani 3, 00019 Tivoli, Italy
[d] CAPES Foundation, Ministry of Education of Brazil, Setor Bancário Norte, Quadra 2, Bloco L, Lote 06, CEP 70040-020 Brasília, DF,Brazil

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A B S T R A C T

The present study investigated the use of perceptual binding processes in schizophrenic (SC) patients and matched healthy controls, by examining their performance on the recall of symmetrical (vertical, horizontal and diagonal) and asymmetrical patterns varying in length between 2 and 9 items. The results showed that, although SC patients were less accurate than controls in all conditions, both groups recalled symmetrical patterns better than asymmetrical ones. The impairment of SC patients was magnified with supra-span symmetrical arrays, and they were more likely to reproduce symmetrical patterns as asymmetrical, particularly at medium and high length levels. Hierarchical regression analyses further indicated that the between-group differences in the recall of supra-span vertical and horizontal arrays, which require a greater involvement of visual pattern processes, remained significant after removing the variance associated with performance on asymmetrical patterns, which primarily reflects intrafigural spatial processes. It is proposed that schizophrenia may be associated with a specific deficit in the formation and retrieval of the global visual images of studied patterns and in the use of the on-line information about the type of symmetry being tested to guide retrieval processes.

1. Introduction

Memory dysfunctions have been widely documented in patients with schizophrenia (SC), both in long-term memory (LTM) and in working-memory (WM) tasks (Aleman, Hijman, Haan, & Kahn, 1999; Forbes, Carrick, McIntosh, & Lawrie, 2009; Lee & Park, 2005). The concept of WM refers to a limited capacity system for the temporary storage and manipulation of information. According to the latest model proposed by Baddeley (2012), WM consists of four separate subsystems: (a) the phonological loop, which maintains verbal traces; (b) the visuospatial sketchpad, which retains visual and spatial stimuli; (c) the central executive, which supervises ongoing processing; and (d) the episodic buffer, defined as a multidimensional store allowing features from different sources, including perceptual input and LTM knowledge, to be bound into chunks or episodes (Baddeley, 2000; Baddeley, Allen, & Hitch, 2011). In recent years, the issue of binding has been the focus of a large body of research. Here, we will refer to a widely accepted distinction between *controlled* and *perceptual* binding processes (Allen, Baddeley, & Hitch, 2006; Allen, Hitch, & Baddeley, 2009; Karlsen, Allen, Baddeley, & Hitch, 2010; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000).

Controlled (or *active*) binding processes refer to the integration of unrelated items or different object features, such as form and colour (Treisman, 2003), or to the association of objects to their spatial positions (Elsley & Parmentier, 2009). For instance, a pair of words such as "elephant" and "umbrella" can be remembered by forming a mental image of an elephant holding the umbrella over its head (Allen et al., 2009; Baddeley, 2007). Most studies investigating this type of binding have asked participants to recall the identity and the spatial position of alphabetical letters located in a 3 × 3 matrix (Burglen et al., 2004; Mitchell et al., 2000) or to recognise colour-shape combinations in a change detection task (Allen, Hitch, Mate, & Baddeley, 2012; Luck & Vogel, 1997; Treisman & Zhang, 2006).

On the other hand, perceptual binding processes (also called *perceptual grouping*: Treisman, 2003) are thought to underlie visuospatial or verbal tasks in which individual items can be grouped together in memory on the basis of bottom-up Gestalt principles (e.g., proximity, symmetry and connectedness: Woodman, Vecera, & Luck, 2003) or LTM semantic knowledge. One of the major challenges leading to the proposal of the episodic buffer (Baddeley, 2000) was the need to account for the interaction between WM and LTM linguistic and visuospatial knowledge. In a series of experiments, Jefferies, Lambon Ralph, and Baddeley (2004)

* Corresponding author. Tel.: +39 06 49917513; fax: +39 06 49917711.
E-mail addresses: vincenzo.cestari@ipsifar.rm.cnr.it (V. Cestari), daniele.saraulli@ipsifar.rm.cnr.it (D. Saraulli), pietro.spataro@uniroma1.it (P. Spataro), alega@tiscali.it (A. Lega), an.sciarretta@libero.it (A. Sciarretta), valeriarsmarques@gmail.com (V.R. Marques), clelia.rossi-arnaud@uniroma1.it (C. Rossi-Arnaud).
[1] These authors contributed equally to the manuscript.

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and later Baddeley, Hitch, and Allen (2009) examined the attentional requirements underlying memory for prose and sentences. According to the revised model of WM (Baddeley, 2000, 2012), the recall of meaningful sentences and prose passages cannot be accounted for by the phonological loop alone, because of its inherent capacity limits. Instead, the assumption is that memory span for prose and sentences can be enhanced by the interaction between the phonological loop and LTM semantic and linguistic knowledge (i.e., long-term representations involved in the comprehension of the theme and the overall meaning of sentences), which would result in the formation of larger, integrated chunks in the episodic buffer (Baddeley et al., 2009). Both studies found that demanding secondary tasks reduced the overall recall performance, but did not eliminate the memory advantage of sentences and prose passages (relative to sequences of unrelated words and meaningless passages), suggesting that the integration of phonological and long-term linguistic information is not attention-demanding per se (Jefferies et al., 2004). Along the same line of work, a number of studies have compared the recall of symmetrical and asymmetrical patterns in healthy participants (Imbo, Szmalec, & Vandierendonck, 2009; Kemps, 2001; Pieroni, Rossi-Arnaud, & Baddeley, 2011; Rossi-Arnaud, Pieroni, & Baddeley, 2006; Rossi-Arnaud, Pieroni, Spataro, & Baddeley, 2012). In short-term memory, the typical finding is that visuospatial performance is significantly better for vertical than for asymmetrical configurations. Paralleling the findings obtained with sentences, twice as many spatial elements can be recalled when they are arranged to form a vertically symmetrical pattern than when they form an asymmetric configuration (at least with a simultaneous presentation: Rossi-Arnaud et al., 2012). The WM model (Baddeley, 2000, 2012) suggests that such an increase in memory span is brought about by an interaction between the visuospatial sketchpad and the LTM knowledge about the configurational properties of symmetrical arrays. In particular, healthy adults presented with symmetrical patterns have been found to use axis-based retrieval strategies, like side–side reflection (i.e., constructing one side of the array and then completing the other side by reflection across the symmetry axis) and point-for-point correspondence (i.e., placing pairs of dots in point-for-point correspondence across the symmetry axis), which would imply the storage in the episodic buffer of a lower number of integrated chunks (Bornstein & Stiles-Davis, 1984). The main result from the aforementioned studies is that the advantage of vertical symmetry was not eliminated by a range of secondary tasks aimed at selectively interfering with the activity of the phonological loop (articulatory suppression: Rossi-Arnaud et al., 2006, 2012), the visuospatial sketchpad (sequential tapping: Kemps, 2001; Pieroni et al., 2011; Rossi-Arnaud et al., 2012) and the central executive (the verbal-trail task: Rossi-Arnaud et al., 2006, 2012). Based on these data, Rossi-Arnaud et al. (2006), and later Karlsen et al. (2010), concluded that the higher performance with vertical paths reflected perceptual binding processes occurring at a pre-attentive stage and largely independent of executive resources.

