THE INTERACTION BETWEEN PERCEPTUAL GROUPING AND ATTENTION

by

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ABSTRACT

I investigated the interaction between perceptual grouping and attention, focusing specifically on distracter rejection. The novelty of the thesis lies in the study of different configural types and their effect on search across space and time. Grouping by configuration is likely to facilitate search by making distracter rejection easier. Grouping can be based on the regular locations of elements, the similarity of elements and whether the elements form a closed shape. The effects of grouping occurred under conditions in which the groups never contained the target, although detection was faster if the target fell internal to the group relative to when it fell outside the group. These results, together with those from neuropsychological studies reported here, are consistent with rapid suppression of irrelevant distractor groups. Primitive grouping, apparently based on clusters of similar proximal elements, took place even when attention was reduced in patients with chronic spatial biases in visual selection. However, neurological damage to attention-related brain regions did disrupt grouping effects dependent on element shape. Attention may, therefore, be more critical for some forms of grouping. Grouping interacts with attention to determine perceptual performance. This operates in a graded manner, determined by the type of grouping.

ACKNOWLEDGEMENTS

I first thank my supervisors, Glyn Humphreys and Harriet Allen, for their excellent guidance. These four years have been very enriching with your advice, comments and insights. You have let me carry out my ideas but have been very helpful in refining them. Thank you also for your patience, care and support throughout my Ph.D. Although I don't have a research job in hand to show, I'm completing my Ph.D with a greater interest in research than when I entered this course. I completely owe this to you.

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CHAPTER 1

INTRODUCTION

What is Attention?

The question of what comprises human attention is philosophical as much as psychological. Researchers have considered attention from different perspectives but there seems to be general agreement that attention is a process by which we 'select' the relevant information and 'ignore/inhibit' irrelevant information. However, disputes and arguments are plenty in the literature regarding how selection operates. This thesis is concerned with how selection in vision operates, and in particular how visual selection interacts with the process of visual perceptual organization, which determines how the 'perceptual units' for object recognition are formed. The literature related to this specific aspect of attention is reviewed here to build a context to the empirical work that will subsequently be presented.

Selective Attention

Early versus Late Selection

Perhaps the first modern theory of human selective attention was put forward by Broadbent (1958), who proposed his filter theory based on experiments in the auditory domain. A typical experiment involved a shadowing task in which stimuli were presented dichotically and participants had to repeat information coming from one of the ears. While participants were good at reporting stimuli from the attended channel with minimal omissions and errors, they were relatively poor at reporting the unattended stimuli, often only noting some of the perceptual characteristics of the input (e.g., whether it was a male or female speaker; see Cherry, 1953; Cherry and Taylor, 1954). Broadbent (1958) suggested that information from both the ears was processed to some extent to extract the basic features of both messages, but only the attended ear received further detailed processing. A filter, operating at a perceptual stage of analysis, allowed only the selected information to reach higher-level processing. In contrast, the late selection approach held that the capacity to process the incoming information is unlimited and processing occurs in parallel without any need for selection in the earlier stages (Deutsch and Deutsch, 1963). Peters (1954), using the same dichotic listening tasks, showed that when the content presented to both the ears was similar, input from the unattended channel interfered significantly with the perception and reporting of the message from the attended ear. Peters (1954) suggested that the content to both the ears was processed sufficiently to allow interference to happen. Similarly, Gray and Wedderburn (1960) also found support for late selection hypothesis. They presented syllables or words to both the ears in such a way that alternating syllable/word from each ear made a meaningful sequence. Participants reported the meaningful sequence instead of disjointed syllables or words indicating processing of the input from both the ears beyond basic attributes. Subsequent to this early work the locus of attentional selection (early, late or intermediate) has been debated and remains unresolved. The perceptual load theory of attention, proposed by Lavie and Tsal (1994), offered to resolve this debate and this is discussed in the next section.

Load theory

Lavie and Tsal (1994) argued that whether selection occurs early or late in the information processing stream depends on the perceptual load that participants encounter. High perceptual load meant that the number of items to be perceived was increased (e.g., a large set size) or for the same number of items the processing requirement was increased (e.g., reporting the meaning of the letters instead of reporting whether they were lower case or upper case). If there is a high perceptual load (e.g., with a large set size), then there will be early selection, to prevent the subsequent overload of cognitive processes. On the other hand, if there is a low perceptual load (e.g., just a few stimuli present), then limitations in perceptual processing may not be encountered and the stimuli may all be processed to a high level (i.e., there is late selection; see Figure 1.1). This was, in fact, the pattern of results Lavie and Tsal (1994) obtained (see also Lavie et al., 2003, Jiang and Chun, 2001). For example, there can be less interference from a distractor (due to early filtering of the distractor) when displays are cluttered. Lavie and DeFockert (2003) showed that the effect of perceptual load was not due to the mere general increase in task difficulty when displays are cluttered by manipulating sensory degradation – a manipulation that increased difficulty but did not reduce distractor interference (Lavie and DeFockert, 2003). In contrast to the effects of perceptual load, an increase in task difficulty (for example, an increase in the working memory load) produced greater interference from distractors – a result attributed to there then being fewer high-level cognitive resources to deal with the stimuli that survived perceptual filtering (Lavie, 2000; Lavie et al., 2004). These studies illustrate the importance of perceptual load and the level of processing achieved by stimuli in accounting for attentional limits on performance (though see Tsal and Benoni, 2010 for an alternative account).

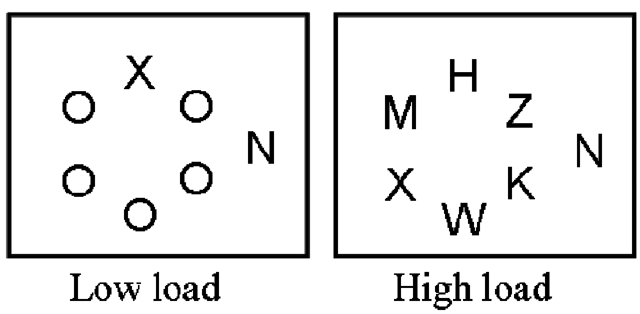

Figure 1.1: *Example stimuli used in a typical perceptual load experiment. X and N are both targets associated with different manual responses. Responses are typically slow in the low load condition (left segment) when an incompatible peripheral distractor is present (N) compared to when a compatible or a neutral distractors was present (e.g., X-X or X-P). This interference from an incompatible peripheral distractor is significantly reduced when there is high load (right segment). It may be noted that in the low load condition distractors group together to distinguish the target and the irrelevant distractor ('N'). However, this is not the case in the high load condition.*

What is 'selected'?

The data on the effects of perceptual load suggest that load may be modulated by whether or not distractors group together. Such data are relevant to a long-standing debate on whether attention selects space or discrete objects independent of the space they occupy. In terms of perceptual load, one might ask if it is determined by the spatial distances and positioning of stimuli, or rather is it determined by whether relevant and irrelevant stimuli form discrete objects. Evidence exists in support of both the space- and object-based views of visual selection. Earlier metaphors of visual attention as a "spotlight" (Posner, Snyder, and Davidson, 1980) or "zoom lens" (Eriksen and Yeh, 1985) essentially emphasized the spatial nature of selection. However, later research revealed that attentional selection could also be based on discrete objects. For example, there can be attentional selection of overlapping forms (Duncan, 1984) while the time to switch location from one stimulus to another is influenced by whether the locations fall within the same or across different objects (Egly, Driver and Rafal, 1994). Space-based accounts are discussed briefly before going on to describe the literature on object-based attention.

Space-based theories

Posner et al. (1980) reported cueing experiments in which the location of a target was cued (validly or invalidly on a proportion of trials). Participants were faster to respond to the target when its location was validly cued compared to when it was invalidly cued. This finding was taken to suggest that, on valid trials, the "spotlight" of attention fell at the cued location and the appearance of the target in the same location led to a fast response. Invalid trials required participants to move their "spotlight" from the invalidly cued location to the correct target location, and this slowed their response to the target. The notion of an attentional spotlight was also supported by Downing and Pinker (1985) who conducted a study in which they cued one of ten spatial locations along the horizontal midline. Reaction times (RTs) increased as the distance between the cued location and the actual target location increased. Later, Eriksen and St. James (1986) extended these results by showing that the size of the spotlight could be modulated by the task and suggested that attention works more like a zoom lens rather than a fixed spotlight. All of these studies supported the notion of spatial selection and also implied that there is only a single focus or spotlight of attention. Converging support for the idea of spatial selection comes from research on the neurological condition of "hemispatial neglect". Hemispatial neglect typically results from unilateral damage to the superior temporal and inferior parietal cortex (Chechlacz et al., 2010); more common after right hemisphere damage although cases of neglect after left parietal damage have also been recorded (Becker and Karnath, 2007). The most characteristic symptom of neglect is the failure to attend to the space contralateral to the lesion (e.g. neglect of the left side space after damage to the right hemisphere). However, other neglect symptoms cannot simply be explained in terms of a spatial deficit. Most notably, neglect has also been shown to exist in an object-centred framework (Driver and Halligan, 1991), and spatial and object-related aspects of neglect may even link back to distinct neuroanatomical substrates (Chechlacz et al., 2010).

Object-based approaches

Space-based theories offer an incomplete account of visual selection. They do not account for phenomena such as featural selection from overlapping stimuli (Duncan, 1984), object-based mediation of attentional cueing (Egly et al., 1994) or object-based neglect (missing the contralesional side of objects irrespective of their location within the field).

The work on object-based attention suggests that visual selection is determined by the perceptual organisation of visual elements. Perceptual organisation could serve to define/segregate objects for attention. Gestalt principles like similarity, proximity, collinearity, uniform connectedness and closure help to define perceptual groups, which are then treated as objects (Koffka, 1935). I discuss some of the relevant literature dealing with such grouping effects and their interaction with attention in normal observers. The first section reviews the evidence from visual search studies. The second section discusses evidence for this interaction from other research paradigms (Kimchi et al., 2007; Trick and Enns, 1997; Yeshurun et al., 2009).

Evidence from visual search

Treisman (1982) showed that serial attention in a difficult conjunction task (Figure 1.2 – middle segment) could operate on groups of items instead of individual elements. The distractors were grouped into clusters of homogeneous items (e.g., green Xs and red Ts grouped in different clusters) and the target appeared in one of these clusters. When the distractors were thus grouped, search for a conjunction target did not depend on the number of items but instead depended on the number of groups. However, this grouping manipulation did not influence feature search (where the target differed from distractors along a single feature; see Figure 1.2 – top segment). Triesman (1982) suggested that the groups were formed preattentively and hence participants were able to scan the groups instead of individual items. Since features are coded preattentively (Treisman and Gelade, 1980) a target defined by a separate feature was detected easily and did not require grouping to facilitate search. This was evidence for featural grouping using colour and shape.

Evidence also exists for grouping between conjunctive elements (Duncan and Humphreys, 1989; Donnelly, Humphreys and Riddoch, 1991; Humphreys, Quinlan and Riddoch, 1989). Duncan and Humphreys (1989) emphasised the importance of homogeneity of distractors in producing efficient search slopes. When the search elements and the target were defined by form conjunctions (e.g., L among rotated Ls), search was efficient if the distractors were all homogeneous compared to when the distractors were a mix of heterogeneous elements. They suggested that homogeneity among distractors strengthens grouping and facilitates search by spreading suppression. In essence the study showed the importance of grouping between distractors and how that could facilitate distractor rejection.

Humphreys et al. (1989) manipulated configural grouping in addition to homogeneity. The distractors (form conjunctions such as differently oriented Ts) were presented on an imaginary circle (termed 'regular') or irregularly in the field (so they did not form any familiar configurations). Although this manipulation did not influence the search slopes greatly, target absent responses were reliably faster with the regularly spaced displays compared to irregular displays when the elements were homogeneous. However, search was even less efficient when heterogeneous distractors were presented in these configurations. This study provides further support to grouping among the distractors facilitating search (Duncan and Humphreys, 1989). Humphreys et al. (1989) suggested that the 'fast absent' responses found in their study reflected display level rejection of the distractors when they were strongly grouped.

Donnelly et al. (1991) took these findings further by showing that even heterogeneous elements could produce efficient search when grouped into a single perceptual object. Oriented line stimuli were grouped by closure and good continuation into regular (a square or a hexagon formed by oriented lines) and irregular displays. The task was to report the presence / absence of a target. Search was efficient when the display was grouped by closure and good continuation than when these cues were absent. Donnelly et al. (1991) also found ‘fast absent’ responses in the grouped displays indicating faster distractor rejection of the grouped elements. The presence of closure alone did facilitate search but the effects were greater when good continuation was also present.

Related evidence was presented by Gilchrist et al. (Gilchrist, Humphreys, Riddoch and Neumann, 1997). They conducted several search experiments that showed that grouping based on brightness and/or collinearity facilitated search. Pairs of circles were oriented either vertically or horizontally (vertical pair was the target; Figure 1.5). Search was independent of the distractors when the distractor pairs (two circles) shared similar brightness (both light compared to the background) compared to when the circles carried opposite contrast polarities (e.g., a light and a dark circle). Contrast polarity, however, did not disrupt grouping when collinearity information was present (e.g., two squares). Gilchrist et al. (1997) suggested that their results support two different systems in grouping processes where brightness-based and edge-based information is processed separately (Grossberg and Mingolla, 1985). More important to the current context, the results showed that grouping could facilitate search by allowing distractor elements to be rejected together.

Evidence of distractor rejection also comes from studies using search over time (preview search; Watson and Humphreys, 1997). In preview search half the distractors appear first (‘preview’) prior to the onset of the target and the rest of the search display (see Figure 1.2 for an example). Typically search for a conjunction in this modified procedure is more efficient than when all the items appear simultaneously. This benefit compared to a standard conjunction search (called ‘full-set’ search) task was termed ‘preview benefit’. Watson and Humphreys (1997) proposed that the locations of the previewed items were marked (inhibited) and rejected as irrelevant when the second search display appeared. More direct evidence to the inhibition account came from probe dot studies (Watson and Humphreys, 2000). Participants had to perform a probe detection task on a proportion of trials in addition to the regular search task. In the full-set condition, probes appeared simultaneously with the search elements. In the preview, the probe dot was presented with the final the display where it appeared either on the 'previewed (old)' elements or on the new search elements. Probe detection was worse when they were presented on the old items compared to when they appeared on the new items. This difference, however, disappeared when probe detection was the only task showing that the participants prioritised new items only when it was beneficial to do so. These results indicated that old items were inhibited and also that this was top-down in nature as participants inhibited old items and prioritised new only when it was useful to do so.

