Segregated objects can be sought simultaneously, i.e., mentally “re-grouped.” Although the mechanisms underlying such “re-grouping” clearly differ from automatic grouping, it is unclear whether or not the end products of “re-grouping” and automatic grouping are the same. If they are, they would have similar impact on visual organization but would be in conflict. We compared the consequences of grouping and re-grouping on the performance cost induced by stimuli presented across hemifields. Two identical and contiguous target figures had to be identified within a display of circles and squares alternating around a fixation point. Eye tracking was used to check central fixation. The target pair could be located in the same or separate hemifields. A large cost of presenting targets across hemifields was observed. Grouping by connectedness yielded two types of target pair, connected and unconnected. Subjects prioritized unconnected pairs efficiently when prompted to do so, suggesting “re-grouping.” However, unlike automatic grouping, this did not affect the cost of across-hemifield presentation. The suggestion is that re-grouping yields different outputs to automatic grouping, such that a fresh representation resulting from re-grouping complements the one resulting from automatic grouping but does not replace it. This is one step toward understanding how our mental exploration of the world ties in and coexists with ongoing perception.

Keywords: top-down control, visual grouping, form perception, object-based attention, spatial attention, interhemispheric transfer


Introduction

Exploring the visual environment involves bottom-up pathways that allow objects and object parts to be identified and distinguished from one another. These mechanisms involve the automatic grouping of local elements into global configurations and the segregation of separate objects (Palmer & Rock, 1994). The observer is also able to associate separate objects mentally, i.e., to “re-group” them. As opposed to the usual links stemming from automatic grouping, the result is unusual links between objects, involving top-down processes and based on different pathways to bottom-up grouping. It is obvious that the two types of grouping take different routes. What is less obvious is how they coexist and interact at a cognitive level and how this affects our conscious perception of the outer world. Subjectively, it is as if automatic grouping would provide a background perception, and we would mentally play with information at the foreground. However, at the same time, we experience a unified perception of the world, not a cloven one. Even though automatic grouping occurs before re-grouping, this “re-grouping” coexists with and is integrated within our ongoing perception of our visual environment. It might, thus, be asked how the output of re-grouping is integrated with the output of automatic grouping at the cognitive level.

This question is all the more justified when automatic grouping and re-grouping result in conflicting links. We usually do not experience any conflict when mentally “re-grouping” separate objects. This means two possibilities. The first one is that grouping and re-grouping not only take different routes but also yield different outputs.
Distinct outputs would allow parallel access to the two types of links. However, it would have to be understood how re-grouping is coded and how it is integrated with our ongoing perception. A second possibility would be that the outputs are the same. It would imply that grouping and “re-grouping” are in competition with each other. If the output of “re-grouping” can replace the output of automatic grouping, automatic grouping would not be as stable as it seems. The two possibilities lead thus to very different questions, and the first step is to know whether or not the end product of “re-grouping,” i.e., the resulting link between objects, is coded in the same way as the end product of automatic grouping. To address this question, we compared the consequences of automatic grouping and what we have termed “re-grouping.” If their status is the same, they should have the same impact on performance as measured in visual search tasks. Alternatively, if the status of the coding of groupings and “re-groupings” is different, they also should differ in their visuo-perceptual consequences.

“Re-grouping”

What we have termed “re-grouping” differs from usual grouping. We can demonstrate this with the example of two pairs of cherries connected to each other at their stalks. The stalks allow cherries to be grouped automatically. When selecting the most appetizing cherries, however, we are able mentally to choose one from each pair and to compare them. We shall call this ability “re-grouping,” inasmuch as it means looking at the two cherries selectively and at the same time. The result of such re-grouping may be a single representation unifying the two dissociated cherries, or it may only allow us to switch our attention between the two cherries we have selected, but in both cases, the cherries chosen are segregated from their surroundings and attention is directed toward them selectively. Hence, the term “re-grouping.”

Such “re-grouping,” if it is selective, conflicts with access to automatic grouping. Due to object-centered attention, attending to one individual in a group should automatically spread attention to the group to which this individual belongs (Duncan, 1984; Egly, Driver, & Rafal, 1994). Selecting two unconnected cherries would then mean the selection of four cherries. On the contrary, attending selectively to two individuals in different groups requires us to separate them from the other individuals nearby, in spite of the existing links (e.g., stalks). Isolating the objects from their respective groups so as to re-group them thus requires a fragmentation of existing links (see Adam, Hommel, & Ulmita, 2003, for a similar question) and produces incompatible groupings, at least at a cognitive level. A conflict should occur, especially if the end products of mental re-grouping and automatic grouping are identical. The conflict could be avoided if the end products differ. We endeavor here to disentangle these two hypotheses.

It could be possible that the end product of both automatic grouping and re-grouping have the same status. First, it might be economical to code all types of links in the same way. Second, the importance of top-down effects and the flexibility of our visual system make this hypothesis plausible. Numerous electrophysiological studies have shown the importance of feedback connections on visual areas (Bentin & Golland, 2002; Bullier, Hupé, James, & Girard, 2001; Gilbert, Ito, Kapadia, & Westheimer, 2000; Lamme & Roelfsema, 2000). Experimental studies, on the other hand, have shown grouping to be flexible (Beck & Palmer, 2002; Giersch & Caparos, 2005; Giersch & Fahele, 2002) and to evolve with time (Kimchi, 1998). It is usually thought that the link resulting from automatic grouping is coded through direct connectivity between neurons or through building a representation that unifies the different objects (Barlow, 1972; Singer & Gray, 1995; Tsotsos, Rodriguez-Sánchez, Rothenstein, & Simine, 2008; Varela, Lachaux, Rodriguez, & Martinerie, 2001; Yu, Huang, Singer, & Nikolic, 2008). It is possible that top-down mechanisms underlying “re-grouping” allow links to be coded in the same way. If information is unified within a single representation, then representations stemming from automatic grouping and “re-grouping” would conflict, with one containing the information that two objects are grouped and the other one containing the opposite information. A similar conflict would arise in the case of coding through connectivity, inasmuch as connectivity would have to convey opposite information in the case of automatic grouping and “re-grouping.”

The hypothesis that the end products of grouping and re-grouping are the same is corroborated by results with schizophrenia that suggest that there is competition between automatic grouping and re-grouping (Giersch, van Assche, Huron, & Luck, 2011). Patients with schizophrenia lose access to usual links when mentally relating separate objects, as if they alternate between mental and usual groupings. Their results show that mental re-grouping can interfere and compete with automatic grouping. Even in healthy subjects, the resistance of automatic grouping to “re-grouping” interference can be questioned. Even though we usually do not lose access to automatic grouping, our subjective experience does not necessarily reflect the way information is really processed. For example, several studies have suggested that perception only seems to be continuous but is, in fact, based on the temporal integration of successive snapshots (Hogendorn, Carlson, van Rullen, & Verstraten, 2010; van Rullen & Koch, 2003). What seems to be simultaneous and stable might as well be ever changing. This might be true also for grouping.