Previous studies have begun to examine the functioning of controlled and perceptual binding processes in SC patients. Regarding controlled binding, the results have been controversial. Although Burglen et al. (2004) and Salamé, Burglen, and Danion (2006) found a disproportionate deficit in the combination condition of an object–location binding task, other researchers reported equal impairments in the single-feature and binding conditions (Luck, Buchy, Lepage, & Danion, 2009), and suggested that the altered performance of SC patients for bound features might be the consequence of a more general reduction in visuospatial span (Luck, Foucher, Offerlin-Meyer, Lepage, & Danion, 2008) or of attentional deficits in the ability to selectively encode information for WM storage (Gold, Wilk, McMahon, Buchanan, & Luck, 2003). A number of studies have also been conducted to examine perceptual binding in SC patients (Silverstein, Bakshi, Chapman, & Nowlis, 1998; Silverstein, Bakshi, Nuernberger, Carpinello, & Wilniss, 2005). Overall, the general consensus is that the processing of stimuli with "prepotent" configurational structures is spared in SC patients, and that their deficits in perceptual organizational reflect difficulties of consolidation and/or a failure in the development of top-down response strategies (Silverstein et al., 2006). Symmetry is considered to be a fundamental, early developing and possibly innate visual property to which the perceptual system is predisposed (Bornstein & Krinsky, 1985; Bornstein & Stiles-Davis, 1984; Fisher, Ferdinandes, & Bornstein, 1981). The available evidence indicates that SC patients are not significantly impaired in the perceptual elaboration of symmetrical patterns and that they are able to use symmetry to enhance their memory performance (Knight, Manoach, Elliott, & Hershenson, 2000; see Uhlhaas & Silverstein, 2005, for a review), as indicated by superior short-term recognition of highly structured compared to unstructured visual patterns (Silverstein et al., 1998, 2005).

The aims of the present study were fourfold. The first and more general purpose was to ascertain whether SC patients (like healthy controls) recalled symmetrical patterns significantly better than asymmetrical ones, which would indicate that they retain the ability to bind the long-term information about symmetry with the short-term content of the visuospatial sketchpad (Baddeley, 2007; Imbo et al., 2009; Kemps, 2001). This was achieved by comparing the overall accuracy of the two groups in the recall of symmetrical (vertical, horizontal and diagonal) and asymmetrical patterns varying in length between 2 and 9 items (Pieroni et al., 2011; Rossi-Arnaud et al., 2006, 2012). Based on previous results (Silverstein et al., 1998, 2005), we predicted that, in the analysis of the overall performance (collapsed across all length levels), SC patients would show lower recall accuracy than healthy controls on all types of patterns (symmetrical and asymmetrical), since they have been found to suffer a reduction in the number of items that can be stored in WM (Gold et al., 2010); however, both groups should exhibit the typical recall advantage of symmetrical over asymmetrical patterns (Silverstein et al., 1998, 2005).

In addition to this general analysis, we aimed at examining in more details the mechanisms involved in the recall of studied patterns. The between-group differences in the overall accuracy cannot provide useful information about this issue, for two reasons: a) because the performance is collapsed across all length levels, making it difficult to determine the influence of such a variable on the performance of controls and SC patients; and b) because symmetrical and asymmetrical arrays rely to a different extent on spatial and visual processes. Therefore, the second aim of our study was to verify whether the impairment of SC patients was magnified when they were confronted with supercapacity arrays. For the present purposes, super-capacity patterns were defined as those comprising 5 or more items, whereas sub-capacity patterns contained 4 or less items. This choice is consistent with the notion that the capacity limit of visuospatial WM is about four integrated objects (i.e., chunks; Cowan, 2001; Luck & Vogel, 1997). We expected to find significant differences between SC patients and controls in the recall of symmetrical patterns at high, but not at low memory loads, since Gold et al. (2003) reported that the decrease in performance from set size 4 to set size 6 was greater for SC patients than for matched healthy adults.

As concerns the role of visual and spatial processes, Lecerf and de Ribaupierre (2005) proposed that three independent mechanisms would be simultaneously recruited when recalling visuospatial arrays such as those employed in the present study: *extrafigural spatial processes* (responsible for anchoring the pattern with respect to an external frame of reference), *intrafigural spatial path processes* (responsible for retrieving the spatial relations between individual items) and *intrafigural visual pattern processes* (responsible for remembering the arrays as integrated, global configurations). Lecerf and de Ribaupierre (2005) found higher recognition memory with a simultaneous rather than with a sequential presentation, and attributed this result to the fact that, in addition to the extrafigural and intrafigural path processes (recruited in both conditions), the simultaneous presentation would also involve the formation of global visual images of the to-be-remembered patterns. In a later study, using procedures and stimuli similar to those employed in the present study, Rossi-Arnaud et al. (2012) showed that vertically, horizontally and diagonally symmetric patterns were better recalled in the simultaneous than in the sequential presentation, whereas asymmetrical patterns were recalled equally well in the two conditions. This lack of effect of presentation modality suggests that the three processes postulated by Lecerf and de Ribaupierre (2005) contribute to a different degree to short-term memory for asymmetric and symmetric configurations. That is, the recall of irregular arrays is heavily based on extrafigural and intrafigural path processes, whereas the recall of symmetric patterns requires a more extensive recruitment of visual pattern processes. Hence, the third aim of the present study was to assess the differential contribution of these three processing modes and ascertain whether SC patients have a selective deficit in the retrieval of the global visual images of studied patterns. To this purpose, we employed a multiple regression procedure illustrated by Lorsbach and Reimer (2005) (see the Results section).

Finally, the fourth aim was to examine the type of errors produced by SC patients when recalling symmetrical patterns. This analysis can provide important clues about the question of whether SC patients are impaired in the retrieval of the global visual images of symmetrical patterns and, more generally, about the nature of SC-related deficits (Brébion, David, Jones, Ohlsen, & Pilowsky, 2005, 2007; Brébion, Gorman, Malaspina, & Amador, 2005; Elvevag, Weinberger, & Goldberg, 2001; Lee, Folley, Gore, & Park, 2008). In agreement with the theoretical framework proposed by Lecerf and de Ribaupierre (2005), in the present study we distinguished between three types of errors that can be attributed to deficits in extrafigural, intrafigural path or intrafigural pattern processes (see the Method section for a detailed description). If SC patients are impaired in the formation and retrieval of the global visual images of studied patterns, they should make significantly more intrafigural pattern errors (relative to healthy controls), particularly when recalling super-capacity symmetrical patterns.

In summary, the present study aimed at providing new evidence concerning the question of whether SC patients are able to use Gestalt principles like symmetry to boost their memory performance. In particular, we were interested in: a) comparing the overall performance of SC patients and age-matched controls on the recall of symmetrical and asymmetrical patterns; b) assessing whether increases in the length of symmetrical and asymmetrical patterns had larger detrimental effects on SC patients than on healthy controls; c) determining, through the use of hierarchical regression analysis, whether SC patients were significantly impaired in the retrieval of the global visual images of symmetrical patterns, independently from their deficits in the use of (spatial) extrafigural and intrafigural path processes; and d) ascertaining whether SC patients made significantly more intrafigural pattern errors than healthy controls when recalling symmetrical configurations.

2. Method

2.1. Participants

Twenty SC inpatients (10 females) and 20 control, healthy adults (9 females) participated in the study. The two groups were matched for chronological age [M(schizophrenics) = 35.30 years (SD = 14.57) vs. M(controls) = 35.20 years (SD = 12.07); $t(38) = -0.024$, $p = 0.98$], but there was a marginal trend for control adults to report more years of formal education [M(controls) = 15.0 vs. M(schizophrenics) = 13.2 years, $t(31.36) = -1.76$, $p = 0.088$]. SC patients were recruited from the Acute Psychiatric Care Unit of the Hospital '*San Giovanni Evangelista*' (Tivoli, Rome), after approval of the local Research Ethics Board. No participant had a history of traumatic brain injury, epilepsy, substance abuse or other neuropsychological disorders. The diagnosis of schizophrenia was based on the DSM-IV criteria (American Psychiatric Association, 1994), as determined by the joint consensus of the senior psychiatrists of the research team. All patients were stabilized at the time of testing and treated with antipsychotic drugs (13 with first-generation antipsychotics and 9 with second-generation antipsychotics). The mean duration of illness was 6.5 years. Symptom severity indexes, as assessed with the Positive and Negative Syndrome Scale for Schizophrenia (PANSS: Kay, Fiszbein, & Opler, 1987), were respectively 16.9 (positive symptoms), 20.6 (negative symptoms) and 32.8 (general psychopathology).