Braithwaite et al. (2003) reported negative colour carry-over effects in preview. They presented two colours in the preview (red majority - 66% and green minority - 33%) and this proportion was flipped in the search display so that in the final display there was equal representation of each colour. According to previous findings search should have been easier when the target carried the minority colour in the second set (search biased to smaller of the two colour groups; Bacon and Egeth, 1997). Surprisingly, but in agreement with preview suppression, targets carrying the minority colour were harder to detect as the inhibition applied to the majority colour carried over to the search displays in the same colour. Braithwaite et al. (2003) suggested that the negative carry-over effects observed were due to group-based inhibition of the preview.

Particularly relevant to the context here is the work showing configural based suppression. Kunar et al. (2003b) studied the effect of configuration and location shift on the preview

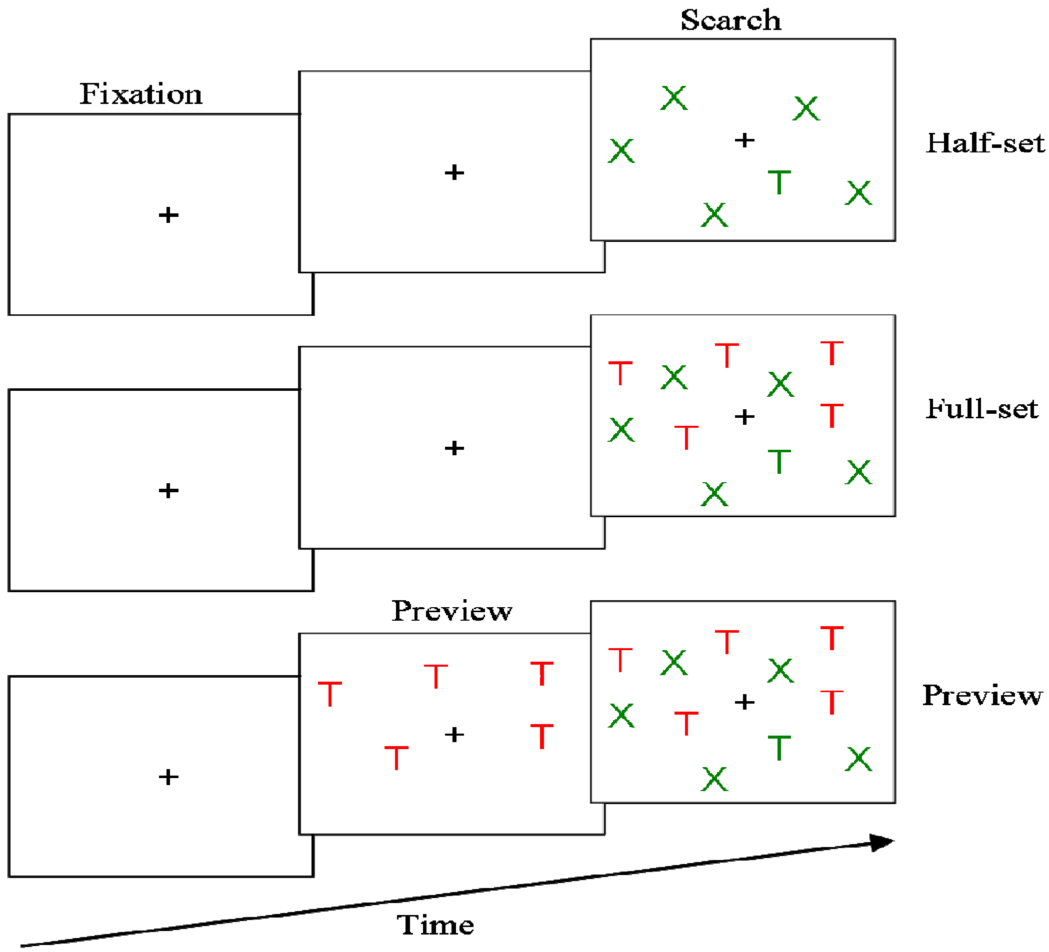

Figure 1.2: *Illustration of the different conditions used by Watson and Humphreys (1997) and subsequent preview studies. The top segment shows a trial from half-set condition which is similar to feature search. Search is typically easy and independent of the number of distractors as opposed to a standard conjunction search (middle segment) where all the items appear simultaneously. The final segment shows a preview trial where half the distractors are presented prior to the onset of rest of the search display with the target (when present). Search in this case is more similar to search in the half-set consistent with inhibition of the preview and prioritisation of the new items.*

benefit. In Kunar et al.'s study the previewed items changed their locations while maintaining or changing their relative positions (their 'configuration'). They found that disrupting the locations abolished the preview benefit only when the configuration was also disrupted. An overall shift in their positions while the configuration remained the same still gave rise to a preview benefit. This finding suggests that suppression could also be based on the entire configuration of the previewed items not just individual locations or features. Though the thesis broadly deals with the question of rejection of grouped distractors, the focus is on configural suppression (Chapters 2-5). Below I discuss how these grouped distractors might be represented.

Object files

Kahneman and Treisman (1984) introduced the concept of an object file to explain the integration of visual information across space and time (see also, Kahneman, Treisman and Gibbs, 1992). Object files draw together the content features of an object, and maintain this representation across its movement. If the changes across space and time are in accordance with our expectations, the existing object file is updated. In case of unexpected changes a new object file might be opened which requires the deployment of focussed attention. Kahneman et al. (1992) used a technique called the reviewing paradigm. A typical trial would involve presenting two objects (shapes) each containing a letter in it (preview). During the linking display, the letters disappeared and the shapes moved to different places. Finally, one of the previous letters appeared in one of the shapes (same-object when it appeared in its previous shape and different-object when it appeared in a different shape). On some of the trials a completely novel letter appeared in one of the shapes (no-match trials). Participants were faster on same-object trials compared to different-object and no-match trials. However, different-object and no-match trials did not differ from each other thus ruling out the possibility of a general benefit from preview. The advantage found for same-object trials shows that some kind of temporary representations of objects/events are maintained over space and time. It is possible that the grouping information (discussed in previous section) in search is represented in such object files helping selection or inhibition depending on the task.

The interaction between perceptual grouping and attention: Evidence from other research paradigms

The interaction between perceptual grouping and attention has been studied in other experimental contexts too, which will be discussed next. The interaction between perceptual grouping and attention has been studied by asking whether and which grouping processes require attention. I discuss two studies that address this question and provide a context to the current thesis.

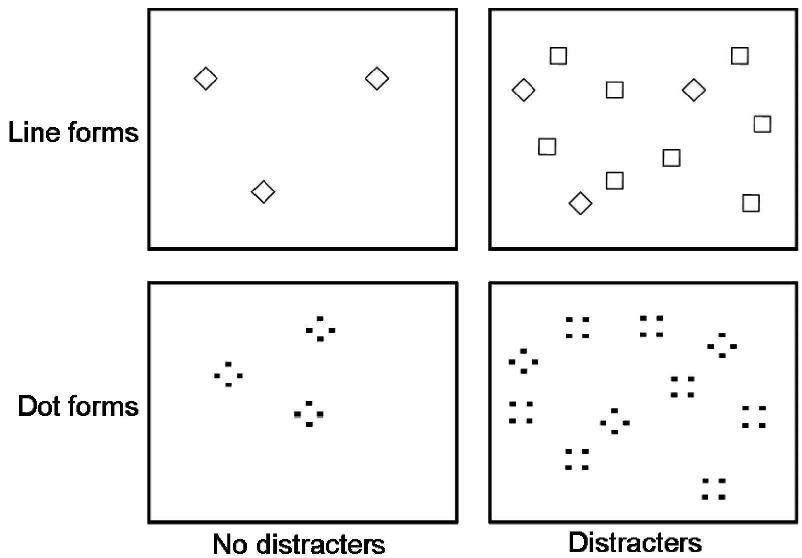

Figure 1.1: *Example stimuli used by Trick and Enns (1997). The task was to enumerate the number of diamonds in each case. The performance across line and dot forms was similar when they were presented without any distractors (left segments). Performance, however, differed significantly when the same forms were presented along with distractors (right segments). The enumeration of dot forms suffered significantly in the presence of distractors.*

Trick and Enns (1997) distinguished between two kinds of grouping (clustering and shape formation) and suggested that the question of whether grouping requires attention should take into consideration the type of grouping and the specific conditions in which the grouping happens. Trick and Enns (1997) used dot forms and line forms (squares and diamonds formed by four dots or lines respectively; Figure 1.3). The task was to enumerate the number of diamonds in the absence (Experiment 1) or presence (Experiment 2) of square distractors. In Experiment 1, enumeration did not differ between the line forms and dot forms. Normal subitising slopes were found for displays containing 1-3 forms and steeper slopes were recorded for 5-7 forms as they fell in the counting range. The task was the same in Experiment 2 but the targets were presented along with distractors forms. The results for the line forms remained comparable across Experiment 1 and 2. The presence of distractors did not affect enumeration; normal subitising and counting slopes were found. However, the results dramatically changed for the dot forms in Experiment 2. With these forms, the presence of distractors abolished any slope difference between the smaller subsets (1-3 targets) and larger subsets (5-7 targets). Trick and Enns (1997) explained that dot forms in the no-distractor condition (Experiment 1) were only required to be clustered together to do the task. However, this was not sufficient when the distractors were present. In addition to clustering, shapes had to be formed and distinguished to perform the task. This prompted Trick and Enns (1997) to propose that there are different kinds of grouping and they differ in their attentional demands depending on the conditions in which they are carried out.

A very similar account has been put forth recently by Kimchi and Razpurker-Apfeld (2004). In their experiment, participants performed a difficult central task while background stimuli that grouped into various patterns were presented. Background stimuli were coloured dots arranged by colour similarity into (i) rows of alternating colours (ii) triangles among other dots. There were two other conditions where (iii) dots formed a triangle but there were no other dots present in the display and (iv) lines formed a triangle and no other elements were present. The central task (participants were required to assess if the target was same or different across two successive displays) was completely unrelated to the grouping stimuli presented in the background. The objective was to test the effect of the grouping present in the background on the central task. The results revealed an influence of the background on the central task when the stimuli grouped by rows/columns but not when the dots formed a triangle among other dots. Kimchi and Razpurker-Apfeld (2004) suggested the existence of separate grouping processes that differ in their attentional requirements. Thus, grouping by rows/columns needs only clustering whereas grouping dots into a triangle when other dots are also present requires figure-ground segregation in addition to shape formation. Hence, they argued that simple forms of grouping (grouping by rows/columns) took place even when very little attention was available. However, grouping processes involving more steps (shape formation, figure-ground segregation) demand attentional resources and hence these processes did not influence the central task, which was attentionally demanding in itself. Their main conclusion from the study was that grouping is not a unitary process but may involve many sub processes. This could change the interaction between grouping processes and attention accordingly (see also Moore and Egeth, 1997 and Lamy, Segal and Ruderman, 2006 for grouping effects under inattention).

Several recent studies suggest that grouping processes can also constrain attention (Davis and Driver, 1997; Moore, Yantis and Vaughan, 1998; Watson and Kramer, 1999). Kimchi et al. (2007) showed that attentional deployment in a bottom-up manner could be influenced by perceptual groups defined by closure (see also Yeshurun et al., 2009). Kimchi et al. (2007) used oriented line stimuli (rotated Ls) to define a closed perceptual group (a diamond; see Figure 1.4). This perceptual group was presented among other distractors (again rotated Ls). The task was to report the colour of the element indicated by a probe and the diamond-like object was irrelevant for this purpose. There were three conditions: inside-object condition (the probe was presented in the object), outside-object (probe was presented outside the object) and no-object condition in which no object was formed. The line stimuli appeared simultaneously on the screen and there was no onset associated with the object, which could facilitate capture. In spite of this, the results showed typical costs and benefits associated with capture. Participants were faster to report the colour when the probe fell within the object compared to no-object and outside-object conditions. Participants needed more time to respond when the probe fell outside the object compared to when there was no object in the display. These results suggested that a globally defined perceptual group could capture attention automatically in a stimulus-driven manner. The kind of configuration used by these studies relate to an important distinction made by Pomerantz (1981). Pomerantz (1981, 1983) suggested that there are two kinds of configuration: one based on the positions of the elements (he called them type P configurations) and another based on the nature of the elements in addition to their positions (type N; see Figure 1.4). The differently oriented Ls could be presented in a diamond or a square – like positions but the nature of the element and its position will determine if a global structure will emerge (there will be no emergent shape if Os were presented instead of Ls). The current thesis employs configurations of both kind (type P and type N) and investigates whether search is differentially modulated by these configural types. It is also investigated whether the capture by a closed object is susceptible to top-down modulation by employing a difficult search task.

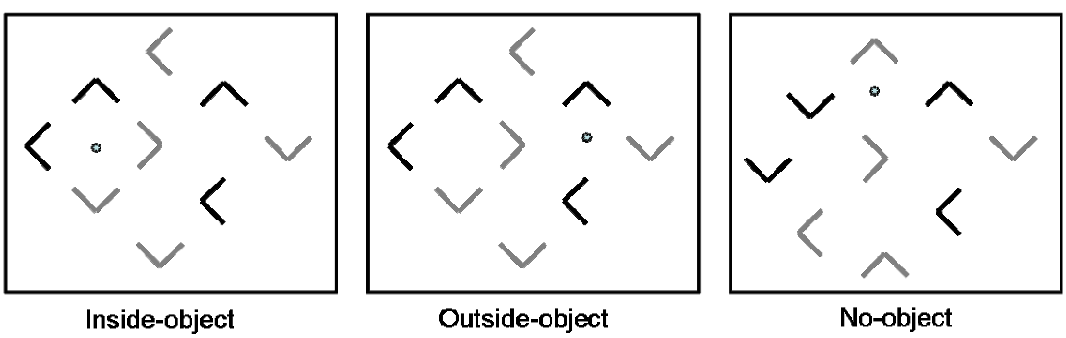

Figure 1.2: *Stimuli used by Kimchi et al. (2007) and Yeshurun et al. (2009). The extreme left segment shows an inside-object condition. In this case, RTs were faster to the probe (a small circle in the diamond object) related task compared to when the probe appeared outside the object (middle segment). There was a cost to the performance in the outside-object condition compared to both*

inside-object and the baseline where no object was present (right-most segment) indicating automatic capture by the closed object.

Grouping-based modulation of attention in neuropsychological studies

Grouping separate units into cohesive perceptual objects has also been shown to modulate attentional deficits like neglect and extinction. Grouping the stimuli based on Gestalt principles like similarity, proximity, good continuation and closure reduces or even eliminates the detrimental effects of neglect and extinction (Boutsen and Humphreys, 2000; Gilchrist, Humphreys and Riddoch, 1996; Mattingley, Davis and Driver, 1997, Ward, Goodrich, Driver, 1994; Pavlovskaya, Sagi, Soroker and Ring, 1997; in neglect patients - Vuilleumier and Landis, 1998). Gilchrist et al. (1996) showed effects of low level grouping cues in a patient with Balint's syndrome who also presented with left extinction. They manipulated edge-based and brightness-based grouping (see Figure 1.5) between the ipsilesional and the contralesional stimuli. Extinction was reduced when the elements across the midline grouped by brightness or edge information (two light circles or two squares). There was an additive effect when grouping was present in both the dimensions (two light squares). They also found effects of proximity in modulating extinction. When the distance between the two items was minimal, grouping helped the detection of the stimulus in the contralateral side.