Alternatively, it is also possible that the outputs of automatic grouping and re-grouping differ. Let us consider
elements are located within the same perceptual group, target pairs: connected target pairs, where the target elements into pairs (e.g., a connector) yields two types of figures. Adding a grouping factor that binds adjacent two adjacent squares) within a horizontal array of other groups. In its original form, the RDT requires observers to remain. 

Grouping and re-grouping

To explore grouping and re-grouping, we used a search task, the Repetition Discrimination Task (RDT; Beck & Palmer, 2002; Palmer & Beck, 2007), so that we could highlight the advantage provided by automatic grouping (Baylis & Driver, 1992; Beck & Palmer, 2002; Behrmann, Zemel, & Mozer 1998; Duncan, 1984; Palmer & Beck, 2007; Prinzmetal, 1981; Richard, Lee, & Vecera, 2008) and could look for pairs of shapes belonging to different groups. In its original form, the RDT requires observers to search for two adjacent and identical target figures (e.g., two adjacent squares) within a horizontal array of other figures. Adding a grouping factor that binds adjacent elements into pairs (e.g., a connector) yields two types of target pairs: connected target pairs, where the target elements are located within the same perceptual group, and unconnected target pairs, where the target elements belong to different perceptual groups. The first main result was that participants identified the targets more quickly when they both belonged to the same perceptual group (connected target pairs) as opposed to different groups (unconnected target pairs). This reflects the advantage provided by grouping (Beck & Palmer, 2002; Palmer & Beck, 2007). Insofar as the advantage for connected pairs results from automatic grouping, it might have been expected to remain impervious to contextual information, but Beck and Palmer (2002) have also observed that the advantage of grouping can be modulated by manipulating the proportion of connected and unconnected targets in three separate blocks: biased toward connected pairs (with 75% connected targets), biased toward unconnected pairs (with 75% unconnected targets), and a reference block with equal proportions (50%) of each target type. More particularly, they found that performance changed for connected targets, with faster RTs when they were in the majority. This effect was considered top-down given that probabilities are a property of the context and cannot be represented in a single trial (Beck & Palmer, 2002). However, the results obtained by Beck and Palmer allowed no distinction to be made between prioritization of connected vs. unconnected pairs. In particular, they found no direct evidence of grouping of unconnected elements: Manipulating target type frequencies yielded no clear advantage when unconnected targets were in the majority compared with when there was no proportion bias. Consequently, the results may have been due mainly to a modulation of the grouping, with more or less weight attributed to the perceptual groups as a function of the context.

Evidence of re-grouping was suggested by Giersch and Rhein (2008), who used grouping by proximity in a variant of the RDT. This time, changes in performance were observed for unconnected pairs. The recording of eye movements throughout the experiment and the use of a yes/no procedure (in answer to the question “Are there two identical targets or not?”) allowed them to analyze visual exploration independently of the targets’ presence, i.e., in absent-target trials. The results showed that participants spent longer looking at unconnected regions during the block with a majority of unconnected targets than in the block with equal proportions of connected and unconnected targets. On the other hand, exploration of connected regions remained the same across blocks. These results suggest that it is possible to select figures previously part of two different groups, i.e., to re-group them, at least when the task provides an incentive to do so (when there is a majority of unconnected targets). As already emphasized, however, it is not clear whether the new links stemming from re-grouping are strictly equivalent to links resulting from bottom-up processes. Does re-grouping produce the same kind of output, with similar effects on the organization of visual information?
Cost of across-hemifield presentation

To compare the impact of grouping and re-grouping, we took advantage of the fact that visual information about two elements can be processed initially in the same cerebral hemisphere or in different cerebral hemispheres, depending on where the elements are located within the visual field. Visual signals from different visual hemispheres are initially processed by the correspondingly different hemispheres, whereas those coming from the same hemisphere are processed within the same hemisphere. In the first case, information from the two hemispheres must be integrated into a single, unified visual scene. The binding of visual elements across hemispheres is mediated mainly by the corpus callosum (Engel, Konig, Kreiter, & Singer, 1991; Nowak, Munk, Nelson, James, & Bullier, 1995). Detection tasks (Clarke & Zaidel, 1989; Hendrich, Hutsler, & Gazzaniga, 2004; Weber et al., 2005) and electroencephalographic recordings (Andressi, Okamura, & Stern, 1975; Ledlow, Swanson, & Kinsbourne, 1978; Westerhausen et al., 2006) have been used to estimate the interhemispheric transfer duration, which is relatively low (3–30 ms depending on the experimental conditions). Our aim here was not to study the cost of across-hemifield presentation per se but to use the difficulties induced by this kind of presentation as a tool to compare the effect of automatic grouping and re-grouping.

To explore whether automatic grouping and re-grouping produce equivalent end products, participants were tested with a variant of the RDT (Beck & Palmer, 2002; Palmer & Beck, 2007), where figures were placed in circular array around a central fixation point. Observers were first required to find two adjacent target figures, regardless of whether they were in the same hemi-field or separate hemifields (Figure 1). Eye movements were continuously recorded to ensure that participants’ fixation on the central point was constant. Observers were significantly slower when targets appeared in separate hemifields (Experiment 1), an initial finding that was replicated in subsequent experiments.

We then systematically manipulated a grouping factor, i.e., connectors (Experiments 3–5). That way, the target elements could be either grouped (connected target pair) or not (unconnected target pair) by a connector independently of their location in the visual field. We also tested the modulation of grouping, by biasing object-based attention toward connected or unconnected targets (i.e., by manipulating the proportion of connected and unconnected targets). Biasing attention toward unconnected pairs, in particular, should facilitate access to unconnected pairs and was expected to promote re-grouping of the figures composing these pairs. This experimental condition was, therefore, critical for providing an answer to our main question about the end products of re-grouping vs. automatic grouping. If the end products of grouping and re-grouping are the same, they should be in conflict with each other in our experiment, and one should not be accessed without the other being inhibited. This means that an advantage for unconnected targets should be associated with a symmetrical disadvantage for connected targets and vice versa. In addition, if the links or representations resulting from re-grouping are the same as those resulting from true connectors, then the effect of re-grouping on the cost of presentation in different hemifields should be the same as for automatic grouping. By contrast, asymmetrical effects of grouping and re-grouping on search speed and on the effect of across-hemifield presentation would suggest that grouping and re-grouping differ in terms of not only their mechanisms but also their end products.