2.2. Materials and procedure

Stimuli were 96 patterns containing 25 squares (2 cm × 2 cm each), arranged in a 5 × 5 matrix (Kemps, 2001; Rossi-Arnaud et al., 2006, 2012; see Fig. 1). They were divided in four sub-sets of 24 symmetrical (vertical, horizontal and diagonal) and asymmetrical configurations. Within each sub-set, there were three different patterns for all length levels between 2 and 9 squares. The to-be-recalled squares appeared in red, while all other squares remained black. Presentation was simultaneous at encoding – that is, the whole pattern of red and black squares appeared at the same time on the screen and remained visible for a fixed presentation time (see below).

Testing was controlled on a laptop with a 15.4-inch screen and a resolution of 1280 × 800 pixels. During the study phase participants were instructed to remember the locations of the red squares. Each trial began with a fixation point for 500 ms, followed by a target configuration (16 × 16 cm) for 3000 ms. After a pause of 2000 ms (during which the screen remained blank), three question marks signalled the beginning of the retrieval phase. Participants were required to recall the positions using an appropriate booklet containing 24 blank matrices of the same size as those reproduced on the computer (Andrade, Kemps, Werniers, May, & Szmalec, 2002). Each matrix was printed on a full page and participants provided their responses by marking the studied squares. For both symmetrical and asymmetrical stimuli, testing started with the presentation of 2-square patterns and continued in ascending order of difficulty until 9-square patterns. The order of vertical, diagonal, horizontal and asymmetrical conditions was counterbalanced across participants. Viewing distance was about 50 cm.

Following the framework proposed by Lecerf and de Ribaupierre (2005), memory errors of SC patients and healthy controls in the recall

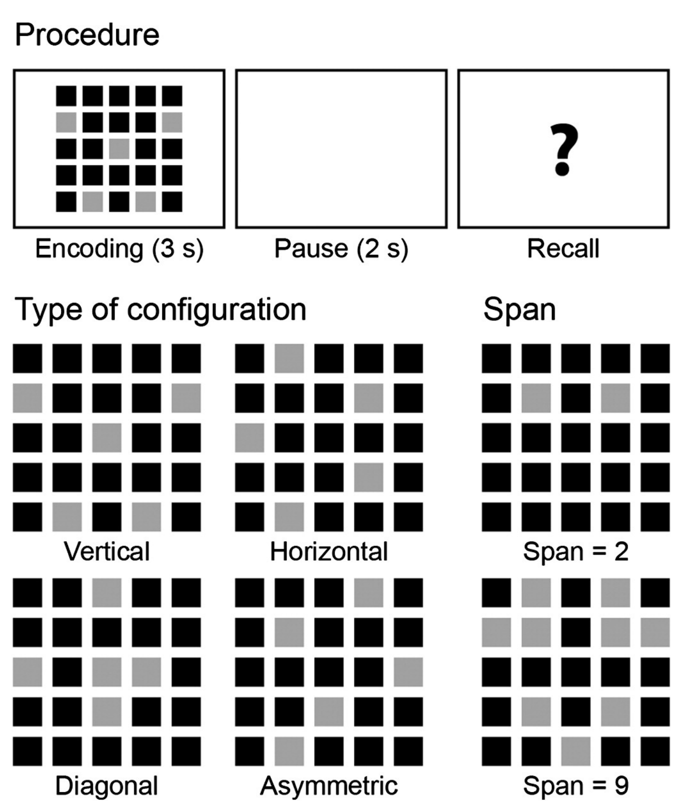

Fig. 1. Materials and procedure employed in the present experiment.

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of symmetrical patterns were classified in three categories. *Extrafigural errors* occurred when the entire configuration, or part of it, was reproduced in a different position of the matrix, but both the symmetrical organization of the whole pattern and the relationships between the individual positions were preserved, thus suggesting a specific deficit in the recall of extrafigural information (i.e., information about the localization of the visuospatial pattern with respect to an external frame of reference). One such error is illustrated in Fig. 2 (Extrafigural error). In that case, the SC patient (AL, 31 years) correctly recalled that the two bottom squares were presented in symmetrical positions on the outermost columns, but erroneously located them in the last row of the matrix. *Intrafigural path errors* occurred when the symmetrical structure of the overall pattern was maintained, but the relationships between individual squares were altered. For instance, in the example reported in Fig. 2 (Intrafigural path error), the patient VA (36 years) incorrectly reproduced a couple of horizontally symmetrical squares as if they were placed along the central (third) row of the matrix. These errors suggest a specific impairment in the recall of intrafigural path information (i.e., information about the way in which individual positions are related to each other). Finally, *intrafigural pattern errors* occurred when the reproduced patterns were no longer symmetrical (see Intrafigural pattern error of Fig. 2), thus demonstrating a deficit in the recall of information about the global visual structure of symmetrical patterns. Indeed, as mentioned above, the advantage offered by symmetrical stimuli is that individual positions can be bound together to form global visual configurations (Jiang, Olson, & Chun, 2000; Karlsen et al., 2010; Rossi-Arnaud et al., 2012).

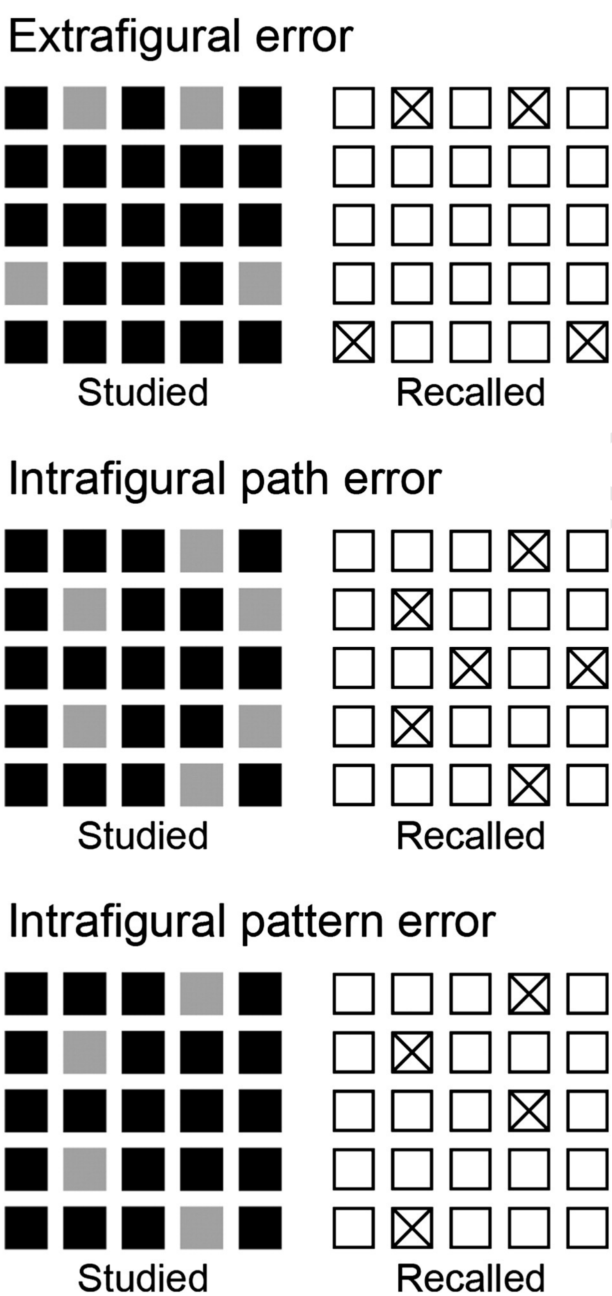

Fig. 2. Examples of different types of errors made by SC patients.