Ward et al. (1994) also manipulated grouping between the stimuli across the midline thus connecting the stimuli on the basis of similarity, symmetry and familiar configuration. These cues reduced extinction considerably by making the stimuli co-operate rather than compete for the attentional resources. Mattingley et al. (1997) and Vuilleumier and Landis (1998) used Kanizsa figures (figures induced by illusory or subjective contours; see Figure 1.6 for an example) to investigate the perceptual completion in the extinction and neglect patients. In both the studies the extinction or neglect of the contralateral stimuli was less severe when the stimuli formed a common surface.

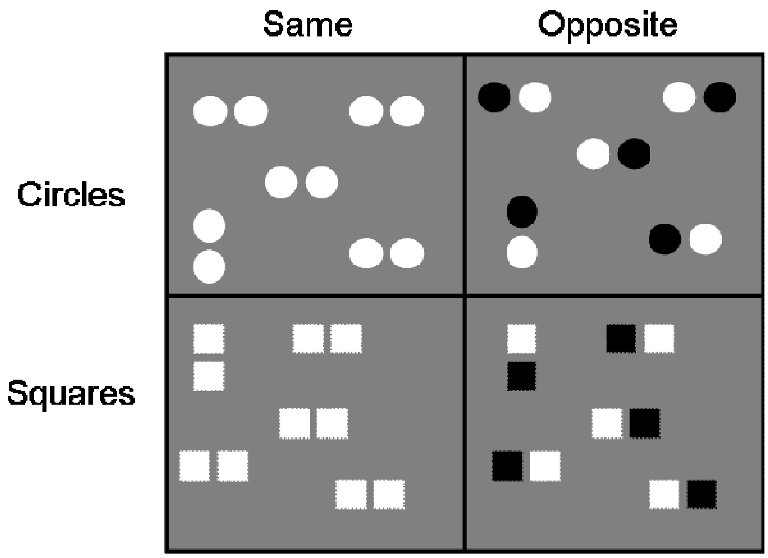

Figure 1.5: *illustrates stimuli used by Gilchrist et al. (1996) and Gilchrist et al. (1997). The two columns represent contrast polarity (same versus opposite). Search was more efficient when the circles shared same contrast polarity (top-left) compared to when they shared opposite contrast polarities (top-right). Search, however, was not different between the two contrast conditions when the stimuli also grouped by collinearity (bottom segments). With normal participants there was no additional advantage of having the stimuli group by both brightness and edge-based information (bottom-left segment; Gilchrist et al., 1997). The findings were similar in a patient (GK) Gilchrist et al. (1996) studied. However, GK benefited from the additive information present in the stimuli (bottom-left segment).*

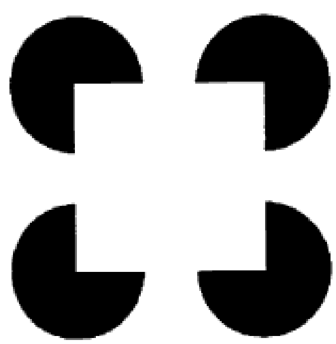

Figure 1.6: *an example of a Kanizsa figure. When the segments making up the figure spanned the midline, patients showed reduced neglect/extinction for the items in the contralateral side.*

A recent study by Shomstein, Kimchi, Hammer and Behrmann (2010) studied the grouping effects slightly differently. In their study dot stimuli (similar to Kimchi and Razpurker-Apfeld, 2004) either grouped into rows/columns or into shapes such as square/cross, and these items were presented to patients with left-side neglect. Grouping stimuli were presented in the left field (‘neglected field’) and the target was presented in the right field (‘intact field’). The stimuli presented in the neglected field were completely irrelevant and unrelated to the task being carried out in the intact field. The pattern in the grouping stimuli either changed or remained the same independently of whether the target changed or not. The task was to indicate if the target remained the same or changed across two successive displays. The results showed an effect of the group present in the neglected field on the task carried out in the intact field (revealed by congruency effects). Therefore, Shomstein et al. (2010) suggested that grouping by rows/columns and simple shapes could come about without attention being focussed on the elements.

Although these studies show that some form of perceptual operations could be intact in patients with extinction and neglect which could be used to ameliorate their attentional deficit, the picture is not that simple. Evidence for perceptual processing being constrained by attention comes from Snow and Mattingley (2006). These investigators used a flanker task in which the target was presented in the centre and a flanker each in the left and right fields. On a typical trial one flanker was congruent, incongruent or neutral (on the relevant dimension - colour or identity of the target) in relation to the target while the other flanker was always neutral. Healthy controls showed significant interference from the incongruent flankers along the task relevant dimension. However, patients were slower on RTs for both task relevant and task irrelevant dimensions in their intact field. Contralesional incongruent flankers interfered only when the task dimension was relevant. These results suggested that stimulus processing even in the intact field might not be normal in these patients. In this case top-down control failed to exert any influence and hence the selection suffered as patients tended to 'over' select information from the intact field.

Evidence for such changes in perceptual grouping also comes from a study by Riddoch et al. (2004) of a patient with damage to the dorsal stream (patient MH) that showed an abnormally strong response to organized patterns. MH had to detect an oriented target that could appear in the context of other oriented lines. MH was strikingly impaired with the orientation-defined target when it grouped with the elements. This was not a general problem in search because MH could easily detect a colour-defined target. Riddoch et al. proposed that, in the absence of dorsally mediated attention due to his lesion, MH showed abnormally strong grouping response within his ventral stream. These data are highly relevant to the work presented here where MH was again tested in search, but in this case using a procedure similar to that of Kimchi et al. (2007) who examined the attention-capturing properties of grouped shapes (the tendency for the shapes to attract and hold attention even when they were irrelevant to the task).

In Chapter 6 the single case work with MH (Chapter 5) was extended further in a study of groups of patients with spatial and non-spatial biases in attention after left or right parietal lesions. Here the question was raised of whether the bias in attention in these patients modulated effects of distractor grouping.

Overview of the current thesis

The current thesis investigates the effects of grouping on the attentional processes in preview search (Chapters 2 and 3) and in a simultaneous search (Chapter 4). The thesis also investigates the interaction between configural grouping and attention using neuropsychological data. In Chapter 5 a case study is presented of a patient (patient MH) with left parietal damage. Chapter 6 evaluates the relations between grouping and attention further by assessing the effects of an irrelevant grouping array on responses to a target in a group of left and right parietal damaged patients with spatial and non-spatial biases in attention. The specific issues and question raised in each chapter are as follows:

Chapter 2

The experiments reported in Chapter 2 investigated the effects of pattern regularity on grouping in search over time (preview search) and space (standard conjunction search). Previous studies (Kunar et al., 2003b, Watson, 2000) suggested that preview suppression could be based on the configuration of the old items, with the configuration defined in terms of the relative locations of the elements to each other. Though these studies showed an effect of configuration, the specific role of pattern regularity was unknown. It was also not known whether the particular grouping relations (e.g., homogeneity of elements or formation of a closed shape) also play a role. Regular and irregular displays were used to manipulate the configuration of the elements. The questions that were considered include:

- Do regular configurations facilitate search more than the irregular configurations?
- Does the nature of local-element grouping interact with the regularity of a pattern?
- Do regularity and element grouping impact differently on search over time and space?

Chapter 3

Chapter 3 attempted to extend the investigation by comparing two preview conditions:

preview with and without a temporal gap. Previous studies have shown that the presence of a temporal gap after a preview display abolishes the preview benefit (Watson and Humphreys, 1997). However, if a further "top-up" preview is presented after the temporal gap, the preview benefit re-emerges (even when the 'top-up' preview itself is insufficient to generate a preview benefit; Kunar et al., 2003a). This latter evidence shows that the preview representation is not lost immediately, since it remains available to combine with the top-up display, but, with the gap alone, grouping of the re-presented preview with the new search items overrides the preview effect. I ask whether this grouping effect remains dominant when the preview forms a regular pattern, and so may be subject to stronger, configural inhibition.

Chapter 4

Chapter 4 leaves behind the preview search paradigm and investigates the effect of configurations defined by closure, similarity and location in a time-restricted search where the elements appear simultaneously. In preview search the presence of a regular preview can be beneficial to search, so it is possible that the initial group was deliberately formed by participants. In Chapter 4 the configuration, when present, could be detrimental to target selection since the configuration could distract search from the target. I asked:

- Does closure capture attention and slow responses to the target even when the task is difficult and requires focussed attention?
- Does a configuration defined by similarity also capture attention?

Chapter 5

Chapter 5 extended the data from Chapter 4 by examining the performance of a left parietal damaged patient, MH, who shows very specific impairments with oriented line stimuli and notably strong effects of configural grouping (Riddoch et al., 2004). Riddoch et al. presented the stimuli centrally but I was interested in testing whether there were any field effects due to his specific lesion. Here I asked:

- Does MH show differential configural processing in his ipsilesional and contralesional fields?
- Is MH sensitive to the different types of configuration?
- Are grouping processes normal in MH compared to age-matched controls?

The studies provide evidence on the role of posterior parietal cortex on grouping and configural processing in vision.

Chapter 6

In chapter 6 I looked at the effect of grouping the background stimuli while patients with left or right parietal lesions, and concomitant spatial biases in attention, carried out an unrelated task in the centre of the display. The background stimuli were manipulated so that on half the trials the patterns were random and on the other half the pattern was grouped by having alternative rows of black and white elements. The study asked:

- Is there any implicit grouping when the stimuli are unattended? This was measured by any influence of the background on the central task, in both the patients and any associated controls.

- Does this implicit grouping vary between the two groups of patients?

Chapter 7

Chapter 7 provides a General Discussion of the results from the thesis. Generally, the results showed that attention was sensitive to the presence of grouping. Search over space (simultaneous search) and time (preview search) were differently influenced by configural grouping. Grouping by orientation facilitated search over time but was not helpful when all the elements appeared together (as in simultaneous search). However, grouping by brightness did help search in this case. Chapter 3 showed that grouping was sensitive to factors which affect object coding such as visual transients ('a temporal gap'). Chapters 4 and 5 showed that capture by objecthood (e.g., a closed object) was not purely automatic. A difficult search task involving a stronger top-down goal counteracted with capture. Evidence was also found for homogeneity and location-based grouping. Chapter 5 supported the finding from Chapter 4 that capture was not completely automatic as MH failed to show any reliable effects of configuration from his contralesional field. Finally, Chapter 6 showed that grouping was possible under reduced attention and left and right parietal patients could be differently sensitive to grouping because of their respective lesions.

The thesis consists of five empirical chapters written as independent journal articles with their own introduction and discussion.

CHAPTER 2

THE ROLE OF CONFIGURAL GROUPING AND FEATURES IN SEARCH

Abstract

Two experiments examined the role that configural grouping might play in search, using a preview search task (Watson & Humphreys, 1997) to isolate the distractor rejection process. The regularity of the configuration of distractors, and the nature of their grouping (whether elements grouped by orientation or brightness) was varied, along with whether the configuration shifted position between the preview and search displays. While preview search was generally easier than full-set search irrespective of the regularity of the configuration, it was easier for participants to reject previewed distractors forming a regular configuration when the preview shifted in space. In addition, the preview conditions benefited when the elements in the preview had the same global orientation (outer-orientation). In contrast, standard conjunction search benefited when the regularly positioned distractors shared brightness similarity. The data suggest differential roles for global configural and local similarity relations in search over time (preview search) and space (conjunction search).

Introduction

Our visual environment is highly complex and dynamic providing us with an excessive amount of information that we must organise and prioritise. Perceptual grouping is critical in this process, allowing us to organise single elements into unified objects and thereby reducing the information load for limited attentional processes. How attention might interact with perceptual grouping is therefore critical in understanding how we efficiently and successfully interact with our environment.

Triesman (1982) looked at the effect of grouping like-distractors (homogeneous) when searching for a target defined by a conjunction of form and colour. Finding a target defined by a conjunction of two features is typically slow and difficult compared to searching for a target which differs from the distractors along only one feature (Treisman and Gelade, 1980). Treisman (1982) however found that when distractors could be integrated into small groups search was faster even in the normally difficult conjunction search. How grouping influences search, however, is unclear. Grouping could help to guide attention to targets (see Kimchi et. al.2004) or it could help in the rejection of distractors (Treisman, 1982).

Data suggesting a role for grouping in distractor rejection were reported by Humphreys, et al. (1989). They used form conjunctions and varied the configuration of the distractors in addition to the homogeneity of the elements. Search was faster when the homogeneous distractors were arranged in a virtual circle and this effect of the configural arrangement was reduced when the distractor elements were heterogeneous. Humphreys et al. (1989) argued that this distractor grouping facilitated segmentation of the target from the distractors. Search was particularly fast on target absent trials, suggesting that in these cases the display could be rejected en masse.

Other evidence for efficient rejection of grouped distractors comes from studies of preview search, where one set of distractors is presented prior to the other distractors plus the target thus temporally segmenting the two sets of elements (Watson and Humphreys, 1997). When the interval between the two displays is around 400 ms or longer, participants are able to effectively ignore the initial distractors (Humphreys et al., 2004a) such that a benefit in search times arises compared to the baseline when all the items appear simultaneously. Studies of the allocation of attention in preview displays have been conducted using probe dot procedures. These studies show that probes are difficult to detect when they fall on previewed distractors (even relative to when probes fell on the neutral locations), consistent with previewed distractors being suppressed (see Watson and Humphreys, 2000; Humphreys et al., 2004b). Kunar, Humphreys, Smith and Hulleman (2003) directly examined the effects of configural grouping on distractor rejection in preview search. In this study the locations of the previewed items changed when the search display appeared, with the initial items either maintaining or losing their configuration. Relative to a ‘full-set’ baseline when all the items appeared together, a preview benefit for search was found when the configuration was maintained but not when it was disrupted. This occurred irrespective of whether the configuration changed location. Given the evidence for distractor suppression in preview search (Watson and Humphreys, 1997), these data suggest that grouping the distractors into a configuration aids their efficient suppression.