The first step in this study was to evidence a sizeable effect of across-hemifield presentation. That is what Experiments 1 and 2 set out to achieve.

Experiment 1: Constrained viewing

Experiment 1 was designed to check that observers experience more difficulty comparing information across hemifields than within the same hemi-field. Contrary to previous studies in which short stimulus exposure durations were used to avoid ocular saccades (no longer than 200 ms; e.g., Ledlow et al., 1978; Weber et al., 2005; Westerhausen et al., 2006), in this experiment, stimuli remained on the screen until participants responded. Continuous eye tracking ensured that participants focused on the central fixation point throughout the trials.

Subjects

Twenty-four students from Strasbourg University took part in this experiment. They were naive to the precise goal of the experiment: They were not informed about the within- vs. across-hemifield presentation manipulation. Participants with a history of neurological disorder, generalized anesthesia within the past 3 months, or drug
abuse were excluded from the study. All participants had a normal or corrected-to-normal visual acuity.

Stimuli

Each display contained 6 figures (0.7° × 0.7° of visual angle each). Figures were circles and squares located around a central fixation point and equidistant from each other (Figure 1). They were positioned along a virtual circle (diameter = 4.5°) that was centered on the central fixation point. Circles and squares were presented in spatial alternation except for two figures, the target pair (i.e., two contiguous figures that were identical, either two squares or two circles) and a single diamond. Unlike the circles and squares, the diamond was always in the same location on the horizontal meridian during a block of trials, either in the right or the left hemifield. This display configuration, and especially the diamond, ensured that (1) only two adjacent figures were identical and (2) the target pair was located in equal proportion in the across-hemifield and within-hemifield conditions. There were two possible target locations for the across-hemifield location and two possible target locations for the within-hemifield location, one above and one below the fixation point.

Equipment

The experiment was run on a Pentium 4 PC equipped with a Cambridge Research System (CRS; Rochester, Kent, United Kingdom) visual stimulus generator (ViSaGe) and programmed in MATLAB 7.0.1 (Mathworks, 1984–2004) combined with the CRS Toolbox. Stimuli were displayed on a Mitsubishi monitor (120-Hz refresh rate) placed at a fixed distance of 114 cm from observers. Eye position coordinates were monitored by a CRS Video Eye Tracker, mounted on a rigid headrest. The eye tracker output was recorded through the analogical-to-digital converter input of the ViSaGe, which also controlled the visual display timing.

Procedure

The task required participants to decide whether the display contained two adjacent squares or two adjacent circles. Participants were shown the 4 possible locations of the target pair before the beginning of each block. The use of a continuous eye tracker recording involved an eye calibration before each block of trials. Each trial began with the presentation of a central fixation point. Once the subject had fixated this area for 250 ms, the 6 figures appeared around this fixation point. The display stayed on as long as the participant kept gazing at the central point area and until he/she responded. The participant pressed a left response key if two adjacent squares were present and a right response key if two adjacent circles were present. The next trial began 1000 ms after the participant’s response. The fixation area was defined by a central virtual square with 1° long sides. This size ensured that stimuli on either side were processed in different hemispheres without this constraint being too demanding for the subject. Indeed, in case of an ocular saccade out of the fixation point area, the trial was terminated, a message was displayed warning the observer to fixate the central fixation point, and the trial was presented again at the end of the block.

Twelve participants were tested with the within-hemifield targets in the right hemifield (and the diamond in the left hemifield) and twelve participants with the within-hemifield targets located in the left hemifield (and the diamond in the right hemifield). That way, the targets’ locations were equally represented across hemifield (up and down) and within hemifield (up and down). The participants were informed about the location of the diamond to minimize errors (e.g., erroneous identification). There was an equal number of trials with circles and squares as targets. Participants were first trained with 30 practice trials, after which the 40 test trials were administered in random order.

Data analysis

Median RTs were derived from individual performance. Analyses of Variance (ANOVAs) were conducted on RTs and on error rates, with the location of the target pair (across hemifield vs. within hemifield) as a within-subject factor. We further took into account the fact that the target pair could be located above or under fixation to check the possibility that this would not impact on the manipulation of the targets’ location within or across hemifields. The overall error rate was 5.4%. There was no speed–accuracy trade-off. If any, errors showed the same effects as RTs, but no effect was significant (Fs < 1). There was no difference according to the hemifield of presentation (Fs < 1), and data were pooled over the diamond’s location.

Results and discussion

Participants were 96 ms faster to find the target pair in the within-hemifield (mean RT = 736 ms) than in the across-hemifield location (mean RT = 832 ms; F(1, 23) = 26.1; p < 0.001). In addition, they were 58 ms faster to find the target pair located above (mean RT = 755 ms) relative to under the fixation point (mean RT = 813 ms; F(1, 23) = 7.1; p < 0.05). There was no interaction between the across/within hemifield and the above/under locations of the target pair (F < 1). Hence, an important cost was associated with the across-hemifield location of
the targets, independently of the above vs. under location of the targets in the visual field. However, the within- and the across-hemifield conditions differ on several parameters. It might be argued that the cost associated with the across-hemifield location is due to other differences than the across-hemifield presentation. We checked this possibility in Experiment 2, by rotating the whole stimulus by 90°.

**Experiment 2: Rotated display**

Experiment 2 was based on the same design as Experiment 1, except that each display used in Experiment 1 was rotated 90° clockwise. That way, all target pairs were now presented within hemifield. If the cost observed for the across-hemifield presentation in Experiment 1 was due to inhibition of across-hemifield pairs due to the proximity of the diamond, a cost should persist for target pairs close to the diamond. If, in contrast, this cost is due to the across-hemifield presentation, it should disappear.

**Methods**

Sixteen students from Strasbourg University took part in this experiment. Displays were rotated 90° relative to the ones used in Experiment 1. Consequently, in one experimental block, the displays had the diamond at the top, whereas in a second experimental block, the diamond was at the bottom. The procedure was otherwise the same as in Experiment 1. All subjects ran the two experimental blocks in random order. There were 40 randomized trials per block, preceded by at least 30 practice trials.

The data analyses were conducted the same way as in Experiment 1. The location of the target pair (close vs. far from the diamond) was the within-subject factor. There was no difference according to the position of the diamond (Fs < 1) and data were pooled over the diamond’s location. The overall error rate was 4.4%. There was no speed–accuracy trade-off. Errors showed the same effect as RTs but without reaching significance (Fs < 2.1).

**Results and discussion**

RTs were similar for target pairs when close compared to far from the diamond’s location (674 ms vs. 681 ms, respectively, F < 1). This indicates that in Experiment 1, the cost associated with the across-hemifield presentation of the targets was not due to an inhibition of the diamond location but to the manipulation of the within-hemifield vs. across-hemifield location. We thus have a tool to explore our main question, i.e., the comparison of the outputs of automatic grouping and re-grouping.