3. Results

3.1. Performance accuracy

Fig. 3 illustrates the mean proportion of squares correctly recalled by SC patients and healthy controls, for vertical, horizontal diagonal and asymmetrical patterns, collapsed across all length levels. Data were analysed through a mixed 4 (Pattern Type: vertical, horizontal, diagonal, asymmetrical) × 2 (Group: schizophrenics vs. controls) ANCOVA, considering Pattern Type as the within-subjects factor, Group as the between-subjects factor and Education as the covariate. Results showed significant main effects of both Pattern Type [$F(3, 111) = 3.81$, MSE = 0.003, $p < 0.05$, $\eta^2 = 0.09$] and Group [$F(1, 37) = 20.65$, MSE = 0.019, $p < 0.001$, $\eta^2 = 0.36$], indicating that: (i) performance was higher for controls than for SC patients ($M = 0.84$ vs. $M = 0.74$); (ii) performance decreased linearly from vertical to asymmetrical patterns, with all pairwise comparisons being significant (all $ps < 0.01$). These effects were qualified by a significant two-way interaction between Pattern Type and Group [$F(3, 111) = 9.12$, MSE = 0.003, $p < 0.001$, $\eta^2 = 0.20$]. A follow-up analysis of simple effects revealed that the differences between controls and SC patients were significant for horizontal, diagonal and asymmetrical patterns [$F(1, 37) = 29.55$, MSE = 0.007, $p < 0.001$, $\eta^2 = 0.44$; $F(1, 37) = 7.56$, MSE = 0.006, $p < 0.01$, $\eta^2 = 0.17$; $F(1, 37) = 22.34$, MSE = 0.008, $p < 0.001$, $\eta^2 = 0.38$], and marginally significant for vertical patterns [$F(1, 37) = 3.75$, MSE = 0.005, $p = 0.06$, $\eta^2 = 0.09$]. Importantly, the same analysis indicated that SC patients recalled vertical, horizontal and diagonal patterns better than asymmetrical arrays ($p < 0.001$ for all comparisons), confirming that SC patients are able to use long-term knowledge about symmetry to enhance their memory performance (Baddeley, 2007; Imbo et al., 2009; Kemps, 2001; Knight et al., 2000; Silverstein et al., 1998, 2005). There were, however, small discrepancies between the two groups: in particular, healthy controls recalled vertical and horizontal patterns equally well ($p = 0.99$), whereas SC patients

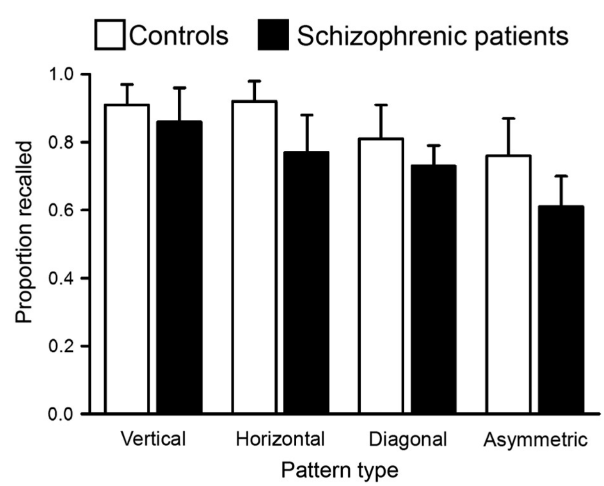

Fig. 3. Proportions of squares correctly recalled, as a function of Group and Pattern Type.

showed a significant advantage for vertical patterns ($p < 0.001$); conversely, SC patients recalled horizontal and diagonal patterns with the same accuracy ($p = 0.46$), whereas healthy controls had a better performance for horizontal than for diagonal patterns ($p < 0.001$). The latter contrasts suggest that the saliency of horizontal symmetry may be reduced in SC patients.

As discussed above, the examination of the overall performance does not allow detailed conclusions about the nature of the processes impaired in SC, for two reasons: a) because accuracy is collapsed across all length levels; and b) because the recall of symmetrical and asymmetrical patterns relies to a different extent on spatial (extrafigural and intrafigural path) and visual (intrafigural pattern) processes. These two questions will be tackled in paragraphs 3.2 and 3.3, respectively.

3.2. Effects of length level

To ascertain whether schizophrenic patients showed a deficit when confronted with supercapacity arrays and whether this impairment was greater than that observed with healthy controls, data were analysed through a series of mixed 3 (Length Level: 2–4, 5–7, 8–9 squares) × 2 (Group: schizophrenics vs. controls) ANCOVAs, one for each Pattern Type (vertical, horizontal, diagonal and asymmetrical patterns). Education was again included in the models as a covariate. The choice of length levels was primarily intended to ensure the possibility to evaluate the performance of SC patients at both sub- and super-capacity levels (Gold et al., 2003). Based on the span scores obtained in previous studies with similar patterns and a simultaneous presentation (Pieroni et al., 2011; Rossi-Arnaud et al., 2012), we reasoned that: a) set size 2–4 assessed recall performance at sub-capacity levels for all types of patterns (including asymmetrical ones); b) set size 5–7 assessed recall performance at super-capacity levels for asymmetrical and diagonal patterns; and c) set size 8–9 assessed recall performance at super-capacity levels for horizontal and vertical patterns.

For vertical symmetry (Fig. 4, left upper panel), results showed significant main effects of both Length Level [$F(2, 74) = 12.14$, $MSE = 0.003$, $p < 0.001$, $\eta^2 = 0.25$] and Group [$F(1, 37) = 6.230$, $MSE = 0.011$, $p < 0.05$, $\eta^2 = 0.15$], which were qualified by a significant two-way interaction [$F(2, 74) = 3.97$, $MSE = 0.003$, $p < 0.05$, $\eta^2 = 0.10$]. A follow-up analysis of simple effects, using the Bonferroni adjustment, demonstrated that controls outperformed SC patients when tested with 8–9 square patterns [$F(1, 37) = 10.30$, $MSE = 0.008$, $p < 0.01$, $\eta^2 = 0.22$], but not with 2–4 and 5–7 square patterns [$F(1, 37) < 1.15$, $p > 0.29$].

For horizontal (Fig. 4, right upper panel) and diagonal symmetry (Fig. 4, left bottom panel), the main effects of Length Level and Group were again significant [for horizontal patterns: $F(2, 74) = 12.01$, $MSE = 0.005$, $p < 0.001$, $\eta^2 = 0.25$, and $F(1, 37) = 29.63$, $MSE = 0.016$, $p < 0.001$, $\eta^2 = 0.44$; for diagonal patterns: $F(2, 74) = 13.99$, $MSE = 0.004$, $p < 0.001$, $\eta^2 = 0.27$, and $F(1, 37) = 8.59$, $MSE = 0.015$, $p < 0.01$, $\eta^2 = 0.19$], as they were the interactions between the two factors [for horizontal patterns: $F(2, 74) = 15.64$, $MSE = 0.005$, $p < 0.001$, $\eta^2 = 0.30$; for diagonal patterns: $F(2, 74) = 4.14$, $MSE = 0.004$, $p < 0.05$, $\eta^2 = 0.10$]. Follow-up analyses of simple effects indicated that, with both types of patterns, healthy controls outperformed SC patients at medium(5–7 squares) and high length levels (8–9 squares) [for horizontal patterns: $F(1, 37) = 27.34$, $MSE = 0.013$, $p < 0.001$, $\eta^2 = 0.42$, and $F(1, 37) = 28.39$, $MSE = 0.010$, $p < 0.001$, $\eta^2 = 0.43$; for diagonal patterns: F(1,