Although these last results fit with the idea that the grouping of distractors can lead to their efficient rejection, it is far from clear what forms of grouping are effective. For example, effects of distractor homogeneity (Humphreys et al., 1989) could reflect both the similarities of local items - which will be termed grouping by brightness - and the elements grouping into a more global spatial configuration. Currently it is not known how these different forms of grouping may interrelate, which is stronger, and what form that configural coding takes. For example, Pomerantz (1983) made a distinction between configurations defined based only on the spatial positions they occupy (type P) and those that are influenced by the featural properties of the elements as well as their positions (type N). Whether distractor rejection is affected by type P or type N configural coding is unknown. In addition, the previous literature has used two different search tasks; standard conjunction (simultaneous presentation of distractors and target; Treisman and Gelade, 1980) and preview search (Kunar et. al., 2003b). However, making comparisons is difficult as each task was used separately in these studies. An interesting next step would be to compare effects of different grouping relations on distractor rejection across different search tasks. In addition, it is unclear whether the regularity of the configuration is important for the efficient rejection of the distractors in preview search, or whether the maintenance of the configuration at the onset of the new search display, common to conjunction and preview search, is sufficient.

The current study was designed to separate the effects of local similarity relations and the regularity of configural grouping on attention, in both preview and standard conjunction (referred to as full-set henceforth) search. I also tested whether the grouping effects were more effective when the distractors changed locations (maintaining their configuration and inter-element grouping) compared to when they remained in the same positions throughout (cf. Kunar et al. 2003b). Accounts of distractor rejection in preview search differ. Watson and Humphreys (1997) originally argued that previewed distractors were rejected by suppression of their locations. Subsequently, however, there has been evidence for the suppression of distractor features (e.g., Braithwaite et al., 2005) and configurations (Kunar et al., 2003b). If there is suppression of distractor locations, then any change in the previewed locations should be disruptive to search. On the other hand, if there is either feature suppression or inhibition of the configuration of the distractors, then performance should be unaffected by a change in the locations of the old distractors provided their features or configurations remain. For a configural account, distractor rejection should be dependent on the goodness of the configuration. In all the experiments, the target was defined by the relations between the outer orientation of an ellipse and the inner orientation of a line within each ellipse. It was predicted that search would be facilitated when there was a regular configuration formed by positioning the outer ellipses, compared with when there was an irregular configuration. By varying the grouping relations between the elements making up the configurations, at either the inner or outer level, I assessed whether local element grouping combined with position-based configural coding (cf. Pomerantz, 1983) to facilitate distractor rejection, and whether grouping at the outer or inner level was critical. Also, by varying whether there was grouping for both the outer and inner elements, I tested whether these aspects of the displays combined in distractor rejection. Alternatively, grouping based on just the outer elements could trump grouping of the inner elements (or vice versa), so that there was no extra gain from being grouped across both sets of elements. Two experiments are reported. Experiment 2.1 varied whether half the distractors formed a regular configuration, and whether there was orientation-based grouping at both outer and inner levels of the elements or at a single perceptual level (outer only or inner only). Experiment 2.2 looked at the effect of the regularity of the configuration when the inner elements grouped by brightness similarity rather than orientation. The experiments were aimed at investigating whether grouping of outer or inner orientations, or of local element brightness, contributes to the effects of configural coding and how this configural coding (regular / irregular) influences search. The experiments were also designed to test the effect of location change of the distractors in preview search.

EXPERIMENT 2.1: Varying grouping in the preview

Participants took part in 3 grouping conditions: outer-inner (elements matched in both their inner and outer orientations), outer-only (elements in the configuration matched only in their outer orientations while the inner orientations differed), and inner-only (elements in the configuration matched only in their inner orientations while the outer orientations differed). Two search conditions were included in the experiment: preview and full-set search. In the preview condition the old or previewed items could fall in either a regular or an irregular configuration, and the configuration could remain in the same location or change location, when the search items appeared. In full-set search half the distractors (the same distractor type that served as previewed items) formed either a regular or an irregular configuration. It was assessed whether the regularity of the configuration and its nature (inner or outer items matching) affected distractor rejection, and whether effects were robust to location change under preview conditions.

Method

Participants

63 participants took part, 22 (4 males) in the outer - inner condition, 20 (5 males) in the outer - only condition and 21 (4 males) in the inner - only condition. All participants were students from a local college (Cadbury College, Birmingham) or the University of Birmingham between the age range of 17-37 (mean age: 22 years). All of them reported normal or corrected - to - normal vision.

Stimuli

The stimuli were horizontal and vertical black ellipses (1.24º x 0.76º) containing an internal white line of varying thickness and orientation (thick or thin; horizontal or vertical). These ellipse elements were arranged in groups of 5 or 8 to create a set of configurations. 'Regularity' ratings were collected from ten independent participants. Regular patterns were those rated as highly regular by all raters (mean: 6.81, with a maximum score of 7) and irregular displays were those rated as highly irregular (mean: 1.68) - verifying that these arrangements were correctly assigned as regular and irregular configurations (examples are shown in Figures 2.1 and 2.2). Regular patterns resembled geometrical figures such as, a square or a diamond whereas irregular patterns did not resemble any familiar shapes or configurations.

In addition to the regularity of how the items were arranged, the likelihood of grouping between the elements was manipulated. Elements forming the configuration could be consistent only in their outer orientations (outer-only, Figure 2.3), consistent in only their inner orientations and differ in their outer orientations (inner-only, Figure 2.4), or consistent in both their outer and inner orientations (outer-inner, Figure 2.5). Distractors that did not form part of the configuration were vertical ellipses with vertical internal lines. The target was based on a combination of form elements. It was a horizontal ellipse with a vertical internal line in the outer-inner and inner-only conditions, and a vertical ellipse with a horizontal internal line in the outer-only condition. Element level grouping was manipulated between groups.

The configuration of half of the distractor items was varied such that on 50% of trials the items were arranged regularly and on the remaining 50%, the elements were arranged irregularly. Participants completed three search conditions (in separate blocks): (i) full-set search in which all the distractors and the target appeared simultaneously, (ii) standard preview in which half the distractors (previewed distractors) were presented before the onset of the rest of the distractors (search distractors) and the target, and (iii) location-change preview, which was similar to the standard preview except that the preview configuration moved up or down (randomly) by 15 pixels at the onset of the search distractors and the target. An initial pilot experiment first established that a 'standard' preview benefit occurred in search with the present stimuli, when comparing the slope of the search function for a preview condition (with randomly positioned stimuli) with a full-set baseline condition. These data are reported in Appendix 1.

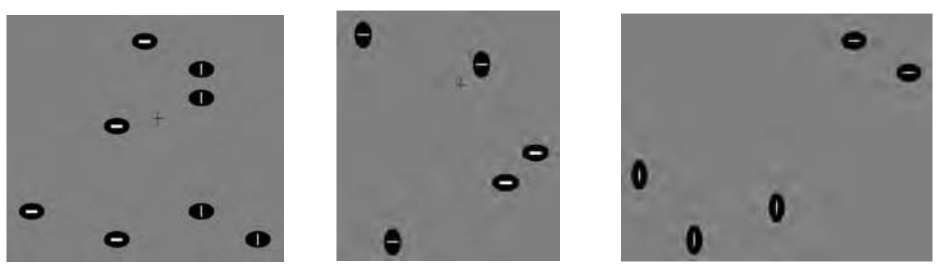

Figure 2.1: *Illustrations of irregular configurations used in the study. The leftmost configuration is for set size 16 (only half the distractors formed the configuration hence there are 8 items. Rest of the configurations are examples for set size 10. These figures are for illustration only. Refer to Stimuli section for details on the exact size and visual angle.*

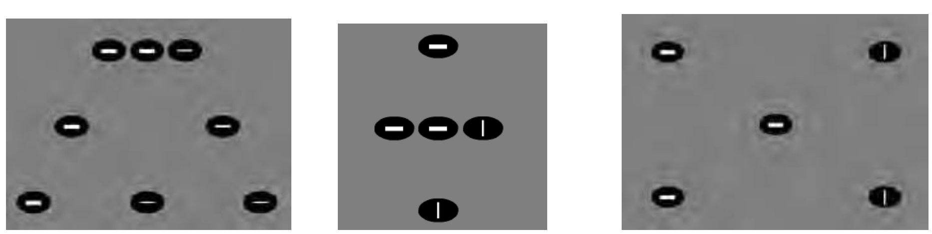

Figure 2.2: *Illustrations of regular configurations used in the study. The first configuration is for set size 16 (only half the distractors formed the configuration hence there are 8 items. Rest of the configurations are examples for set size 10. These figures are for illustration only. Refer to Stimuli section for details on the exact size and visual angle.*

Procedure

Participants viewed the stimuli on a gray-display at a distance of approximately 60cm. They were asked to find the incongruent item (the 'target') and report the width of its internal line by pressing "Z" for 'thick' and "M" for 'thin'. It was emphasised that participants should respond as quickly and as accurately as possible. Participants completed 24 practice trials to familiarise themselves with the task.

The trial sequence began with a central fixation cross displayed for 500ms (black). In the full-set baseline condition this was instantly followed by the search display and participants immediately searched for the target. In the preview conditions, half of the distractor items were presented 1000ms before the remaining distractors and the target (Figure 2.3). Participants were informed that the target would appear only in the second set. The search items remained on the screen until participants responded. An interval of 500ms preceded the onset of the subsequent trial. Participants completed 6 experimental blocks (2 blocks per search condition) consisting of 288 trials in total. The order of experimental trials was fully randomised throughout and the block order was counterbalanced across participants.

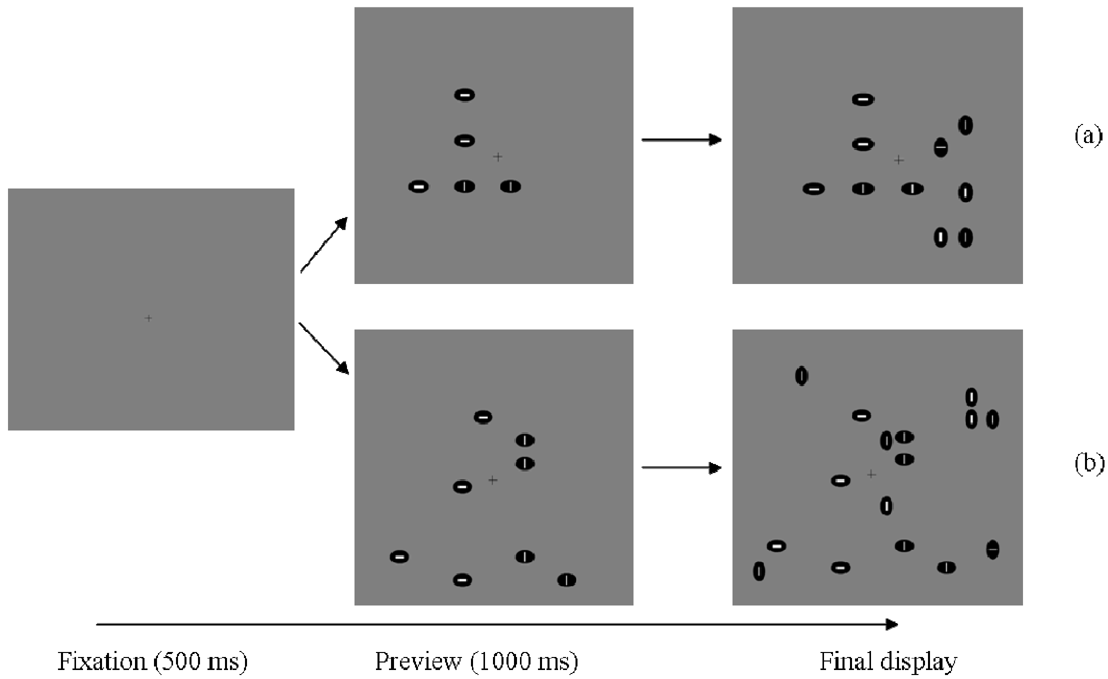

Figure 2.3: *Examples for (a) regular and (b) irregular configurations and a typical trial from outer-only condition (Experiment 2.1). The elements in the configurations grouped only by outer orientation*

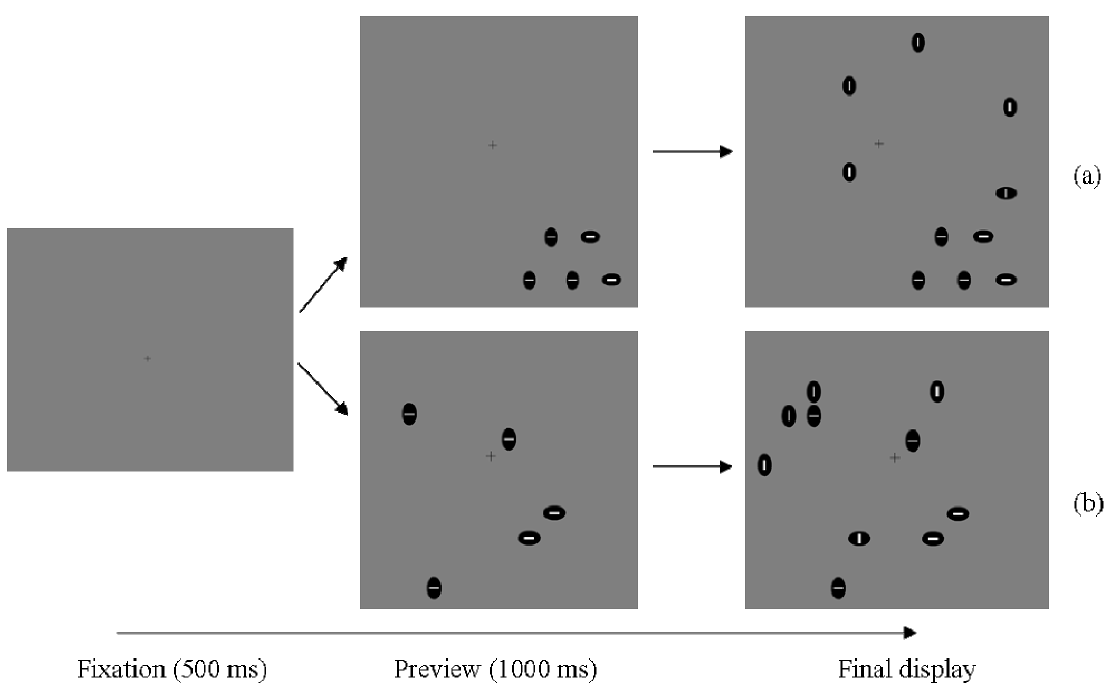

Figure 2.4: *Examples for (a) regular and (b) irregular configurations and a typical trial from inner-only condition (Experiment 2.1). The elements in the configurations grouped only by their inner orientation*

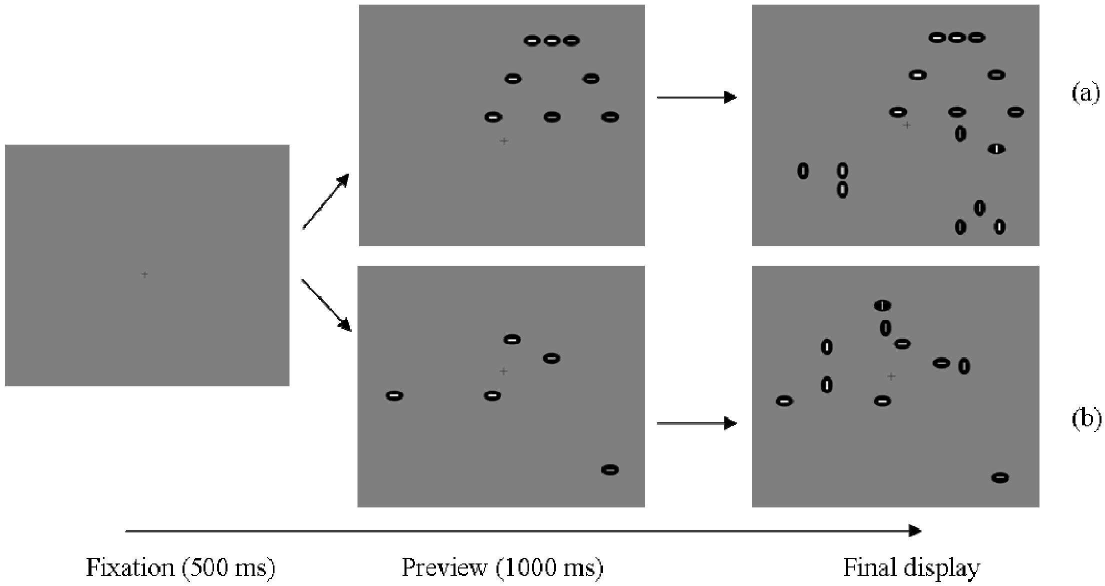

Figure 2.5: *Examples for (a) regular and (b) irregular configurations and a typical trial from outer-inner condition (Experiment 2.1). The elements in the configurations grouped both by outer and inner orientations*

Results

All incorrect trials were removed (4% removed, see Table 2.2). An outlier analysis removed all response times (RTs) that exceeded 2.0 standard deviations above and below the mean (2%). RTs below 200 ms were also removed. The resulting mean search RT data are displayed in Figures 2.6, 2.7 and 2.8.