In the following experiments, the stimulus was again displayed in the center of the screen and we tested whether grouping via automatic mechanisms or re-grouping affects the cost of across-hemifield presentation in the same or in different ways.

**Experiment 3: Grouping by connectedness and object-based attention**

In Experiment 3, by manipulating element connectedness (Palmer & Rock, 1994), we verified whether the cost associated with the across-hemifield location would be lessened by grouping or re-grouping. Stimuli were identical to those used in Experiment 1, except that 3 solid connectors linked figures by pairs (Figure 2). That way, the target pair could be linked by a connector (connected target pair) or not (unconnected target pair) and could be located across both hemifields (across-hemifield location) or within the same hemifield (within-hemifield location). Within each display, there was an equal probability of finding a target pair either between hemifields or within the same hemifield.

Our question principally concerns the type of links produced when selecting unconnected targets. Re-grouping is expected when the subject is seeking unconnected figures, and this should occur especially when unconnected pairs are prioritized. To induce prioritization, we manipulated the proportion of connected and unconnected target pairs in three different experimental blocks, like Beck and Palmer (2002), then checked whether the prioritization of unconnected pairs was efficient enough to induce a significant and selective improvement of performance for unconnected targets. If “re-grouping” yields similar links as automatic grouping, the two types of grouping should compete with each other, and an improvement for unconnected targets should result in a symmetrical cost for connected targets. In addition, the prioritization of unconnected targets should offset the cost of across-hemifield presentation like connectors. On the contrary, efficient prioritization without a symmetrical cost for automatic grouping and without an effect on the cost of across-hemifield presentation would argue against similar end products for grouping and re-grouping.

**Methods**

Eighteen students from Strasbourg University took part in this experiment. None of them had participated in Experiment 1 or 2 and, more generally, in any experimental psychology testing. This is important because such experiences might affect the amplitude of a grouping
 modulation. Indeed, Beck and Palmer (2002) showed that the amplitude of this effect was reduced by training. The present participants were naive to the purpose of the experiment. Exclusion criteria were the same as in Experiment 1. Stimuli were identical to those in Experiment 1, except that 3 connectors linked the figures in pairs (length = 1.5°; Figure 2).

The procedure was the same as in Experiment 1, except that participants were subjected to 3 blocks of trials that differed according to the proportion of connected and unconnected targets: a block with a bias toward unconnected pairs (75% of unconnected + 25% of connected targets), a reference block (50% of unconnected + 50% of connected targets), and a block with a bias toward connected pairs (25% of unconnected + 75% of connected targets). Participants were not told about this probability manipulation. We tested the effects of probability knowledge in a preliminary experiment in two different groups of subjects. The design of the experiment was similar, with connectors relating shapes, although the shapes were arranged in a horizontal array like in the original paradigm by Beck and Palmer (2002). One group of subjects was told about the probability manipulation, and one group was not. As a rule, participants are not able to report the manipulation after the experiments when not informed. We found no effect of group ($F_{1} < 1$).

The order of the experimental blocks was randomized across subjects. Nine participants were tested on within-hemifield conditions in the right hemifield (with the diamond located in the left hemifield) and nine participants on within-hemifield conditions in the left hemifield (with the diamond located in the right hemifield). Note that the results were identical and as clearly significant if we included only twelve subjects in order to achieve perfect randomization. We increased the number of subjects to increase statistical power and test for the effect of probability on the across-hemifield cost. There were 192 trials per block in random order, preceded by at least 30 practice trials.

**Results and discussion**

The data analyses were conducted in the same way as in Experiment 1, except that the ANOVA was performed on a three-way within-subjects design: location of the target...
pair (across hemifield vs. within hemifield), the type of target pair (connected vs. unconnected), and probability of connected vs. unconnected targets (block with a bias toward unconnected pairs vs. reference block vs. block with a bias toward connected pairs). There was an advantage for the above/below location like in Experiment 1 (965 ms vs. 1026 ms, respectively; $F(1, 17) = 11.6; p < 0.01$), but this factor did not significantly interact with any other variable. There was no difference according to the hemifield of presentation ($F$s $< 1$). Data were consequently pooled over the above/below location and diamond’s location.

The results are plotted in Figure 3. Although the graph might suggest a 3-way interaction, with the cost of across-hemifield presentation decreasing across block in the case of connected targets but not in the case of unconnected targets, this interaction did not reach significance ($F < 1$).

The across-hemifield cost varied according to the type of target pair, i.e., connected vs. unconnected (target type $\times$ location interaction; $F(1, 17) = 33.7; p < 0.001$). For unconnected targets, participants were slowed by 202 ms in the across- compared to the within-hemifield location ($F(1, 17) = 29.9; p < 0.001$). For connected targets, there was rather an advantage for across-hemifield vs. within-hemifield presentation (85 ms). However, the effect did not reach significance ($F(1, 17) = 4.3; p = 0.06$).

Successful prioritization of either connected or unconnected pairs leads to a variation of the grouping by connectors’ advantage across blocks (Beck & Palmer, 2002). Such a variation was indeed observed, as suggested by a target type (connected vs. unconnected) $\times$ block (bias toward unconnected pairs vs. reference vs. bias toward connected pairs) interaction ($F(2, 34) = 32.2; p < 0.001$). Focusing on unconnected targets is estimated by the performance improvement for unconnected targets from the reference block to the block with a bias toward unconnected targets. In this case, participants became faster by 123 ms for unconnected targets ($F(1, 17) = 6.1; p < 0.05$). This result suggests participants “re-group” unconnected targets. This is further supported by the results showing an advantage for unconnected relative to connected targets when targets are presented within the same hemifield in the block with a bias toward unconnected pairs (196 ms, $F(1, 17) = 23.4; p < 0.001$). This improvement occurred independently from performance modulations for connected targets. Performance for connected targets was stable from the reference block to the block with a bias toward unconnected pairs (RTs increased not significantly by 30 ms, $F < 1$). This indicates that performance for connected targets is stable when performance improves for unconnected targets. Performance modulation across these two blocks (reference vs. bias toward unconnected pairs) differed significantly for connected vs. unconnected targets, $F(1, 17) = 47.3, p < 0.001$. This shows that the improvement for unconnected targets is selective and does not induce a symmetrical cost for connected targets.