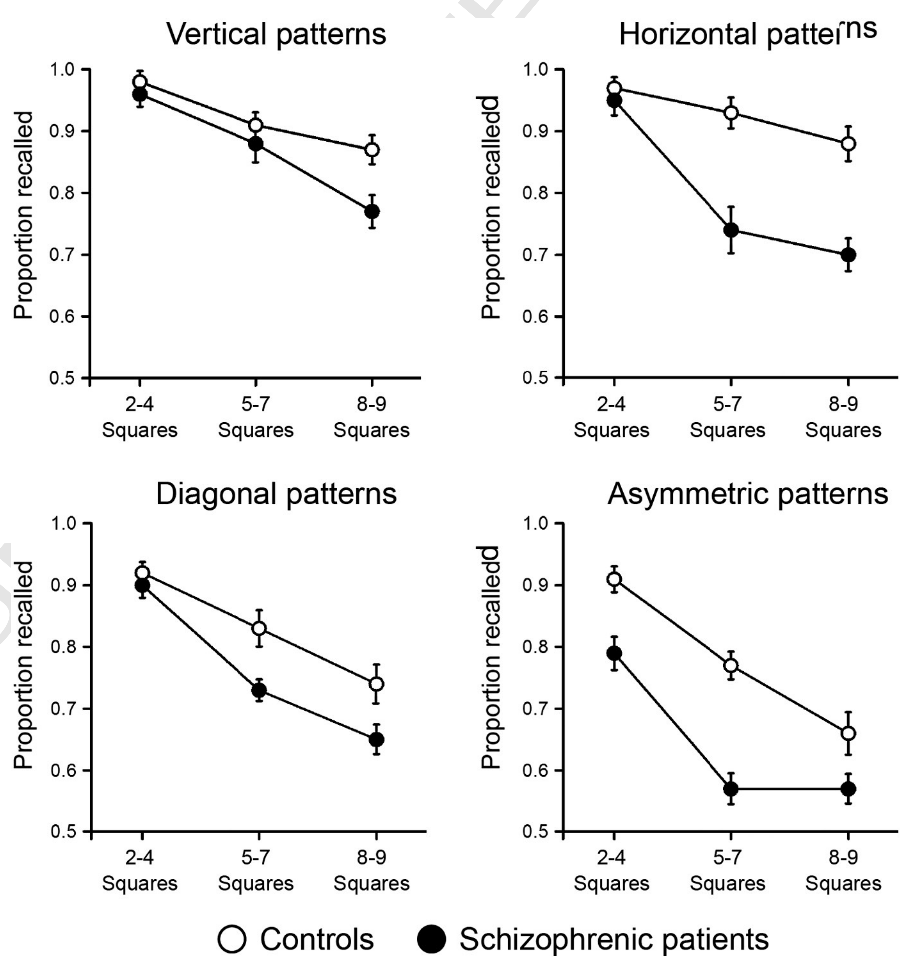

Fig. 4. Proportions of squares correctly recalled, as a function of Group, Pattern Type and Length Level.

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37) = 12.34, MSE = 0.007, $p \leq 0.001$, $\eta^2 = 0.25$, and $F(1, 37) = 5.62$, MSE = 0.013, $p < 0.05$, $\eta^2 = 0.13$], but not at low length levels (2–4 squares) [for horizontal patterns: $F(1, 37) = 2.80$, $p = 0.10$; for diagonal patterns: $F(1, 37) = 1.18$, $p = 0.28$].

Finally, a significant interaction between Length Level and Group was also obtained in the analysis concerning asymmetrical patterns [$F(2, 74) = 5.07$, MSE = 0.006, $p < 0.01$, $\eta^2 = 0.12$]. However, in the latter case the difference between SC patients and healthy controls was significant in all conditions (Fig. 4, right bottom panel) [for 2–4 square patterns: $F(1, 37) = 17.76$, MSE = 0.006, $p < 0.001$, $\eta^2 = 0.32$; for 5–7 square patterns: $F(1, 37) = 36.89$, MSE = 0.010, $p < 0.001$, $\eta^2 = 0.50$; for 8–9 square patterns: $F(1, 37) = 4.24$, MSE = 0.018, $p < 0.05$, $\eta^2 = 0.10$][1].

One problem with the above analyses is that the recall accuracy for 2 to 4 square vertical, horizontal and diagonal patterns, and for 5 to 7 square vertical patterns was near ceiling, raising questions about the extent to which these data violate the typical assumptions of parametric analyses (e.g., normality, equality of variance). Regarding vertical patterns, it is worth noting that the performance of both controls and SC patients increased from medium to high length levels [$t(19) = 4.18$, $p < 0.01$ and $t(19) = 4.56$, $p < 0.001$]: thus, the absence of significant differences between the two groups with 5–7 square patterns cannot be simply explained by a ceiling effect. Nonetheless, non-parametric analyses were conducted to verify the foregoing results. A series of Mann–Whitney *U*-tests confirmed that the recall accuracy of SC patients and healthy controls did not differ for 2–4 and 5–7 square vertical patterns [$Zs > -1.36$, $p > 0.18$], and for 2–4 square horizontal and diagonal patterns [$Z > -1.18$, $p > 0.29$]. In contrast, the difference between the two groups was significant for 2–4 square asymmetrical patterns [$Z = -4.08$, $p < 0.001$].

3.3. Hierarchical regression analyses

One purpose of the present study was to ascertain whether SC patients showed a significant deficit in the retrieval of visual global images of the studied patterns, after removing variance associated with the use of extrafigural and intrafigural path processes. To examine this issue, we used the method illustrated by Lorsbach and Reimer (2005). Using hierarchical multiple regression analyses, these authors found that age remained a significant predictor of memory performance in the combination condition of an object-location task, even when the variance associated with children's performance in the single-feature conditions was removed. Here, we applied the same procedure to verify whether the differences between SC patients and healthy controls in the recall of symmetrical patterns (i.e., in the use of intrafigural pattern processes) remained significant after removing variance associated with performance on asymmetrical patterns (i.e., with the use of extrafigural and intrafigural path processes). The rationale was provided by previous evidence suggesting that, with a simultaneous presentation, the recall of asymmetrical patterns is primarily based on spatial extrafigural and intrafigural path processes, whereas the recall of symmetrical patterns requires a greater involvement of visual intrafigural pattern processes (Lecerf & de Ribaupierre, 2005; Rossi-Arnaud et al., 2012). Following Lorsbach and Reimer (2005), in the first step the recall accuracy with asymmetrical patterns (i.e., the variable whose contribution had to be partialled out) was entered in the regression model as the initial predictor. Then, in the second step, we added to the equation the main effect of group, in the form of a contrast dummy variable (by assigning the values 0 and 1 to SC patients and healthy controls, respectively; Frazier, Tix, & Barron, 2004). The dependent measure was the participants' performance with symmetrical patterns. We only focused on those length levels in which differences between SC patients and healthy controls were significant (i.e., 8–9 square patterns for vertical symmetry and 5–7 and 8–9 square patterns for horizontal and diagonal symmetry).

Table 1
Hierarchical regression analyses.

		β	t	ΔR	R^2 (AdjR^2)
		Vertical symmetry (8–9 square patterns)			
Step 1	Accuracy asymmetrical patterns (8–9 squares)	0.60	5.31***	0.521	0.521 (0.508)
Step 2	Group difference	0.31	2.74**	0.081	0.601 (0.580)
		Horizontal symmetry (8–9 square patterns)			
Step 1	Accuracy asymmetrical patterns (8–9 squares)	0.40	3.69***	0.380	0.380 (0.363)
Step 2	Group difference	0.54	4.96***	0.248	0.628 (0.607)
		Horizontal symmetry (5–7 square patterns)			
Step 1	Accuracy asymmetrical patterns (5–7 squares)	0.53	3.48***	0.570	0.570 (0.559)
Step 2	Group difference	0.30	1.96*	0.040	0.611 (0.590)
		Diagonal symmetry (8–9 square patterns)			
Step 1	Accuracy asymmetrical patterns (8–9 squares)	0.63	5.18***	0.503	0.503 (0.490)
Step 2	Group difference	0.20	1.64	0.034	0.537 (0.512)
		Diagonal symmetry (5–7 square patterns)			
Step 1	Accuracy asymmetrical patterns (5–7 squares)	0.62	3.61***	0.492	0.492 (0.479)
Step 2	Group difference	0.09	0.57	0.004	0.497 (0.469)

* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.