A repeated measures ANOVA was carried out on the errors and the results are shown in Table 2.1. There was a main effect of configuration indicating that participants made more errors on the irregular configuration compared to regular configuration trials. There was a main effect of element grouping (the between-subject factor). There was greater number of errors in the outer-inner condition compared to outer-only and inner-only conditions. Least number of errors was recorded in the outer-only condition.

Table 2.1 *summarises the statistical results from an ANOVA conducted on the errors from Experiment 2.1. Significant effects are marked with asterisk.*

Effects	F value	p value
Set size	F(1,60) = 3.259	0.076
Configuration	F(2,120) = 3.700	0.059*
Element grouping	F(2,60) = 4.718	0.013*
Search condition	F(1,60) = 1.672	0.192
Set size x element grouping	F(2,60) = 0.578	0.564
Set size x search condition	F(2,120) = 0.407	0.667
Set size x configuration	F(1,60) = 0.347	0.558
Configuration x element grouping	F(4,120) = 0.998	0.375
Configuration x search condition	F(2,120) = 5.121	0.007*
Search condition x element grouping	F(2,60) = 0.925	0.452
Set size x configuration x element grouping	F(2,60) = 0.728	0.487
Set size x search condition x element grouping	F(4,120) = 0.690	0.6
Set size x configuration x search condition	F(2,120) = 0.120	0.887
Configuration x search condition x element grouping	F(4,120) = 1.173	0.326
Set size x configuration x search condition x element grouping	F(4,120) = 0.692	0.599

RTs were analysed using a mixed ANOVA including set size (10 or 16), configuration (regular and irregular), and search condition (full-set, standard preview, and location-change preview) as within - subject factors and element grouping as a between - subject variable (outer-inner, outer-only, and inner-only). The within-subject factors are reported first.

There were reliable main effects of set size [F(1,60)=337.84, p<0.001], configuration [F(1,60)=82.19, p<0.001] and search condition [F(2, 120)=85.72, p<0.001]. All the two-way interactions were significant: configuration x set size [F(1, 60)=19.00, p<0.001]; configuration x search condition [F(2, 120)=7.576, p<0.001]; set size x search condition [F(2, 120)=17.302, p<0.001]. Three-way interaction between set size, configuration and search condition was not reliable [F(2, 120)=1.272, p=0.284]

The between-subjects factor of element grouping was not reliable [F(1,60)=1.919, p=0.156], but this factor did significantly interact with set size and search condition [element grouping x set size x search condition; $F(4, 120)=3.694$, $p<0.01$].

There were two two-way interactions involving the configuration factor, which were not qualified by any higher-order interaction. The configuration x set size interaction was due to a greater cost of set size when items were arranged in an irregular configuration (Figures 2.6, 2.7, 2.8). The configuration x search condition interaction occurred because the effect of configural regularity was greater for the location-change preview condition than for the other search conditions (full-set and standard preview) [(i) $F(1,62)=4.46$, $p<0.05$, and (ii) $F(1,62)=19.47$, $p<0.001$, for the interaction between configural regularity and location-change preview vs. (i) full-set and (ii) standard preview]. There was no interaction between configural regularity and search condition when the full-set and standard preview conditions were considered [$F(1,62)=2.46$, $p=0.122$], though the main effect of configuration remained reliable [$F(1,62)=38.12$, $p<0.001$].

The three-way interaction (element grouping x set size x search condition) was decomposed by analysing the effects of grouping and set size for each search condition. For the full-set condition there was only a main effect of set size [$F(1,60)=139.51$, $p<0.001$] and this was not qualified by the grouping condition [$F(1,60)=1.43$, $p=0.248$]. For the two preview conditions, the effect of set size changed across the grouping conditions ($F(1,60)=3.45$, $p<0.05$ and $F(1,60)=4.60$, $p<0.05$ for interactions of grouping x set size for the standard preview and location-change preview conditions respectively). This interaction reflected a significant effect of element grouping on the search slope across both the preview search conditions. The slopes for the standard preview conditions were 28ms/item, 48ms/item and 42ms/item for the outer-only, inner-only and outer-inner grouping conditions respectively. RTs in the outer-only condition were faster compared to inner-only [$t(19) = -2.465$, $p<0.05$] and outer-inner [$t(19) = -1.994$, $p<0.05$] conditions. Inner-only and outer-inner conditions did not differ from each other [t(20)<1, p=0.214]. The effects were slightly different for the location-change preview condition: RTs were slower in the inner-only condition compared to both outer-only [t(19) = -2.362, p<0.05] and outer-inner [t(20) = 2.454, p<0.05] conditions. Outer-only and outer-inner conditions did not differ from each other [t(19) < 1, p= 0.25] (all of the tests are 1-tailed). The slopes were 66ms/item, 90ms/item and 56ms/item respectively for the outer-only, inner-only and outer-inner grouping conditions (Figures 2.6, 2.7, 2.8).

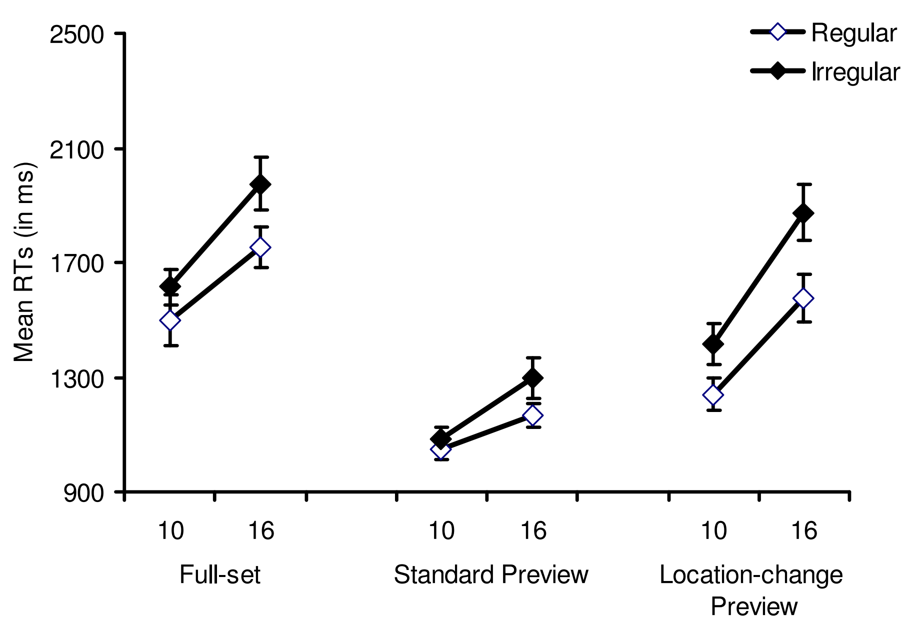

Figure 2.6: *RTs as a function of set size for the outer-only condition (Experiment 2.1). Open symbols represent regular trials and filled symbols represent irregular trials. Set sizes and search conditions are drawn on the x-axis.*

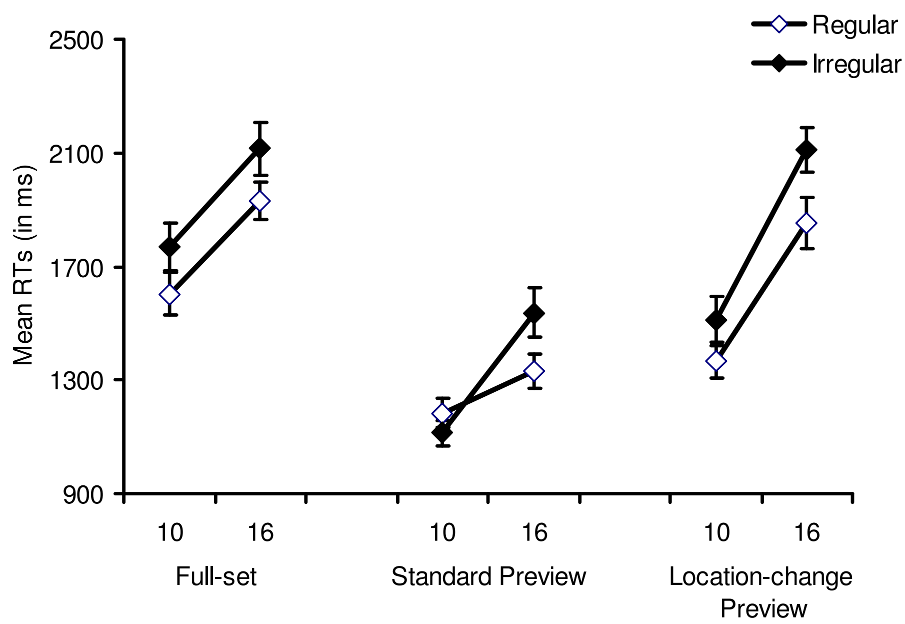

Figure 2.7: *RTs as a function of set size for the inner-only condition (Experiment 2.1). Open symbols represent regular trials and filled symbols represent irregular trials. Set sizes and search conditions are drawn on the x-axis.*

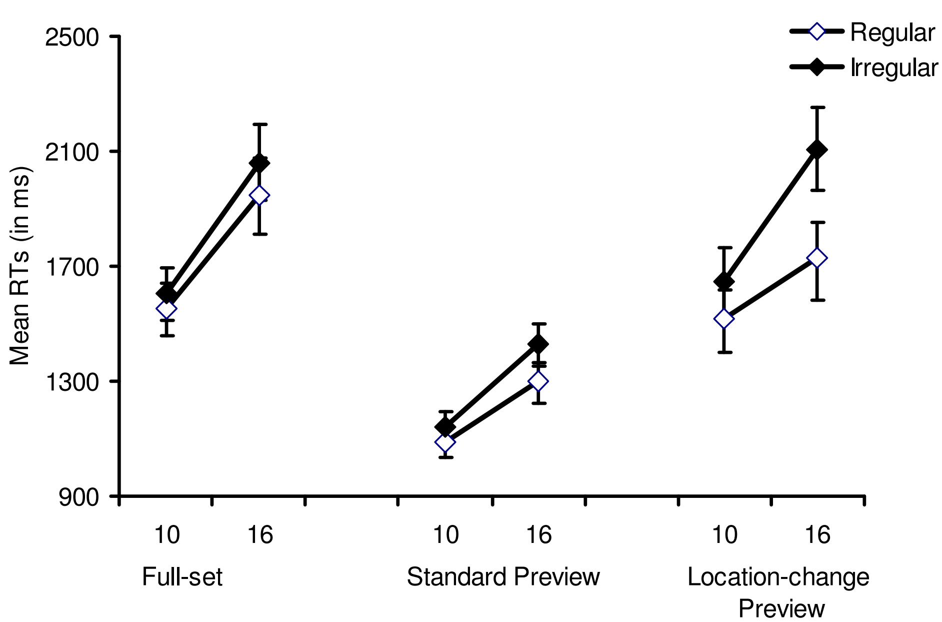

Figure 2.8: *RTs as a function of set size for the outer- inner condition (Experiment 2.1). Open symbols represent regular trials and filled symbols represent irregular trials. Set sizes and search conditions are drawn on the x-axis.*

Table 2.2: *Percentage error rates for Experiments 2.1 and 2.2 as a function of set size, configuration and search condition (Std. preview = standard preview, LC preview = the location-change preview)*

Display Size	10		16	
Configuration	Regular	Irregular	Regular	Irregular
Experiment 2.1 (Outer-inner)				
Full-set	3.59	3.03	3.4	4.16
Std. preview	2.84	5.68	3.21	4.92
LC preview	3.40	3.78	3.59	3.97
Experiment 2.1 (Outer only)				
Full-set	1.04	2.29	1.66	1.04
Std. preview	1.45	2.29	2.7	3.33
LC preview	1.45	1.66	2.5	1.45
Experiment 2.1 (Inner only)				
Full-set	2.38	1.19	3.37	1.98
Std. preview	0.79	2.38	2.38	3.57
LC preview	2.77	2.77	2.38	3.57
Experiment 2.2				
Full-set	4.17	4.17	2.90	3.44
Std. preview	5.25	5.43	4.17	3.44
LC preview	5.25	2.90	2.36	3.44

Discussion

There were effects of both the regularity of the configuration, and of the type of element grouping involved, on preview search. Across the different search conditions, regular configurations showed less effects of set size than irregular configurations and, across the set sizes, the effects of configuration were stronger on the location-change preview condition relative to the other conditions (preview and full-set search – though the effects of configuration remained across these conditions). The type of element grouping affected slopes on preview search more than full-set search. Type of grouping did not interact with configural regularity.