Figure 3 shows the performance for connected and unconnected targets across locations and blocks. Despite the effects of probability manipulation on performance for unconnected targets, this did not affect significantly the across-hemifield cost. In the case of unconnected targets, the across-hemifield cost remained substantial across blocks (block with a bias toward unconnected pairs: 163 ms, $F(1, 17) = 19.4; p < 0.001$; reference block: 205 ms, $F(1, 17) = 24.6; p < 0.001$; block with a bias toward connected pairs: 237 ms, $F(1, 17) = 19.8; p < 0.001$). There was no block $\times$ location interaction for unconnected targets ($F(2, 34) = 1.5; ns$). In the case of connected targets, there was no across-hemifield cost, but there was a significant block $\times$ location interaction ($F(2, 34) = 3.6; p < 0.05$; this was not enough to yield a 3rd level interaction between the block, the location, and the target type, $F < 1$). The interaction can be attributed to the fact that performance improved significantly for the within-hemifield location from the block with a bias toward unconnected targets to the block with a bias toward connected targets ($F(1, 17) = 6.2; p < 0.05$). This contrasted with stable performance in the across-hemifield location ($F < 1$; Figure 3).
The overall error rate was 5.2%. The ANOVA performed on error rates revealed a target type by location interaction ($F(1, 17) = 15.6; p < 0.01$). For unconnected targets, participants made more errors in the across-compared to the within-hemifield location (7.1% vs. 3.5%; $F(1, 17) = 4.6; p < 0.05$). There was no such difference for connected targets ($F < 1$). No other effect was significant. Thus, the interaction effect between target type and location went in the same direction for both error rates and RTs.

Experiment 3 shows that the across-hemifield cost can be abolished when the target figures are linked by a connector across hemifields. This echoes results obtained in neglect patients, in whom a partial recovery of visual extinction is observed when figures are associated by a grouping factor across the midline (Boutsen & Humphreys, 2000; Brooks et al., 2005; Driver, 1995; Gilchrist et al., 1996; Pavlovskaya et al., 1997). In addition, successful attentional prioritization toward unconnected and connected pairs was observed, replicating previous findings (Beck & Palmer, 2002; Giersch & Rhein, 2008). Most importantly, the results suggested that attention prioritization enables the re-grouping of figures in unconnected pairs. First, performance improvement for unconnected pairs was observed independently of performance variations for connected pairs, and second, this performance improvement yielded a significant advantage for unconnected as compared to connected pairs, when targets were displayed within the same hemifield. Despite this, the size of the across-hemifield cost for unconnected targets was very high (217 ms) and was higher than in Experiment 1 (no grouping factor: 96 ms). In addition, the cost remained elevated across blocks, indicating that attention prioritization does not affect this cost. All in all, attention prioritization enabled the re-grouping of figures in unconnected pairs but was without effect on the cost of across-hemifield presentation. These results suggest that re-grouping does not reduce the cost of across-hemifield presentation like automatic grouping does. However, alternative possibilities must be considered first.

It might be questioned whether putting connectors across hemifields somehow attracted attention toward connected pairs in the center, i.e., in the across-hemifield location, at the expense of unconnected pairs. This possibility was explored in the following experiment, by manipulating the connectors’ form to facilitate the grouping of unconnected figures. If the mere presence of connectors biases attention toward connected pairs in the center (i.e., in the across-hemifield location) and explains the results observed in Experiment 3, then these results should remain unchanged. If, in contrast, it is the grouping conveyed by the connectors that underlies these effects, then the across-hemifield cost should decrease even in the absence of connecters, when the experimental manipulation enables the automatic grouping of unconnected figures.

**Experiment 4: Manipulation of connectors**

The aim of Experiment 4 was to check whether it was possible to reduce the cost of across-hemifield presentation even in the absence of connectors. We manipulated the form of connectors to enable mechanisms that are known to elicit automatic grouping, i.e., the parallelism of line segments. This was done by breaking down connectors into two or three parts of different orientations. This way, the orientation of the line ends of adjacent connectors varied, and in one case, it was parallel. The alignment of line ends has been suggested to facilitate the integration of information even in the presence of only few contour elements (Giersch, 1999; Giersch, Boucart, & Danion, 1997; Giersch & Caparos, 2005; Giersch & Fahle, 2002; Lesher & Mingolla, 1993; von der Heydt & Peterhans, 1989). This manipulation was thus expected to enable the grouping of unconnected figures, i.e., in the absence of a direct connecting link. A general effect on grouping should result in varying RTs according to the form of the connectors. In addition, a more specific effect on the grouping of unconnected figures was expected to impact also on the cost of across-hemifield presentation observed in case of unconnected targets.

**Methods**

Eighteen new students from Strasbourg University took part in this experiment. Many had already taken part in at least one experimental psychology study but were naive to the precise goal of the experiment. Exclusion criteria were the same as in Experiment 1.

The form of the connectors was manipulated in order to vary the parallelism of the line segments attached to unconnected but adjacent figures. In order to manipulate the relative angle of adjacent connectors, each connector was broken down into two or three parts of different orientation, leading to three types of figures, with an angle of 0° between adjacent connectors (i.e., parallel), 60°, or 120° (see Figure 4). It might be noted that this manipulation may also affect the strength of the grouping induced by the connector itself. Several parameters may intervene here, like the relatability of the line segments composing the connector, depending on the angles between the line segments (Kellman & Shipley, 1991), or the number of elements. These effects are expected to lead to varying levels of advantages for connected relative to unconnected conditions. In addition, automatic grouping of unconnected figures is expected to reduce the cost of across-hemifield presentation.

Here again, object-based attention was manipulated by means of 3 blocks of trials: a block with a bias toward
unconnected pairs, a reference block, and a block with a bias toward connected pairs. Nine participants were tested for the right hemifield (within-hemifield targets located in the right hemifield) and nine participants for the left hemifield (within-hemifield targets located in the left hemifield). Each block order was used three times, once with the diamond on one side and twice with the diamond on the other side. Like in Experiment 3, the results were identical and as clearly significant if we included only twelve subjects in order to achieve perfect randomization, but here again, we increased the number of subjects to increase statistical power and test for the effect of prioritization on the cost of across-hemifield presentation. There were 144 trials per block, preceded by at least 30 practice trials. The procedure was otherwise identical to the one described in Experiment 3.

The data analysis was conducted the same way as in Experiment 1, except that the ANOVA was performed with the location of the target pair (across hemifield vs. within hemifield), the type of target pair (connected vs. unconnected), the type of connector (0° vs. 60° vs. 120°), and the block (with a bias toward unconnected pairs vs. reference vs. with a bias toward connected pairs) as within-subjects factors. There was no significant effect of the above/under location of the target pair (Fs < 1.2). The overall error rate was 4.8%. There was no speed-accuracy trade-off. If any, the effects on errors were similar to those observed on RTs, but none was significant (Fs < 2.7).