The results of these multiple regression analyses are illustrated in Table 1. As can be noted, the performance with symmetrical patterns could be always predicted from the recall accuracy with asymmetrical patterns [for 8–9 square vertical symmetry: $F(1, 38) = 41.26$, MSE = 0.007, $p < 0.001$; for 8–9 and 5–7 square horizontal symmetry: $F(1, 38) = 23.25$, MSE = 0.012, $p < 0.001$, and $F(1, 38) = 50.41$, MSE = 0.010, $p < 0.001$; for 8–9 and 5–7 square diagonal symmetry: $F(1, 38) = 38.50$, MSE = 0.009, $p < 0.001$, and $F(1, 38) = 36.82$, MSE = 0.006, $p < 0.001$]. In addition, group membership significantly improved the prediction of the dependent variable for vertical and horizontal symmetry [for 8–9 square vertical symmetry: $F(1, 37) = 7.49$, $p < 0.01$; for 8–9 and 5–7 square horizontal symmetry: $F(1, 37) = 24.62$, $p < 0.001$, and $F(1, 38) = 3.84$, $p = 0.05$], but not for diagonal symmetry [$F(1, 37) = 2.68$, $p = 0.11$, and $F(1, 37) = 0.32$, $p = 0.57$].

In sum, these regression analyses indicated that, with supra-span vertical and horizontal patterns, SC patients showed a significant impairment in the retrieval of visual global images of the studied patterns, even after accounting for variance associated with the use of extrafigural and intrafigural path processes. The null result with diagonal stimuli is consistent with previous evidence showing that this type of symmetry is the most difficult to be detected in visual discrimination tasks (Wenderoth, 1994) and the latest to develop in young children (Bornstein & Stiles-Davis, 1984). Therefore, the role of intrafigural pattern processes may have been quite limited for diagonal configurations, explaining the lack of significant differences between SC patients and healthy controls.

3.4. Error analysis

Error frequencies for symmetrical patterns were analysed through a series of mixed 3 (Error Type: extrafigural errors, intrafigural path errors and intrafigural pattern errors) × 3 (Length Level: 2–4, 5–7, 8–9 squares) × 2 (Group: schizophrenics vs. controls) ANCOVAs, with

Error Type and Length Level as repeated factors, Group as the between-subjects factor and Education as the covariate. For the purpose of statistical analyses, the raw frequencies of the three types of errors were transformed into proportions, by dividing by the total number of patterns presented at each length level (i.e., for the maximum number of possible errors).

For vertical patterns (Fig. 5, upper panel), the results showed significant main effects of Length Level [$F(2,\ 74) = 22.63$, MSE = 0.006, $p < 0.001$, $\eta^2 = 0.38$] and Group [$F(1,\ 37) = 7.31$, MSE = 0.017, $p \leq 0.01$, $\eta^2 = 0.17$], indicating that: (i) error rates were lower for 2–4 than for 5–7 square patterns ($M = 0.01$ vs. $M = 0.08$, $p < 0.001$), and lower for 5–7 than for 8–9 square patterns ($M = 0.08$ vs. $M = 0.15$, $p < 0.001$); (ii) SC patients made more errors than healthy controls ($M = 0.10$ vs. $M = 0.06$). The main effect of Error Type did not reach the significance level [$F(2, 74) = 1.30$, $p = 0.27$], but the two-way interactions between Error Type and Group and between Error Type and Length Level were significant [$F(2,\ 74) = 4.57$, MSE = 0.027, $p \leq 0.01$, $\eta^2 = 0.11$ and $F(4, 148) = 2.74$, MSE = 0.016, $p < 0.05$, $\eta^2 = 0.07$, respectively], as well as the three-way interaction between all factors [$F(4,\ 148) = 4.78$, MSE = 0.016, $p < 0.001$, $\eta^2 = 0.12$]. A follow-up analysis

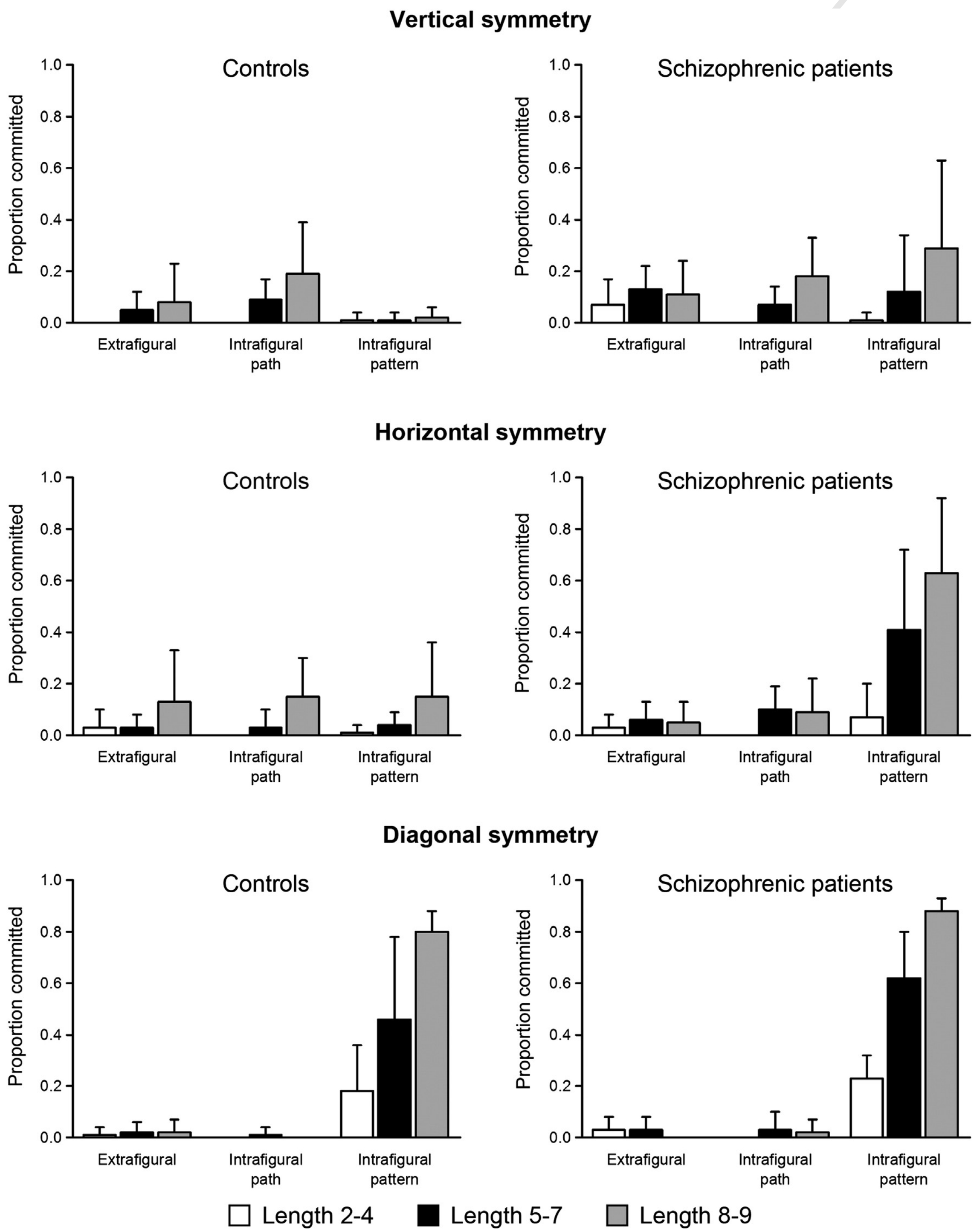

Fig. 5. Proportions of errors, as a function of Group, Error Type and Pattern Type.