Previous studies have reported that the effects of configural regularity were greater on preview search than on full-set search. Though this was the case for the location-change preview condition here, it did not hold for the standard preview condition itself. It is likely that the standard preview benefited from the initial items remaining in the same location irrespective of their regularity. For instance, Watson and Humphreys (1997) proposed that the locations of old items were inhibited and this location-based inhibition may occur irrespective of display regularity. The preview benefit would be the same magnitude then, for regular and irregular arrays though search through both preview and full-set displays may benefit if search does not return to items in regular positions as much as it does to items positioned randomly in the field. The more important result is that there was a greater effect of regularity of the initial items in the location-change preview. This suggests that, participants found it difficult to keep out old items from search when there was a location shift, but were facilitated in doing this when the old items appeared in a regular configuration. This is consistent with a regular configuration being carried over from the old to the new displays, even if the absolute locations of the items shifted. That is, there may be suppression of both a regular configuration as well as the locations of the old elements. When the preview remains in the same location, location-suppression is sufficient to make search efficient. When the preview shifts location, only suppression of the configural representation is effective.

The grouping effect here indicates that search is not only sensitive to the relative locations (type P configuration) of the elements but also to the nature of the element grouping forming the configuration (e.g. here their outer orientation, type N configuration; Pomerantz, 1983). This aspect of the results goes against the idea that previews are suppressed solely by inhibition of their locations (cf. Watson and Humphreys, 1997), but is consistent with the inhibition of the configural form of the whole initial display (Kunar et al., 2003b) and/or with location-based inhibition being more effective when the global elements also have the same orientation.

EXPERIMENT 2.2: Grouping by brightness

Experiment 2.1 examined grouping based on orientation similarity at various levels (e.g. outer and inner orientations) and grouping had a significant influence on preview search (in both the standard and the location-change preview conditions). However, full-set search did not benefit from orientation grouping. This is surprising given the evidence in the literature about grouping effects when items are presented simultaneously, as in full-set search (Treisman, 1982). However, a closer comparison of the stimuli and grouping manipulation used in Experiment 2.1 relative to the stimuli and grouping manipulations in previous studies (Treisman, 1982), reveals that past studies have mostly used homogeneous elements which group into clusters (for example, similar shapes or colours). In contrast, the grouping manipulation in Experiment 2.1 was configural in nature and the elements grouped based on their orientation. In Experiment 2.2 I assessed performance when the inner lines had a common width, but their inner and outer orientations changed across the elements in a display. Elements with the same width may group on the basis of their brightness. Does brightness grouping facilitate search in the full-set condition in this case? How does it affect preview search? This was again examined by contrasting the preview and full-set search conditions.

Method

Participants

22 participants (2 males) took part in the study in exchange for course credits. All were students of University of Birmingham in the age range of 18-26 years (mean age: 21 years).

All reported normal or corrected-to-normal vision.

Stimuli

Distractors forming the configuration were horizontal and vertical ellipses containing horizontal and vertical inner lines respectively. Importantly, all of the inner lines were of the same thickness (thin) to allow grouping based on brightness/density. Search distractors were horizontal and vertical ellipses containing horizontal and vertical inner lines respectively (all were thick). Target was a horizontal ellipse containing a vertical line (of varying thickness). An example is shown below (Figure 2.9).

Design

This was a within-participant design with the following variables: set size (10 and 16), configuration (regular and irregular), and search condition (full-set, standard preview and location-change preview).

Procedure

The procedural details remained same as for the previous experiment. Participants completed 6 experimental blocks (2 blocks per search condition) consisting of 288 trials in total. The order of experimental trials was fully randomised throughout and the block order was counterbalanced across participants.

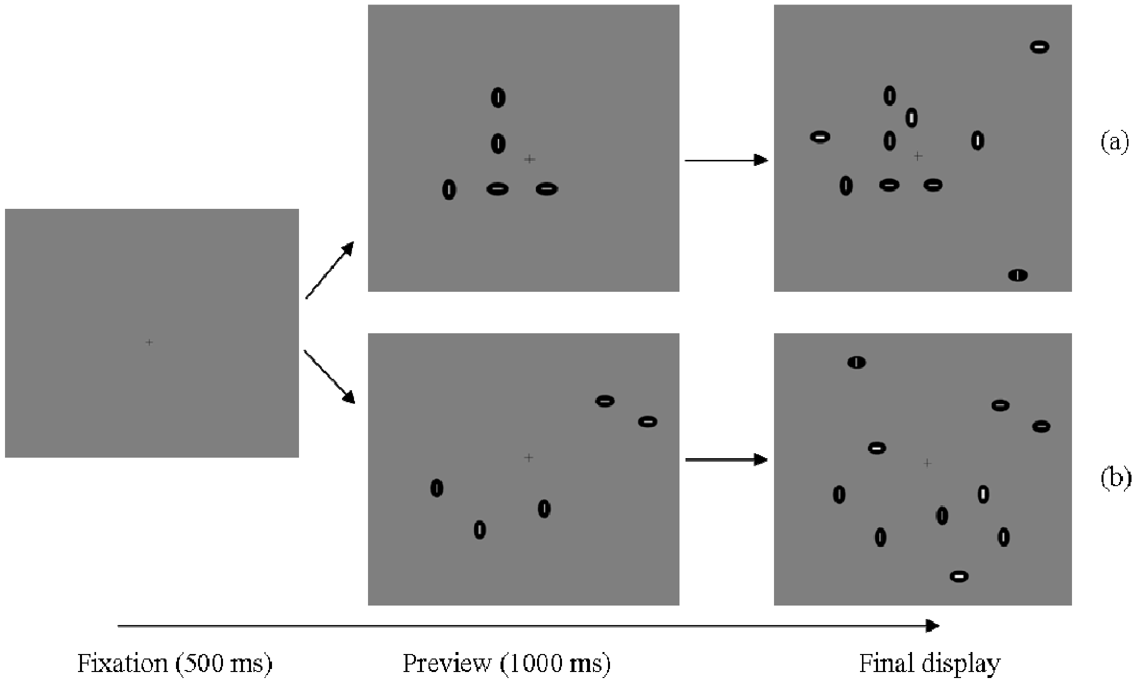

Figure 2.9: *Examples for (a) regular and (b) irregular configurations and a typical trial from Experiment 2.2. The elements in the configurations grouped by brightness (previewed items carried inside lines which were thin and the search distractors in the final display carried thick lines inside).*

Results

Incorrect RTs (4.3%) were removed from the analysis (Table 2.1). An analysis of the errors is presented in Table 2.3. Errors decreased with increasing set size (see Table 2.2). Though this indicated the presence of overall speed-accuracy trade-off, no effects involving the test variables (e.g. configuration or search condition) were significant.

Table 2.3 *summarises the statistical results from an ANOVA conducted on the errors from Experiment 2.2. Significant effects are marked with asterisk.*

Effects	F value	p value
Set size	F(1,21) = 5.638	0.027*
Configuration	F(1,21) = 0.262	0.614
Search condition	F(2,42) = 2.499	0.094
Set size x configuration	F(1,21) = 0.986	0.332
Set size x search condition	F(2,42) = 0.113	0.894
Configuration x search condition	F(2,42) = 0.345	0.711
Set size x configuration x search condition	F(2,42) = 1.551	0.224

The results are shown in Figure 2.10. RTs increased with larger set sizes [$F(1,21)=148.010$, $p<0.001$]. RTs were faster for regular configurations compared to irregular configurations [$F(1,21)=21.027$, $p<0.01$]. There were significant differences in performance across the three search conditions [$F(2,42)=10.952$, $p<0.01$].

The two-way interaction between set size and configuration was significant [$F(1,21)=12.081$, $p<0.01$]. Regular configurations were less affected by the set size compared to irregular configurations suggesting that some distractors were being treated as groups. The two-way interaction between search condition and configuration and between search condition and set size did not reach significance [$Fs<1$]. However, the three-way interaction between set size x regularity x search condition was reliable [$F(2,42)=4.502$, $p<0.05$], indicating that rejection of distractors in groups was not the same for all the search conditions.

Further ANOVAs were carried out to understand the three-way interaction, analysing the data for the three search conditions separately. For both the full-set baseline and the location-change preview there were interactions between set size and configuration [Full-set: $F(1,21)=12.918$, $p<0.01$; location-change preview: $F(1,21)=5.894$, $p<0.05$]. Set size had a reduced influence on the regular configuration trials compared to irregular configuration trials. This effect was not evident in the standard preview condition [$F<1$; see Figure 2.10].

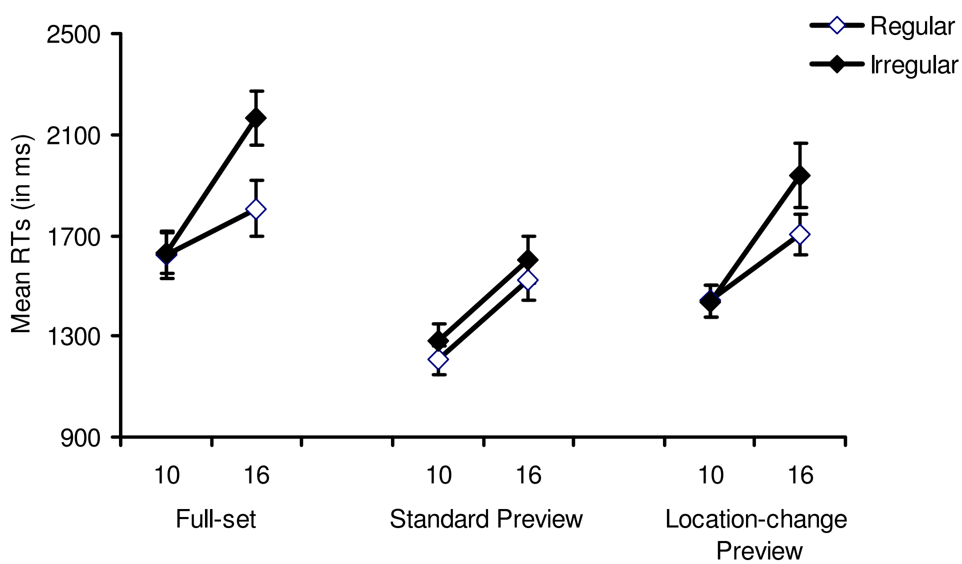

Figure 2.10: *RTs as a function of set size (Experiment 2.2). Open symbols represent regular trials and filled symbols represent irregular trials. Set size and search conditions are drawn on the x-axis.*

Discussion

The results from Experiment 2.2 differed from those of Experiment 2.1 in several ways. Most notably, there was an effect of configural regularity on slopes in the full-set baseline, which was not apparent in Experiment 2.1. This suggests that grouping by edge orientation (Experiment 2.1) differs from grouping by common brightness (Experiment 2.2), and that grouping by brightness is more effective in conjunction-type search tasks. This fits with previous work on conjunction search, where placing targets with homogeneous distractors has been shown to modulate performance (Treisman, 1982). When stimuli have common orientations, the presence of irrelevant distractors in the full-set may compete to form alternative groups, weakening any grouping effects. In contrast, local brightness-based segmentation may still take place and enable the grouped distractors to be rejected together, making search more efficient. This effect seems particularly strong when the brightness-defined group forms a regular configuration. The effect of common brightness in the location-change preview condition may come about in the same way as for the full-set baseline, given that there was not a strong effect of the preview in this condition. That is, brightness segmentation may take place between the old and new items once the new items have appeared, since (i) rejection of the old distractors cannot be location based in this condition, and (ii) there were also no global cues for configural grouping here (which would facilitate rejection of the old distractor configuration).

For the standard preview condition, the regularity of the brightness grouped elements exerted weaker effects compared to the full-set baseline and the location-change preview. This contrasts with the data from Experiment 2.1, where preview search was more sensitive than full-set search to the type of grouping. This suggests that the orientation grouping of the configuration (manipulated in Experiment 2.1) is more important than grouping by brightness (in Experiment 2.2) for efficient rejection of the initial distractors in preview search. However, relatively efficient search was observed for standard preview condition compared to both full-set baseline and location-change preview conditions on just irregular trials. There were no consistently identifiable global shapes present on the irregular trials. This implicates the operation of some other process such as suppression based on the locations of the elements (Watson and Humphreys, 1997), generating a preview benefit even with irregular configurations here. In the location-change display, this position-based suppression may be less effective, enabling some effects of the regularity of the brightness-grouped elements to emerge.

General Discussion

The present experiments examined the effects of configural coding in search, focussing on the preview paradigm in order to isolate effects on distractor suppression. Experiment 2.1

manipulated whether the grouped elements formed a regular configuration or were irregular and whether the outer or inner elements grouped by orientation. Effects of configural regularity on search efficiency were apparent for preview search when there was a location change, but not for full-set or for standard preview search. In the standard preview search it may be sufficient for participants to reject old distractors by suppressing their locations (Watson & Humphreys, 1997), so that the regularity of configuration adds little to the performance. In the full-set condition the regularity of the configuration will be difficult to detect as all the items appear simultaneously and, in this case, neither inner nor outer orientation grouping was sufficient to segment one set of distractors from the other. In the location-change condition, though, suppression of a configural representation of the old items helped performance, enabling a preview benefit to emerge when the configuration has a regular form.

There were also effects of the inter-element grouping, which differed for preview and full-set search. In the preview conditions, distractors with common outer orientations were rejected most easily. Global orientation grouping here may enhance either rejection of the configuration of previewed items or the locations of those stimuli. The lack of an effect of grouping with full-set displays may then reflect the presence of items outside the configuration, which compete to form alternative, orientation-based groups. These competing elements would not be present in preview conditions. Experiment 2.2, however, showed that it is possible for grouping effects to emerge under full-set conditions when the elements group by local similarity relations (line density and / or brightness). The effects of grouping by local similarity relations were less pronounced with preview search, though, which can again be attributed to grouping at the outer (not local) level being most critical for suppressing the initial preview display.

The role of collinearity principle in the regularity effects

Previous research has shown that collinear elements produce good continuation, which helps the visual system to integrate contours (Field, Hayes and Hess, 1993). Field et al. (1993) showed that collinear elements forming a common path were detected better in a noisy background than elements that were orthogonally oriented to the path. These investigations also showed that the ability to integrate contours depended on the orientation of neighbouring elements and the spatial distance between them. These findings have found support from research on early visual processing in area V1 of visual cortex (Bosking, Zhang, Schofield and Fitzpatrick, 1997; Schmidt, Goebel, Löwel and Singer, 1997). One possibility is that regularity effects based on the global configuration result from local contour integration of this type, since all our regular patterns tended to have defined contours based on the orientations of the global elements, while irregular configurations lacked them. Interestingly, the results suggest that grouping by orientation in preview displays may have operated independently for outer and inner parts of the configuration. This follows from the finding that standard preview search tended to be less efficient in the outer-inner condition than in the outer-only condition. In fact, there is evidence that grouping operates independently within different spatial scales (Dakin and Hess, 1998, 1999). Possibly, there was competition for attention between the inner and outer groups, and selection of the more inner groups then made it more difficult to reject the more outer configural preview. However, one reason why collinearity alone could not account for the results was the presence of orthogonally oriented elements in our configurations and contour integration has been shown to be less effective for orthogonally oriented elements (Field et al., 1993). In any case, the contour integration by collinearity is not completely at odds with my account of configuration effects as grouping remains the common aspect of both the accounts.