Results and discussion

Like in Experiment 3, the across-hemifield cost varied according to the target type, connected vs. unconnected (target type × location interaction, F(1, 17) = 10.8; p < 0.005). For unconnected targets, participants were 115 ms slower in the across- compared to the within-hemifield location (F(1, 17) = 30.2; p < 0.001). This slowing down was only of 46 ms for connected targets (F(1, 17) = 7.2; p < 0.05).

The target type (connected vs. unconnected) × connector type (120° vs. 60° vs. 0°) interaction reached significance (F(2, 34) = 13.9; p < 0.001). Performance for connected targets remained unchanged, whatever the angle between adjacent connectors (120°: 808 ms; 60°: 822 ms; 0°: 810 ms; F < 1). In contrast, performance for unconnected targets varied as a function of the connector type. RTs for unconnected targets were faster when adjacent connectors were parallel than when the angle between adjacent connectors was of 60° (advantage of 39 ms; F(1, 17) = 8.7; p < 0.01) and better when the angle was of 60° than when it was of 120° (advantage of 70 ms; F(1, 17) = 16.3; p < 0.001). Consequently, the advantage for connected over unconnected targets decreased as the angle between adjacent connectors approached parallelism (advantage of 118 ms for an angle of 120° between adjacent connectors, F(1,17) = 47.3; p < 0.001; 34 ms for an angle of 60°, F(1, 17) = 3.6; p = 0.07; 7 ms when adjacent connectors were parallel, F < 1). Hence, the connectors’ manipulation led to the expected changes regarding the grouping of unconnected targets.

A target type (connected vs. unconnected) × location (intra- vs. across hemifields) × connector type (120° vs. 60° vs. 0°) interaction was observed (F(2, 34) = 6.5; p < 0.005; Figure 5). For angles of 120° between adjacent connectors, the amplitude of the across-hemifield cost was larger for unconnected targets (cost of 129 ms, F(1, 17) = 18.6; p < 0.001) than for connected ones (cost of 59 ms; F(1, 17) = 10.3; p < 0.005), and the target type × location interaction reached significance (F(1, 17) = 8.1; p < 0.05). Performance was similar in case of angles of 60° between adjacent connectors, with an across-hemifield cost of 173 ms for unconnected targets (F(1, 17) = 32.5; p < 0.001) and of 30 ms for connected ones (F(1, 17) = 1.9;
The costs for connected and for unconnected targets differed significantly \((F(1, 17) = 13.4; p < 0.005)\).

However, when adjacent connectors were parallel, this cost was of 43 ms for unconnected targets \((F(1, 17) = 2; ns)\) and of 50 ms for connected ones \((F(1, 17) = 6.5; p < 0.05)\). This time, the costs for connected and for unconnected trials did not differ significantly \((F < 1)\).

As a consequence, the across-hemifield cost varied according to the connector type for unconnected targets \((129 ms vs. 173 ms, F(2, 34) = 6.3; p < 0.005)\) but not for connected targets \((59 ms vs. 30 ms vs. 50 ms, F(2, 34) = 1.4; ns)\).

A target type (connected vs. unconnected) × block (with a bias toward unconnected pairs vs. reference vs. with a bias toward connected pairs) interaction was observed \((F(2, 34) = 18.1; p < 0.001)\), indicating that prioritization was efficient. Performance for connected targets improved by 28 ms between the block inciting to prioritize unconnected pairs and the one inciting to prioritize connected pairs \((F < 1)\). For unconnected targets, performance varied by 100 ms across blocks \((F(1, 17) = 7.3; p < 0.05)\).

Figure 6 shows the performance for connected and unconnected targets across locations and blocks, averaged over connector types. The across-hemifield cost for unconnected targets remained substantial across blocks (block with a bias toward unconnected pairs: 144 ms, \(F(1, 17) = 40.7; p < 0.001\); reference block: 116 ms, \(F(1, 17) = 21.4; p < 0.001\); block with a bias toward connected pairs: 84 ms, \(F(1, 17) = 5.0; p < 0.05\), and no block × location (within vs. across hemifields) interaction was observed \((F(2, 34) = 1.3; ns)\). Regarding connected targets, this cost remained low across blocks (block with a bias toward unconnected pairs: 61 ms, \(F(1, 17) = 3.7; p = 0.07\); reference block: 55 ms, \(F(1, 17) = 6.7; p < 0.05\); block with a bias toward connected pairs: 23 ms, \(F(1, 17) = 1.4; ns)\), and no block × location interaction was observed \((F < 1)\).

Like in Experiment 3, connecting figures across hemifields reduced the cost of across-hemifield presentation. In addition, variations in the form of connectors altered grouping, by yielding decreasing RTs for unconnected targets with increasing parallelism between adjacent connectors. However, it was only when adjacent connectors were strictly parallel, i.e., when unconnected targets could be grouped through orthogonal completion, that the across-hemifield cost was reduced. This shows, first, that the cost for across-hemifield presentation can be reduced even in the absence of connectors. This suggests that the results observed in Experiment 3 are not mediated by an attention bias toward the connectors in the center (across hemifields) but rather by the grouping induced by these connectors. Second, it suggests that it is only when unconnected targets can be grouped automatically, as opposed to re-grouped through attention that the cost for unconnected targets across hemifields is reduced. Finally, like in Experiment 3, attention prioritization toward unconnected pairs was efficient in improving performance for unconnected targets selectively. Despite this, the across-hemifield cost remained constant across blocks, suggesting again that re-grouping does not yield the same end product as automatic grouping. In Experiment 5, we checked whether focalizing attention on the midline would be more efficient than attention centered on unconnected pairs to reduce the cost of the across-hemifield presentation.

**Experiment 5: Manipulation of spatial attention**

Experiments 1 and 3–4 showed that comparing information located between hemifields induces a time processing cost compared to when they are displayed within a hemifield. This cost was reduced by linking information across hemifields, either with connectors (Experiments 3 and 4) or by eliciting grouping through aligned line ends (Experiment 4). In contrast, manipulations intended to draw attention to unconnected pairs were unsuccessful in reducing the cost of across-hemifield comparisons. The importance of this cost contrasts with the apparent ease with which information is processed across hemifields in everyday life. Here, we used spatial prioritization and, more specifically, attention oriented toward the midline. We were mainly interested to find out whether this manipulation would reduce the across-hemifield cost for
unconnected elements and whether this reduction would be enough to catch up for the performance difference with connected elements.