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on the latter interaction revealed that SC patients made significantly more extrafigural errors at low (2–4 squares) and medium (5–7 squares) length levels [$F(1, 37) = 6.69$, MSE = 0.004, $p \leq 0.01$, $\eta^2 = 0.15$ and $F(1, 37) = 5.20$, MSE = 0.008, $p < 0.05$, $\eta^2 = 0.12$], and more intrafigural pattern errors with 8–9 square patterns [$F(1, 37) = 9.61$, MSE = 0.055, $p < 0.01$, $\eta^2 = 0.21$], compared to healthy controls.

For horizontal patterns (Fig. 5, central panel), the same analysis as above revealed significant main effects for all factors [Error Type: $F(2, 74) = 14.13$, MSE = 0.030, $p < 0.001$, $\eta^2 = 0.27$; Length Level: $F(2, 74) = 15.65$, MSE = 0.008, $p < 0.001$, $\eta^2 = 0.29$; Group: $F(1, 37) = 34.44$, MSE = 0.021, $p < 0.001$, $\eta^2 = 0.48$], indicating that: (i) intrafigural pattern errors ($M = 0.24$) occurred more frequently than extrafigural and intrafigural path errors ($M = 0.05$ and $M = 0.06$); (ii) error rates were lower with 2–4 than with 5–7 square patterns ($M = 0.02$ vs. $M = 0.12$, $p < 0.001$), and lower with 5–7 than with 8–9 square patterns ($M = 0.12$ vs. $M = 0.21$, $p < 0.001$); (iii) error rates were higher for SC patients than for healthy controls ($M = 0.16$ vs. $M = 0.07$). In addition, there were significant two-way interactions between Error Type and Group [$F(2, 74) = 26.72$, MSE = 0.030, $p < 0.001$, $\eta^2 = 0.41$] and between Length Level and Group [$F(2, 74) = 14.89$, MSE = 0.008, $p < 0.001$, $\eta^2 = 0.28$], which were qualified by a three-way interaction between all variables [$F(4, 148) = 14.13$, MSE = 0.015, $p < 0.001$, $\eta^2 = 0.27$]. A follow-up analysis on the latter interaction showed that the differences between SC patients and healthy controls were significant for intrafigural path errors at medium length levels (5–7 squares) [$F(1, 37) = 8.44$, MSE = 0.007, $p < 0.01$, $\eta^2 = 0.19$] and for intrafigural pattern errors at medium and high length levels (5–7 and 8–9 squares) [$F(1, 37) = 24.72$, MSE = 0.040, $p < 0.001$, $\eta^2 = 0.40$ and $F(1, 37) = 46.91$, MSE = 0.047, $p < 0.001$, $\eta^2 = 0.56$].

Finally, for diagonal patterns (Fig. 5, bottom panel), the ANOVA found significant main effects for all factors [Error Type: $F(2, 74) = 50.62$, MSE = 0.026, $p < 0.001$, $\eta^2 = 0.57$; Length Level: $F(2, 74) = 19.81$, MSE = 0.006, $p < 0.001$, $\eta^2 = 0.34$; Group: $F(1, 37) = 4.51$, MSE = 0.026, $p < 0.05$, $\eta^2 = 0.10$], together with a marginally significant interaction between Error Type and Group [$F(2, 74) = 3.01$, MSE = 0.026, $p = 0.055$, $\eta^2 = 0.07$]. A follow-up analysis indicated that, compared to healthy controls, SC patients made more intrafigural pattern errors at high length levels (8–9 squares) [$F(1, 37) = 3.60$, MSE = 0.025, $p = 0.066$, $\eta^2 = 0.09$], whereas there were no differences between the two groups with respect to extrafigural and intrafigural path errors [$F(1, 37) < 1.21$, $p > 0.27$].

4. Discussion

The present study aimed at examining the functioning of perceptual binding processes in SC patients and matched healthy controls, by analysing their performance in a WM visuospatial task requiring the recall of symmetrical and asymmetrical patterns varying in length between 2 and 9 items (Rossi-Arnaud et al., 2006, 2012). The results showed that: a) the overall recall accuracy was lower for SC patients than for healthy controls with all types of patterns, but both groups showed the typical advantage of symmetrical (vertical, horizontal and diagonal) over asymmetrical stimuli; b) increasing length levels had larger detrimental effects on SC patients than on controls, with both symmetrical and asymmetrical configurations; c) the impairment of SC patients in the recall of 8–9 square vertical patterns and 5–7 and 8–9 square horizontal patterns remained significant after removing the variance associated with performance on asymmetrical patterns; and d) SC patients made significantly more intrafigural pattern errors (i.e., errors in which the symmetrical organization of the studied patterns were lost) when recalling 8–9 square vertical configurations, and 5–7 and 8–9 square horizontal and diagonal configurations. The latter two findings suggest a selective deficit in the ability to form and retrieve the visual global images of supra-span symmetrical configurations.

Regarding our first aim, the analysis of the overall performance showed that both SC patients and healthy controls recalled symmetrical patterns significantly better than asymmetrical ones. These results confirm earlier evidence indicating that SC patients are not impaired in the processing of stimuli with strong configurational properties (Knight et al., 2000; Uhlhaas & Silverstein, 2005) and that they are able to exploit the symmetrical structure of the to-be-remembered patterns in order to improve their memory span (Baddeley, 2007; Imbo et al., 2009; Kemps, 2001; Silverstein et al., 1998, 2005). In agreement, Knight et al. (2000) examined the performance of SC patients, depressed individuals and healthy controls in a same-different judgement task in which they had to decide whether symmetric letter pairs were physically the same (i.e., the same letter in the same orientation). In this condition, the typical result is that decision times are slower to symmetrical (e.g., vertical-axis bilateral) than to asymmetrical letter pairs. Importantly, such symmetry interference was obtained in all groups, suggesting that SC patients processed symmetrical stimuli as gestalts that had to be broken down so that element comparison could proceed (Knight et al., 2000). More pertinent for the present study, Silverstein et al. (2005) showed that both SC patients and healthy controls recognised symmetrical arrays of six asterisks better than asymmetrical arrays, although the accuracy of SC patients was significantly worse than that of controls; furthermore, the patients' performance with regular patterns normally increased as a function of repeated exposure, whereas memory for asymmetric stimuli did not improve, indicating that SC patients were less able to consolidate novel, unstructured visual information (relative to controls).

However, unlike previous studies, we parametrically manipulated the length of the to-be-remembered patterns, introduced a detailed classification of error types and evaluated the independent contributions of spatial (extrafigural and intrafigural path) and visual (intrafigural pattern) processes to recall accuracy. These additional analyses qualified the foregoing general conclusions in important ways. First, when the performance of the two groups was analysed in terms of increasing length levels, it turned out that SC patients were significantly impaired in the recall of supercapacity symmetrical arrays (5–7 square patterns for horizontal and diagonal symmetry, and 8–9 square patterns for vertical, horizontal and diagonal symmetry). Analogous findings have been reported by Gold et al. (2003), who tested visual WM for single features (colour and orientation) and feature combinations in schizophrenia using a change detection task. They showed that, unlike controls, the WM capacity of SC patients declined from set size 4 to set size 6, and attributed this decrement to a deficit of selective attention. From a theoretical point of view, our results support the view that binding processes are relatively automatic (i.e., operating at pre-attentive stages, independently from attentional resources) at low load levels, but become more attention-demanding at medium and high load levels (Kochan et al., 2011). Using an object–location task, Kochan et al. (2011) have recently reported that, during the retrieval phase, the performance of healthy adults with high load patterns was associated with a stronger deactivation of the default mode network – an interconnected system of cortical regions which is preferentially active when the brain is in a state of wakeful rest and memory load is low (Raichle & Snyder, 2007) – and argued that binding becomes a resource-intensive process at higher memory loads. Interestingly, a large number of studies have reported dysfunctions of the default mode network in schizophrenia (including hyperactivation: see Whitfield-Gabrieli & Ford, 2012, for a review), potentially accounting for the deficits exhibited by our SC patients with supra-span patterns. Kochan et al. (2011) further proposed that bound representations may be more fragile than single feature representations (Allen et al., 2006), and that they may be more easily disrupted when demands on visuospatial attention are high at retrieval. Accordingly, in the present study, the need to recall increasing amounts of items (and their spatial relationships) may have led to concurrent impairments in the ability to bind the short-term information of the visuospatial sketchpad with the LTM knowledge about symmetry.