Are the effects due to contextual cuing?

Research on contextual cuing suggests that attention can be guided by contextual regularities in the visual world (Chun and Jiang, 1998). Chun and Jiang (1998), for example, employed a search task in which the distractor configurations were repeated on half of the trials, while new randomly generated configurations appeared on the other trials. The target appeared in a consistent location within the repeated configurations. Search for the target was facilitated on the repeated configuration trials compared to new configuration trials. Chun and Jiang (1998) attributed this finding to learned associations between the distractor configuration and the target's location. Current study also demonstrated that configural regularity can facilitate search. However, contextual cuing may not serve as an explanation for the regularity effects here. For example, there was no consistent relationship between the position of the preview and the location of the target, which is the case in the contextual cuing studies. Also, regular and irregular configurations were repeated on equal number of trials. Therefore, a benefit should have occurred for both the regular and the irregular displays if contextual cuing was playing a role. This was not the case.

Inhibition of the configuration

Rather than attributing the preview effects to contextual cuing, it is suggested that the current preview effects reflect the ease of rejecting distractors as competitors for targets. This is in accord with evidence using probe dot detection to examine where attention is allocated during search. Probe dot experiments demonstrate that it is difficult to detect probes falling on old distractors, especially when participants adopt the set to reject these items and to prioritise new stimuli (Humphreys et al., 2004b; Watson and Humphreys, 2000). Interestingly, the evidence for inhibition of the distractors in preview search occurs alongside evidence that participants initially attend to the distractors, perhaps in order to subsequently suppress them (Humphreys et al., 2004b; see also Tsal and Makovsky, 2006). It may be that a configurally-organized initial preview may be easier to attend to in the first place (perceptual groups have been shown to capture attention; Kimchi et al., 2007; Yeshurun et al., 2009), and may consequently be easier to inhibit. This needs to be tested in future studies that examine the time course of the present effects in more details.

Object persistence

Kahneman, Treisman and Gibbs (1992) introduced the concept of an object file to explain the integration of visual information across space and time. Object files draw together the content features of objects, and maintain this representation even when the stimulus moves. The preview conditions in these experiments had strong spatiotemporal continuity across the old and new displays and the evidence for the rejection of the configural previews fits with the notion that search is facilitated by rejection of an object file for the initial items. This appears to contrast with the effects of grouping in the full set baseline condition, where local (brightness) similarity relations were critical. It may be that local brightness similarity may affect grouping within an object file (within the whole display in the standard conjunction condition) while the global formation of configural shape is more critical to the segmentation of different object files (the old and new displays under preview search conditions).

Conclusions

The data indicate two new results: (i) that in preview search the regularity of the initial configuration can influence search but primarily when the old items shift their location in the visual field, and (ii) while the similarity of the global orientations of the elements affects preview search, full-set search is influenced by similarity of local brightness. The data suggest that different grouping processes can modulate search, and that these grouping processes operate independently for different properties of form (outer and inner). Most notably, data here suggest a double dissociation between different effects of grouping based on inner and outer features on conjunction and preview search. I suggest that these results are consistent with separate codes contributing to segmentation within and between object files.

CHAPTER 3

CONFIGURAL EFFECTS IN THE PRESENCE OF A TRANSIENT

Abstract

Chapter 2 assessed the effects of configural grouping on search. Regular configurations produced efficient search in the preview conditions compared to irregular configurations. It is not known, however, if the regularity of the previewed items was strong enough to withstand the visual disruptions from eye-movements, occlusions or offsets that have been shown to abolish the preview benefit in previous studies (e.g. Watson and Humphreys, 1997). Chapter 3 asessed whether regular configurations could override the effects of a strong transient (a brief blank interval between the preview and the search display) on preview search. The results showed that the transient abolished all the preview benefits observed in the preview search without a temporal gap (as in Chapter 2). Although regular configurations speeded the RTs, regularity of the previewed items was not sufficient to override the effect of a visual transient on preview search.

Introduction

Search in complex real life environments depends on tracking stimuli over both space and time. Studies of search over space have revealed the factors that guide attention with, for example, search typically being more efficient when the target is defined by a feature difference relative to the background compared to when it is defined by a conjunction of features (Treisman and Gelade, 1980). Search over time has been examined within the preview paradigm, where displays are temporally staggered with half the distractors appearing earlier than the other distractors and the target (when present). When distractors are segmented over time in this way conjunction search can become efficient (under preview conditions; Watson and Humphreys, 1997). Various pieces of evidence suggest that this efficient search is at least partly due to participants inhibiting the initial distractors. For example, if probes are presented during the search task then they are difficult to detect if they fall on the previewed (old) distractors (Humphreys et al., 2004b; Watson and Humphreys, 2000). Active inhibition of old distractors may provide a means by which efficient search operates over time as well as space.

In the real world, though, search over space and time can be disrupted by discontinuities due either to changes in the observer (e.g. when the eyes blink) or occlusions in the environment. How do such transient discontinuities impact on visual processing? This was examined by Kunar et al. (2003a). They employed a modified version of the preview paradigm in which the previewed distractors disappeared after their initial appearance and either appeared simultaneously with the new distractors or briefly before the new items appeared (the 'top-up' condition). When the old items reappeared with the new distractors, the efficient search in the preview condition was disrupted. However, in the top-up condition, efficient preview search was re-established. This occurred even though the brief appearance of the preview before the full search display was not sufficient to generate efficient search if the preview had not appeared earlier (see also Humphreys et al., 2004b; Watson and Humphreys, 1997, for data on the long time course of the preview effect). These data indicate that a memory for the preview display was encoded and remained across the gap period (when the preview disappeared). The memory was not effective in any suppression of the old stimuli, though, if the old items reappeared with the new search stimuli. To account for these findings Kunar et al. proposed that a new factor – temporal grouping of the old and new stimuli – disrupted any effects of memory suppression. That is, when the old and new stimuli onset together, temporal grouping between the items overrode any suppression of the old stimuli, so that they again competed for attention and slowed search. Thus selection over time and space may involve a complex interplay of factors including not only the suppression of irrelevant old items but also their grouping with new stimuli: if a temporal discontinuity is common to both items.

The present study set out to investigate which factors can modulate effects of temporal grouping in selection over space and time. In doing this, the study also assesses the nature of the representations that may be suppressed under preview conditions. Prior work has shown that the effect of a temporal offset can be overcome in some conditions. Kunar and colleagues (Kunar et al., 2003c) studied the effect of occlusion on preview effects. In one of their preview conditions the old distractors were briefly occluded by rectangular blocks before the old items reappeared with the new items. Offset of the old items before the appearance of the new items is known to disrupt the preview effect (Watson and Humphreys, 1997). Occlusion also results in the offset of the occluded items (in this case, previewed items) but Kunar et al. (2003c) found that occlusion did not abolish the preview benefit. In contrast to this, an offset preview (where disappearance of the preview was not consistent with occlusion) did eliminate the preview effect. This suggests that, even though occlusion resulted in the brief offset of the previewed items, it did not change their “old” status. The previewed stimuli were treated as old items when they reappeared after the brief occlusion and hence did not compete with the new items.

Chapter 2 here showed that preview search could benefit from regular configurations. Regular and irregular configural previews were contrasted to assess their effect on search efficiency. The results showed that regular configurations, when presented as previews, produced efficient search compared to irregular configuration, with this effect being particularly strong when the location of the configuration changed.

Given the positive effects of configural grouping on preview search, it is possible that presenting the preview in a configuration will enable it to remain suppressed, even if the preview offsets and then onsets along with the new search items. For example, grouping the elements in the preview into a particular configuration may enable the continuity between the old and new displays to be coded, so that any suppression of the distractors is carried over even when the new old display onsets again with the new. A preview benefit on search should then emerge.

Two experiments are reported. Performance was examined with a ‘standard’ preview (where the old items remained at the same location when the new search display appeared), a full-set baseline (where all the items appeared simultaneously) and a location-change preview (where the old items moved to a new location when the search display appeared), with either all the items positioned randomly or with some distractors in a regular configuration. Under preview conditions the regular configuration of distractors, when present, was always in the preview. In Experiment 3.1 there was no temporal gap between the preview and the new search display; in Experiment 3.2 there was a temporal gap. In the location-change version of preview search, any location-based inhibition (cf. Watson & Humphreys, 1997) should be ineffective, whereas it should be effective in the standard preview condition. Hence, when there is no temporal gap, the standard preview should be better than the location-change condition (see also Kunar et al., 2003a). In the temporal gap condition, though, this advantage should decrease, as location-based inhibition would not be effective. However, if there is independent suppression of the configuration of the preview then a preview benefit might emerge when a regular configuration is present even with a temporal interval between the old and new displays. Alternatively, temporally grouping the old and new items could abolish any preview effects (Jiang et al., 2002). The study tests the relative strength of configural and temporal grouping.

EXPERIMENT 3.1: The effect of configuration on preview search without a temporal gap

The data for this study were taken from the outer-inner condition of Experiment 2.1 from Chapter 2.

Results

An analysis of errors is summarised in Table 3.1 (see also Table 3.3 for the percentage errors in each condition). There were no effects of any of the variables on the errors.

Table 3.1 *summarises the statistical results from an ANOVA conducted on the errors from Experiment 3.1.*

Effects	F value	p value
Set size	F(1,21) = 0.075	0.787
Configuration	F(1,21) = 3.102	0.093
Search condition	F(2,42) = 0.540	0.587
Set size x configuration	F(1,21) = 0.004	0.951
Set size x search condition	F(2,42) = 0.229	0.796
Configuration x search condition	F(2,42) = 2.231	0.12
Set size x configuration x search condition	F(2,42) = 0.541	0.586

An analysis of the RTs revealed main effects of set size, configural type and search condition (a summary of all the statistics is presented in Table 3.2). All of the two-way interactions were also significant (set size x configuration; search condition x configuration; and set size x search condition). The interaction between set size and configuration showed that regular configurations were less affected by the number of items present (see Figure 3.1). The interaction between search condition and configuration occurred because the effect of configural regularity was stronger for the location-change preview condition compared to the full-set [$F(1,21)=9.197$, $p<0.006$] and standard preview conditions [$F(1,21)=10.065$, $p<0.005$]. However, this interaction was not significant when the full-set and standard preview conditions were compared [$F<1$]. Set size effects were reduced in the standard preview condition compared to full-set and location-change preview conditions [$F(1,21) = 7.518$, $p<0.05$ and $F(1,21) = 3.551$, $p=0.07$ for the interaction between set size and search condition for comparisons with full-set and location-change conditions respectively]. The three-way interaction between set size, configuration and search condition was not reliable [F(2,42 = 1.250, p = 0.297].

Table 3.2 *summarises the statistical results from an ANOVA conducted on the mean RTs (Experiment 3.1).*

Effects	F value	p value
Set size	F(1,21)=93.325	0.000
Configuration	F(1,21)=22.577	0.000
Search condition	F(2,42)= 18.679	0.000
Set size x configuration	F(1,21)=7.917	0.010
Set size x search condition	F(2,42)=4.723	0.014
Configuration x search condition	F(2,42)=6.370	0.004
Set size x configuration x search condition	F(2,42)=1.250	0.297

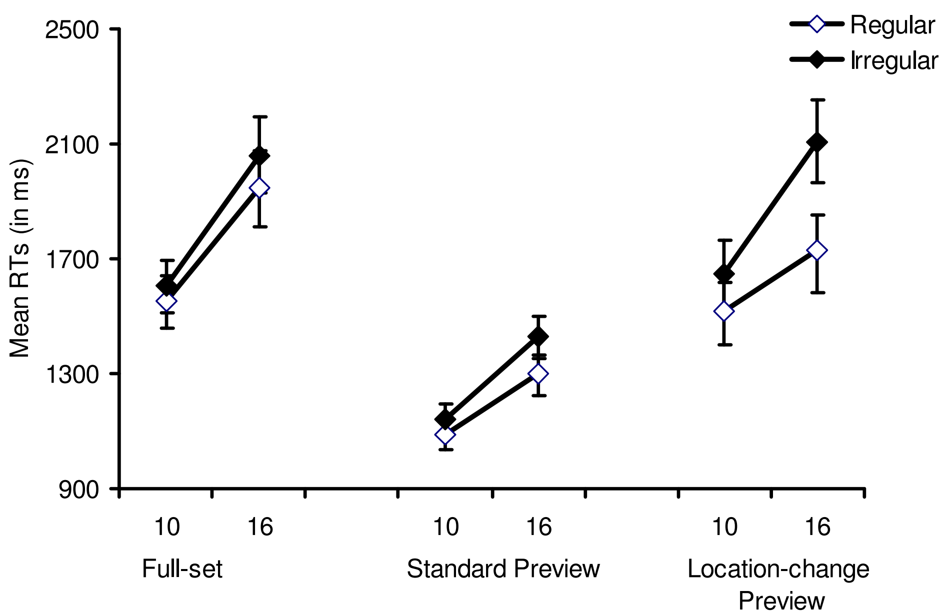

Figure 3.1: *RTs as a function of set size (Experiment 3.1). Open symbols represent regular trials and filled symbols represent irregular trials. Set sizes and search conditions are drawn on the x-axis.*

Table 3.3 *Percentage error rates for Experiments 3.1 and 3.2 as a function of set size, configuration and search condition (Std. preview = standard preview, LC preview = location-change preview).*

	Experiment 3.1				Experiment 3.2			
Display Size	10		16		10		16	
Configuration	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular
Full-set baseline	3.6	3	3.4	4.1	1.2	3.1	4.9	2.9
Standard preview	2.8	5.6	3.2	4.9	3.6	4.4	4.1	3.6
LC preview	3.4	3.7	3.5	3.9	3.6	3.6	4.6	4.6

Discussion

The data showed an effect of configural regularity on preview search under location-change conditions. Full-set search and standard preview conditions, however, did not benefit from the regularity of the configuration. These data show that, selectively for preview search, participants are able to take advantage of the regularity of the initial display, especially when the location-based coding becomes ineffective (in location-change preview) and to use this information to help reduce the impact of the old items in search. Interestingly, the presence of a regular preview enabled participants to overcome any effect of changing the location of the preview, so that a preview benefit then emerged. This result is consistent with participants directly suppressing a configural representation of the preview, which carries across the transient change produced by the location change, when the configuration remains same. Alternatively, participants might match the configuration across the preview and the search displays and then ignore/suppress the preview (post-onset suppression). In either case, the net effect is that a preview benefit is sustained across the transient changes produced when the preview is re-located. The effects of configuration and search condition also modulated the slopes, given the interactions between configuration and set size and between search condition and set size. Experiment 3.2 tested the generality of this result by introducing a blank interval between the preview and the search display. Does this additional transient change or eliminate the preview benefit found for the location-change preview condition with a regular configuration display or does the presence of the regular configuration enable suppression still to be applied?