Methods

Twelve new students from the Strasbourg University took part in this experiment. They were naive to the precise goal of the experiment. Exclusion criteria were the same as in Experiment 1. We used the same stimuli as the ones displayed in Experiment 3, because it was those where the cost for unconnected pairs in the across-hemifield location was greatest (Figures 2 and 3). We used only the reference condition, with 50% connected trials and 50% unconnected trials in all blocks. To bias attention toward the midline region, the target pair was located in the across-hemifield location in 75% of the trials and in the within-hemifield location in 25% of the trials. Participants were not told about this probability manipulation.

Each subject was tested both for the right hemifield (within-hemifield targets located in the right hemifield) and the left hemifield (within-hemifield targets located in the left hemifield) in separate blocks of trials, and the order of the blocks was counterbalanced across participants. There were 160 trials per block, preceded by at least 30 practice trials. The procedure was otherwise identical to the one described in Experiment 1.

The data analysis was conducted in the same manner as in Experiment 1, except that the ANOVA was performed with the location of the target pair (across hemifield vs. within hemifield) and the type of target pair (connected vs. unconnected) as within-participants factors. The overall error rate was 1.5%. There was no speed–accuracy trade-off. If any, effects on errors showed the same trends as RTs, but no effect was significant (Fs < 2.9). There was no significant difference according to the hemifield of presentation (Fs < 1) or the above/under location of the targets (Fs < 3.7), and data were pooled over these two conditions.

Results and discussion

The location effect (within vs. across hemifields) varied according to the target type (connected vs. unconnected): location × target type interaction, F(1, 11) = 6.2; p < 0.05; Figure 7). There was an advantage of 78 ms for unconnected targets located across hemifields compared to within the same hemifield, which only tended toward significance (F(1, 11) = 3.9; p = 0.07). This advantage reached 214 ms in the case of connected targets (F(1, 11) = 23.6; p < 0.001). Accordingly in the across-hemifield location, there was an advantage of 115 ms for connected over unconnected targets (F(1, 11) = 8.8; p < 0.05). In contrast, performance in the within-hemifield location did not differ significantly according to the target type (difference of 20 ms, F < 1).

Biasing attention toward the across-hemifield location was successful in erasing the global cost associated with this position, even in the case of unconnected targets. However, this effect was much larger for connected than for unconnected targets. Given the strength of spatial prioritization, it is remarkable that in case of unconnected targets, the advantage for across-hemifield targets does not reach significance. This contrasts with the effects of the connector form manipulation in Experiment 4. In Experiment 4, the possibility to group unconnected figures in the case of stimuli with an angle of 0° between adjacent connectors led to an equalization of performance between connected and unconnected trials. This was not the case here. Regarding connected targets, the results indicate that spatial prioritization increased the benefit of linking elements across the midline, showing that stable performance for connected targets across and within hemifields in Experiments 3 and 4 was not due to a floor effect.

General discussion

Throughout the experiments, observers consistently experienced difficulties when searching for a pair of identical figures located across hemifields when they were not automatically bound together (Table 1).

The role of the presentation across hemifields was supported by the results in Experiment 2, which showed that observers experienced less difficulties when the whole stimulus was rotated 90°. On the other hand, connecting targets across hemifields reduced the cost associated with the across-hemifield location (Experiments 3 and 4, connected trials). In Experiment 4, the cost observed for unconnected figures was also reduced due to the manipulation of
Cost of the across-hemifield presentation (in ms):

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Connected targets</th>
<th>Unconnected targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias toward</td>
<td>Bias toward</td>
</tr>
<tr>
<td></td>
<td>unconnected pairs</td>
<td>connected pairs</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$-128 \pm 49$</td>
<td>$-93 \pm 45$</td>
</tr>
<tr>
<td>4</td>
<td>$61 \pm 32$</td>
<td>$55 \pm 21$</td>
</tr>
<tr>
<td>5</td>
<td>$-213 \pm 44$</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Mean cost ± SEM of the across-hemifield presentation across experiments.

grouping cues to enable the automatic binding of unconnected figures. Unlike the manipulation of grouping factors, manipulations enabling re-grouping did not affect the across-hemifield cost (Experiments 3 and 4). Prioritization of unconnected pairs improved performance for unconnected targets selectively, i.e., independent of performance changes for connected targets, but despite this, the cost of across-hemifield presentation remained constant. Lastly, attention directed toward the vertical meridian again reduced the across-hemifield cost for unconnected targets, although not sufficiently to improve performance as much as for connected targets (Experiment 5). All in all, it seems that grouping and re-grouping had no same impact on the cost of across-hemifield presentation. However, the discussion looks first at the across-hemifield cost itself, which was unusually high.

Cost of across-hemifield presentation

In the across-hemifield location, figures were far enough away from each other to ensure that they were initially processed within different cerebral hemispheres. The rationale behind this arrangement was that information had to be exchanged between hemispheres so that a comparison and a decision could be made about whether or not the figures were identical. Time savings were expected when the target pair appeared within a given hemifield, since the comparison process takes place within the same hemisphere. Yet, even if behavioral estimates of interhemispheric transfer times found in the literature vary, they are still generally lower than the cost observed here with our across-hemifield locations (Clarke & Zaidel, 1989; Fendrich et al., 2004; Weber et al., 2005). The use of heterogeneous stimulus eccentricities in the literature may be one explanation for this difference (see Hopfman & Davidson, 1994 for a review). In addition, interhemispheric transfer time is usually estimated with detection paradigms involving less elaborate processing than the present shape discrimination task. Even earlier studies based on shape discrimination tasks, where the cost of interhemispheric transfer was close to 25 ms (Egeth & Epstein, 1972; Weissman & Banich, 2000), differ from our own on a number of points. First, there were usually fewer stimuli than in the present study, and the stimuli involved letters. Second, Experiment 5 shows that the cost of across-hemifield presentation can be reduced efficiently when spatial attention is directed toward the targets selectively. In contrast in Experiments 1–4, attention was divided between the different possible locations for the targets. This constraint may have increased the effect of across-hemifield presentation. Third, in earlier studies, the display presentation duration lasted no more than 200 ms, making it difficult for the subject to check the identity of the targets. Such checking procedures might have been involved in our paradigm, where stimuli remained on the screen until the subject responded. This would then imply repetitive transfer of information across hemispheres and slowing down. This explanation is supported by the results showing that the cost of across-hemifield presentation was particularly high for participants who had never been involved in experimental psychology investigations, in other words participants who could be expected to be more involved in checking processes in the across-hemifield location. This all suggests that our paradigm does not provide a pure estimation of interhemispheric transfer and that a number of factors may play a role in the amplitude of the cost we observed in the present results. However, whatever the explanation for the very high cost observed in the across-hemifield presentation, our paradigm provides a way of comparing the effects of automatic grouping and re-grouping.