In addition, we used multiple regression analyses to tease apart the contribution of extrafigural and intrafigural spatial processes (responsible

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for coding the position of the pattern with respect to an external frame of reference and the spatial relationships between individual items) from that of intrafigural visual processes (responsible for remembering the arrays as integrated, global configurations; Lecerf & de Ribaupierre, 2005). The results showed that, at medium and high length levels, the differences between SC patients and healthy controls in the recall of vertical and horizontal patterns (which was assumed to require a more extensive use of intrafigural visual processes) remained significant even after removing the variance associated with performance on asymmetrical patterns (which was assumed to reflect primarily the use of extrafigural and intrafigural spatial processes). Therefore, when the size of the to-be-remembered patterns exceeded the capacity of the visuospatial sketchpad (about four items, according to Cowan, 2001), SC patients demonstrated significant deficits in the retrieval of the global visual images of studied patterns, above and beyond their impairment in the retrieval of spatial information about individual items.

This conclusion was further supported by the error analysis. In recent years, an increasing number of studies have pointed out that the mechanisms underlying memory errors must be taken into account when comparing the performance of SC patients and healthy controls (Brébion et al., 2005, 2007; Elvevag et al., 2001; Lee et al., 2008). Accuracy measures, like the proportion of squares correctly recalled, can only provide information about the number of items that participants are able to simultaneously store into visuospatial WM, whereas a finer analysis of error types may provide crucial information about the specific processes that are impaired in SC patients (Elvevag et al., 2001; Lee et al., 2008). Lee et al. (2008), for instance, reported that SC patients had an increased frequency of "false memory" errors (i.e., errors with high confidence ratings) and that these errors were associated with higher activation of the prefrontal regions of both hemispheres during the delay interval, suggesting that they encoded incorrect stimuli and maintained their internal representations until the test phase. The present results showed that, compared to healthy controls, SC patients were more likely to reconstruct symmetrical patterns as if they were asymmetrical. Interestingly, this type of errors occurred most frequently with horizontal and diagonal configurations of medium and high length levels, confirming that the formation and the maintenance of global visual images was more demanding for these patterns than for vertical ones (Pieroni et al., 2011; Rossi-Arnaud et al., 2006, 2012). A similar conclusion has been reached by Rossi-Arnaud et al. (2012) with healthy adults. Using a dual-task methodology, these authors showed that the advantage of vertical over asymmetrical patterns was significant for both high and low performers (on the basis of their mean span scores), and was not eliminated by secondary tasks designed to interfere with WM subsystems. In contrast, in the low performing group, the advantage of horizontal and diagonal patterns was abolished by both visuospatial and executive interferences, indicating that, for low performers, the recall of the global visual configurations of horizontal and diagonal patterns may be more dependent upon controlled processes, relative to vertical patterns.

A possible explanation for our findings is that SC patients are less efficient than controls in the development of an effective top-down control over perceptual processes (Schwartz Place & Gilmore, 1980; Silverstein et al., 1996). Several studies have suggested that SC patients might have a deficit "in the ability of current sensory input to initiate a simultaneous recreation of aspects of experience associated with past occurrences of the stimulus" (Silverstein et al., 1996, p. 411). Schwartz Place and Gilmore (1980), for instance, found that, in contrast to controls, SC patients did not show superior grouping of stimuli after a repeated exposure to other grouped configurations, suggesting a weaker influence of the regularity of previous input on current perception. Similarly, Knight et al. (2000) reported that a familiarization with vertical stimuli enhanced the ability of controls to use the presence of this type of symmetry as a diagnostic for subsequent responses, whereas SC patients failed to learn this strategy. In the present study, presentation was blocked by symmetry (with all patterns of a given type being tested in sequence), a condition which creates a sustained top-down mental set for a particular kind of processing (Jaswal & Logie, 2013). The implication is that, with increasing task difficulty and SC patients being progressively overwhelmed by the high number of items to be remembered, they might have become less able to exploit knowledge on the type of symmetry being tested to guide retrieval processes.

A related account is that SC patients may be less efficient in the use of redintegration processes, whereby partially decayed traces are completed on the basis of stored knowledge in LTM (Lewandowsky & Farrell, 2000; Schweickert, 1993). The importance of redintegration for visuospatial memory has been demonstrated by Kemps (2001), who explored the short-term recall of irregular (random) and regular sequences in healthy participants. She found that a brief training similar to the Hebb procedure, which leads to the creation of LTM representations, increased the recall of random stimuli to the same levels achieved with structured paths. On the basis of these findings, Kemps (2001) proposed that LTM representations about the structure of regular paths are consulted during the process of retrieving block sequences from visuospatial WM, facilitating their reconstruction when the capacity of the visuospatial sketchpad is exceeded (see Imbo et al., 2009, for a similar argument). As mentioned above, Bornstein and Stiles-Davis (1984), found that healthy adults tend to reproduce symmetrical patterns by using a side–side reflection strategy (i.e., retrieving one side of the array and then completing the other side by reflection across the symmetry axis). A plausible hypothesis is that, under high load memory conditions (i.e., when recalling patterns of medium and high length levels), SC patients may be less capable to take advantage of these axis-based strategies, compared to healthy controls.

In conclusion, we found that, although SC patients were less accurate than healthy controls in the recall of all types of stimuli, they maintained the typical advantage of symmetrical over asymmetrical patterns (Pieroni et al., 2011; Rossi-Arnaud et al., 2006, 2012), suggesting an intact ability to bind LTM semantic knowledge with the short-term information held in the visuo-spatial sketchpad. On the other hand, SC patients were significantly impaired in the formation and retrieval of the global visual images of symmetrical supercapacity arrays, as indicated by multiple regression analyses and the finding that they were more likely to reproduce symmetrical patterns as asymmetrical, particularly at medium (5–7 squares) and high (8–9 squares) length levels. The latter results are consistent with the hypothesis that schizophrenia may be associated with a specific deficit in the ability to use the on-line knowledge of the type of symmetry being tested to guide retrieval processes (Knight et al., 2000; Schwartz Place & Gilmore, 1980; Silverstein et al., 1996).

Similar results were achieved when analysing all length levels. A series of mixed 8 (Length Level: 2–9 squares) × 2 (Group: schizophrenics vs. controls) ANCOVAs found significant two-way interactions between Group and Length Level for all types of patterns [vertical: $F(7, 259) = 2.64$, MSE = 0.007, $p \leq 0.01$, $\eta^2 = 0.07$; horizontal: $F(7, 259) = 6.35$, MSE = 0.010, $p < 0.001$, $\eta^2 = 0.15$; diagonal: $F(7, 259) = 2.51$, MSE = 0.008, $p < 0.05$, $\eta^2 = 0.06$; asymmetric: $F(7, 259) = 5.46$, MSE = 0.011, $p < 0.001$, $\eta^2 = 0.13$]. Follow-up analyses of simple effects demonstrated that controls outperformed SC patients: a) with 3- and 9-square vertical patterns (all $ps < 0.05$); b) with 5-, 6-, 7-, 8- and 9-square horizontal patterns (all $ps < 0.001$); c) with 3-, 6-, 7-, 8- and 9-square diagonal patterns (all $ps < 0.05$); d) with 3-, 4-, 5-, 6-, 7- and 9-square asymmetrical patterns (all $ps < 0.05$).

5. Uncited reference

Barch, 2005

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