Effect of grouping cues on the cost of across-hemifield presentation

When processing two figures displayed in the two hemifields, grouping figures via a connector reduced the
across-hemifield cost (Experiment 3). However, since we
contrasted connected and unconnected figures, with an
across-hemifield cost in the latter case only, there was an
alternative explanation for the advantage of connecting
targets across hemifields. It could have been argued that
subjects prioritized some regions of the stimulus at the
expense of the others. The advantage for the position
above the fixation point (Experiments 3 and 5) certainly
suggests that attention can be directed in priority in one or
another direction, depending on subjects’ strategies of
exploration. This precise spatial strategy globally affected
the speed of the responses but did not affect the impact of
the other variables. It was not observed in Experiment 4,
respectively the fact that the pattern of results in Experiment 4
was very similar to the pattern observed in Experiments 3
and 5 (at least when the angle between connectors was
of 60° or 120°). Thus, the advantage for the position
above the fixation point does not seem to account for
the results. However, yet another possibility was that
connectors themselves attracted attention on the midline.
Experiment 4 was especially important in this respect, in
that it allowed us to rule out this hypothesis. Facilitating
the linkage of unconnected figures showed that the cost of
across-hemifield presentation could be reduced, even
when figures were not physically linked (i.e., when
unconnected figures could be re-grouped through orthog-
onal completion).

Re-grouping unconnected targets

The fact that automatic grouping allowed for a
reduction in the across-hemifield cost meant that it was
possible to check whether grouping and re-grouping
produced the same type of links. To that end, we first
had to check whether unconnected targets could really be
re-grouped as a result of probability manipulations, even
though they initially belonged to different perceptual
groups. The relationship between the two elements of a
connected pair is obvious, insofar as they are physically
related in pairs by virtue of bottom-up cues. It is also quite
a strong relationship, as shown by the considerable
advantage connected pairs have over unconnected pairs.
Consequently, even the similarity of the shapes cannot
overcome this advantage in the case of unconnected
targets, such that re-grouping unconnected targets is still
incompatible with grouping by connectors. Despite this,
the present study showed efficient prioritization of uncon-
connected targets. Performance in respect of unconnected
targets was better when they were prioritized, i.e., when
they were in the majority rather than mixed in equal
proportion with connected targets. This improvement
occurred even though performance for connected targets
was stable (Experiments 3 and 4). In the case of within-
hemifield presentation (Experiment 3), this produced a
significant advantage for unconnected targets compared
with connected targets (which might be due to the fact that
participants were new to experimental psychology testing;
as already noted, Beck & Palmer, 2002 showed the effect
of probability manipulation diminished with training).
Subjects clearly sought and accessed unconnected targets
before connected targets. This involves some kind of re-
grouping. It would appear therefore that pairs of figures
can be mentally isolated even when their constitutive
elements are unconnected. This is consistent with results
observed previously with a similar task and independently
of a similarity effect (Giersch & Rhein, 2008). In short,
the results suggest that participants can efficiently re-
group unconnected figures when prompted to do so.

Comparing the impact of grouping
and re-grouping

Our main question was whether or not searching for
unconnected items would produce links between items
similar to those induced by automatic grouping. The fact
that subjects were faster in the case of unconnected targets
(Experiment 3) suggests that the re-grouping associated
with such prioritization had taken place. By the time of
the response, it influenced the search rate and thus could
be expected to also reduce the cost of across-hemifield
presentation. However, although prioritizing unconnected
pairs seemed to enable unconnected figures to be
successfully re-grouped, it failed to compensate for the
across-hemifield cost. This dissociation between success-
ful prioritization and an unwavering across-hemifield cost
was confirmed in subsequent experiments and persisted
even when the number of participants was increased from
12 to 18 in Experiments 3 and 4. In other words, subjects
were successfully biased toward pairs of unconnected
figures and established some kind of link between
unconnected figures, but the link was not enough to reduce
the across-hemifield cost. This contrasts with the link
relating figures in the case of connected targets, which
reduces the across-hemifield cost to nil. It would seem
therefore that the end product of automatic grouping and
re-grouping is not the same.

Even spatial attention was not enough to equalize
performance between connected and unconnected targets.
Spatial attention biased toward the across-hemifield loca-
tion helped improve performance with both connected and
unconnected targets. This may explain why we usually
have no difficulty processing information across hemi-
fields, i.e., by attending selectively to the space in the
midline. However, spatial attention is not supposed to
enable the re-grouping of between-group pairs, which
might explain why spatial attention benefited connected
targets far more than unconnected targets. It was striking
that despite the powerful effect of spatial attention, the
advantage created by this manipulation only approached
significance in the case of unconnected targets and was
significantly different to the advantage observed with connected targets. In contrast to Experiment 4, the effect of across-hemifield presentation for connected and unconnected targets was not equal, which suggests that automatic grouping of unconnected figures by means of orthogonal completion was more efficient than spatial attention at making up for the cost of presenting unconnected figures across hemifields.

All in all, a link such as occurs with automatic grouping was the only way of offsetting the cost of across-hemifield presentation. Neither spatial attention nor prioritization of unconnected pairs was as efficient. It suggests that the mechanisms involved in re-grouping separate figures do not include creating a link similar to the one that occurs with automatic grouping. This is not to say it is impossible in the case of unconnected elements to establish links similar to those occurring with grouping by connectors, but it does mean some of the links established via re-grouping, as in the present experiments, are not equivalent to the links established via automatic grouping processes.

So, what are the possible mechanisms underlying the differential impact of connected and unconnected pairs across hemifields? The transient and mental link created between elements of unconnected pairs does not appear to induce a direct link between neurons coding for the two objects of the pair or the building of a single representation including both objects. The link might thus rely on more indirect connections relating to attention pathways, although this would not explain how re-grouping ties in with automatic grouping. Another possibility is that mental re-grouping includes information about automatic grouping. For example, re-grouping two unconnected cherries would involve not only a link between the two unconnected cherries but also information about the fact that each cherry in the group is connected to another at the stalk. This would mean that it is possible to create mental links between separate elements while maintaining access to groups stemming from automatic grouping, even if mentally created links conflict with those stemming from automatic grouping. Such coding would mean that it is possible both to explore the visual environment in a flexible way and to maintain its stability (see Fulvio, Maloney, & Singh, 2009, for direct investigations regarding the influence of grouping on visual stability).

To conclude, new associations of unrelated elements can be formed and used independently of automatic grouping processes. However, mental re-grouping yields different outputs and hence representations, which might then coexist rather than compete with the output of automatic grouping to access consciousness. It remains to be seen whether re-grouping is more effective with training, and further experiments are also needed to investigate exactly how re-grouping is implemented in the brain and integrated with automatic grouping so that we can explore the world around us in a flexible manner while maintaining a sense of stability.

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