EXPERIMENT 3.2: The effect of a visual transient on configuration effects in search

Method

Participants

Twenty participants (3 males) took part in the study for course credit. All were post-graduate and undergraduate students of University of Birmingham in the age range of 18-25 (mean age: 19 years). All had self-reported normal or corrected – to - normal vision.

Stimuli and Design

Stimuli and design remained the same from outer-inner condition of Experiment 2.1 from Chapter 2 (Figure 3.2).

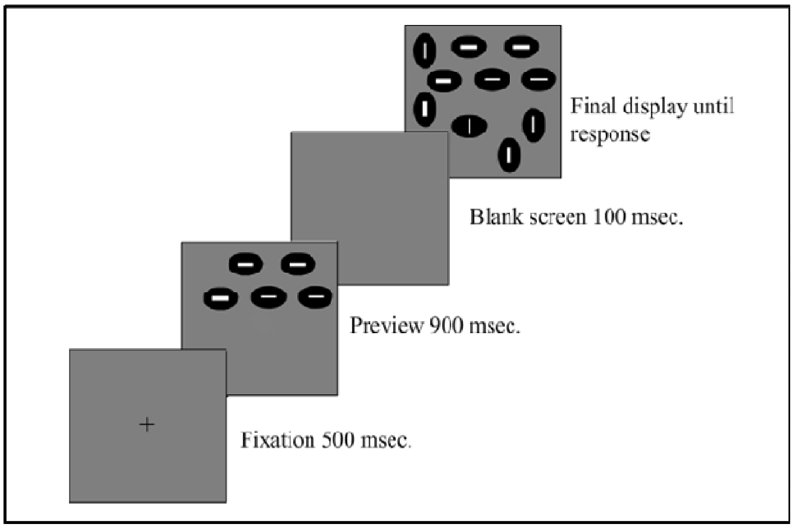

Figure 3.2: *A typical trial from a standard preview search condition. Full-set search (where all the items appeared simultaneously) display resembled the final display shown in the figure. A brief offset was introduced between the preview and the search display in Experiment 3.2 as shown above. The trial procedure was very similar in Experiment 3.1 except that there was no blank and the preview duration was 1000ms.*

Procedure

The procedure remained the same except for the changes noted here. There was no change to the full-set baseline condition. The preview duration was reduced to 900 msec (1000 msec in Experiment 3.1) and a blank screen appeared immediately after the preview display for 100ms in both the preview conditions (Figure 3.2). Search items and the target followed this brief blank. Participants completed 6 blocks (2 per each condition). The order of search conditions and blocks was randomised and counterbalanced. All other details remained the same as in Chapter 2.

Results

Accuracy and RTs were recorded for each participant. Data from three participants were removed due to high percentage of errors (>10%). The analysis was carried out on the data from the remaining 17 participants. Incorrect trials (<4%, see Table 3.2) were dropped from the analysis. Reaction times greater than two standard deviations away from the mean and RTs less than 200ms (6%) were also excluded.

An analysis of the errors is presented in Table 3.4. There were no effects involving any of the variables.

Table 3.4 *summarises the statistical results from an ANOVA conducted on the errors from Experiment 3.2.*

Effects	F value	p value
Set size	$F(1,16) = 2.371$	0.143
Configuration	$F(1,16) = 0.003$	0.956
Search condition	$F(2,32) = 2.535$	0.095
Set size x configuration	$F(1,16) = 3.073$	0.099
Set size x search condition	$F(2,32) = 0.856$	0.434
Configuration x search condition	$F(2,32) = 0.012$	0.988
Set size x configuration x search condition	$F(2,32) = 1.927$	0.162

A repeated measures ANOVA was carried out on the RTs with set size (10 and 16), search condition (full-set baseline, standard preview and location-change preview) and configuration (regular and irregular) as three factors.

As can be seen in Figure 3.3 RTs increased with the increasing set size [$F(1,16)=116.831$, $p<0.001$] and were overall faster on regular configuration trials than on irregular configuration trials [$F(1,16)=18.538$, $p<0.01$]. The search conditions differed from each other [$F(2, 32)=8.383$, $p<0.01$)]. This main effect of search condition was not qualified by any interactions. Hence different search conditions were compared and the results revealed that RTs for the full-set baseline were slower compared to the standard preview [t(16)=3.419, p=0.002 – 1-tailed] and the location-change preview condition [t(16)=2.761, p=0.007 – 1-tailed]. The two preview conditions did not differ from each other [t(16)=-0.692, p=0.249 – 1-tailed].

The two-way interaction between set size and configuration failed to reach significance [F(1,16)=2.334, p=0.134]. No other interactions reached significance [Fs<1].

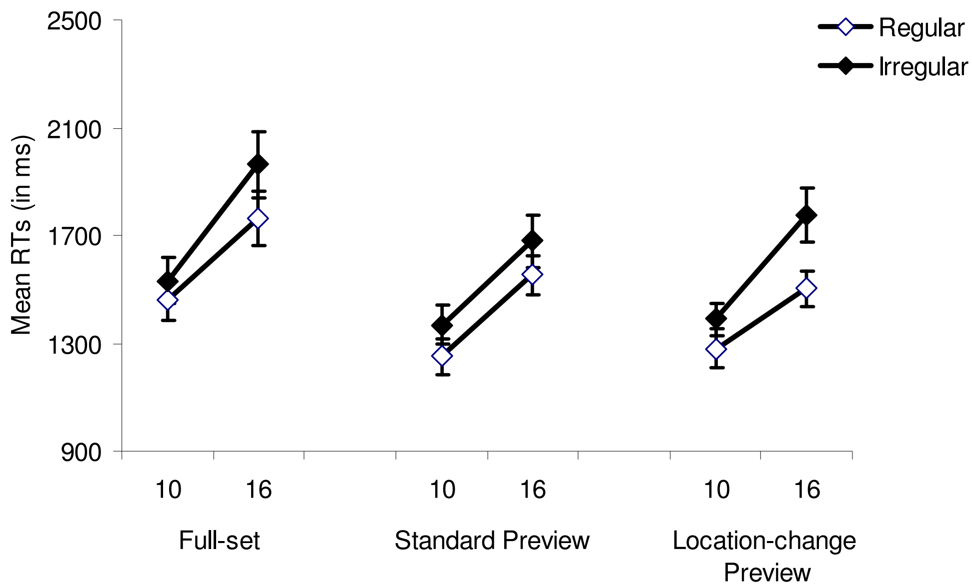

Figure 3.3: *RTs as a function of set size (Experiment 3.2). Open symbols represent regular trials and filled symbols represent irregular trials. Set sizes and search conditions are drawn on the x-axis.*

Across experiment analysis

Data across Experiments 3.1 and 3.2 were analysed in a mixed ANOVA with experiment as a between-subject factor and set size, search condition and configuration as within-subject factors. The between-subject factor (experiment) interacted significantly with search condition [F(2,74)=7.886, p<0.01]. In Experiment 3.1 RTs in the standard preview condition were faster compared to full-set [$t(21)=5.502$, $p<0.001$; 1-tailed] and location-change preview [$t(21)= -4.952$, $p<0.001$; 1-tailed] conditions whereas the latter two conditions did not differ from each other [$t(21)=0.415$, $p=0.341$; 1-tailed]. However, in Experiment 3.2 both the preview conditions were faster compared to the full-set baseline (statistics are discussed in the section above). The interaction mainly occurred because of the location-change preview condition. As is evident from Figure 3.1, participants were slower in the location-change condition in Experiment 3.1. Perhaps the visible movement from the preview to the search display captured their attention and slowed RTs. This location-change was masked by the brief transient in Experiment 3.2 which might have helped to reduce interference caused by the location-change, enabling participants to speed their responses.

Discussion

The aim of this experiment was to see if the configural effects observed in Experiment 3.1 persisted when the preview search was offset by a brief blank interval. The blank introduced a dynamic change between the preview and search displays, which Kunar et al. (2003c) found was sufficient to 're-set' preview search. At least in terms of the slopes of the search functions, the present results support this finding. There was no evidence for a benefit in search efficiency for either of the previews compared with full-set baseline in Experiment 3.2. There was however a benefit in terms of overall RTs, and there was also an overall effect of configuration on RTs. These overall benefits on search could arise for several reasons. One is that participants initiate search more quickly under preview conditions and when a regular configuration is present, perhaps because the preview provides a temporal warning signal for search and a regular configuration provides a spatial anchor from which to initiate the search process. An alternative is that there is a change in the response criterion after a preview or when a configuration is present – though the reason why this should be the case is unclear. The loss of the preview benefit and regularity effect on search efficiency, though, is consistent with preview search being re-set when a strong transient is present – here even when there is a configuration available to facilitate suppression of the old items.

General Discussion

The experiments in this chapter were aimed at studying the effect of a transient (brief offset by a blank interval in this case) on configural effects in search. Experiment 3.1 showed that regular configurations had a significant impact on performance in "location-change" preview search. This suggests that regular configurations helped participants to maintain an object-like representation in the presence of a location change and this enabled them to maintain the preview benefit in search. In light of these findings, Experiment 3.2 was aimed at studying whether the presence of regular configurations could override the effects of an offset of the preview produced by a brief blank interval between the preview and the search display. The results showed that this was not the case: the presence of regular configurations, though speeding the overall RTs, did not help overcome the effect of the brief offset. In terms of search slopes there was no preview benefit in either of the preview conditions compared to the full-set search. This held for regular and irregular configurations alike indicating that the location-based and the object-based suppression observed in the Experiment 3.1 was overridden by temporal grouping by the transient when the old items were offset briefly and reappear with the new stimuli. Participants, however, were faster in the preview conditions than in the full-set baseline condition. These intercept effects obtained for regular configurations and the preview conditions reveal the effect of processes that occur before the beginning of search or between the termination of search and production of the response. For example, the preview search might have provided a temporal cue to the participants to start searching and regular configurations might have spatially anchored the start of search. In essence, the participants were better prepared to search in the preview conditions compared to full-set search where no such cues would have been present owing to the simultaneous presentation of the items. Alternatively, a change in the response criterion could have resulted in the intercept effects observed. In total, the results from Experiment 3.2 suggest that the presence of regular configurations was not sufficient to override the effect of the brief transient between preview and search display. Notably, the blank completely took away the preview benefit found in Experiment 3.1. Thus it appears that any memory of the preview is effective only when certain conditions are satisfied (e.g. under conditions of occlusion; see Kunar et al., 2003c). Clearly a regular configuration on its own is not sufficient to override the effect of a strong transient without adhering to other principles that define objects and their spatio-temporal continuity. In addition, temporal grouping might have been stronger than configural grouping in the presence of a transient overriding any benefit from configuration coding.

CHAPTER 4

ATTENTIONAL CAPTURE VERSUS DISTRACTOR REJECTION: THE ROLE OF CONFIGURAL GROUPING

Abstract

The previous two chapters discussed how configural grouping by regularity can modulate distractor rejection in search over space and time. There is also evidence, however, that some perceptual groups attract attention automatically and can produce a cost in target detection/report (Kimchi et al., 2007; Rauschenberger and Yantis, 2001; Yeshurun et al., 2009). The stimuli in the distractor-rejection and distractor-capture studies, however, have not been matched, and so the relations between capture and suppression in search are poorly understood. The aim of the studies presented in this chapter was to examine the effect of grouping based on different stimulus properties on search, and to assess how grouping modulated both attentional capture and distractor rejection. The results revealed that, depending on the task and stimulus conditions, perceptual groups defined by closure and pattern similarity could be rejected efficiently after they capture attention.

Introduction

Chapters 2 and 3 demonstrated that configural grouping helps in rejecting distractors thereby facilitating responses to targets in visual search. Notably, preview search was faster in displays with regular configurations of previewed distractors compared to displays with irregular configurations (see also Kunar et al., 2003b). The regular configurations presented in Chapter 2 and 3 occupied positions that defined geometrical patterns such as a square or a trapezium. The grouping of the elements within the configurations was also manipulated. When elements grouped by a global attribute (in this case grouping by global orientation), distractor rejection was easier in the preview conditions compared to when the elements grouped based on just the local orientations. When the configuration appeared simultaneously with the other search elements (in full-set search) any effect of the configuration lessened. In contrast to this, there is evidence that perceptual groups defined globally can be attention capturing even when they appear with other display elements (Rauschenberger and Yantis, 2001; Kimchi et al. 2007; Yeshurun et al. 2009). Rauschenberger and Yantis (2001) reported results showing attentional capture by a globally defined object (a square induced by partly segmented disks, “pacmen”) while performing a task at the local level (detecting a semi-disk). On half the trials these pacmen induced a square, whereas on the remaining trials a global shape was not induced. RTs to the target were slowed on the trials when the shape was induced, indicating attentional capture by the globally defined object. Kimchi et al. (2007) and Yeshurun et al. (2009) also provided evidence in support of attentional capture by perceptual objects. Their studies used stimuli made up of differently oriented capital Ls which, on some trials, formed a square or a diamond. Responses to probes/targets presented within these perceptual objects were facilitated compared to when the probes/targets appeared outside the objects. The conditions that lead to disruptive or beneficial effects of distractors grouping into configurations are currently not understood. Nor do we understand how automatically these effects occur. The present study aimed to address these issues using displays where all the elements appeared simultaneously.

Attentional selection / capture by stimulus-driven factors

Previous research has shown that several factors capture attention in a stimulus-driven manner such as abrupt onsets (Yantis and Jonides, 1984, 1990), motion change (Hillstrom and Yantis, 1994) and local colour differences (Folk, Remington and Wright, 1994). In most of these studies participants were asked to search for a pre-specified target in an array. On the critical trials the array would contain an additional singleton (a unique element among a set of items). When this additional singleton is an irrelevant distractor RTs are slowed down to report the target (Theeuwes, 1991, 1992). This suggests involuntary selection of the singleton feature, or the object itself, even when participants know that the feature or object is irrelevant to the task being performed.

Although these effects appear to be quite robust, they are not immune to top-down attentional control / strategies. This is demonstrated by work on so-called ‘contingent capture’ showing that the likelihood of a singleton feature capturing attention is increased if the feature fits the ‘attentional set’ of the observer (Folk et al., 2002, 1992).

The present chapter is focused on attentional capture produced by perceptual grouping (Rauschenberger and Yantis, 2001; Kimchi et al 2007; Yeshurun et al. 2009), which is less studied than capture by feature-defined singletons. Here, the question of whether attentional capture by perceptual grouping is modulated by top-down strategies was addressed. I was also interested in studying whether a group of homogeneous elements forming a configuration attracts attention, as there is evidence from visual search for homogeneous groups being selected efficiently (e.g., Duncan and Humphreys, 1989; Humphreys et al., 1989), but it is not known whether these elements automatically attract attention when they form an irrelevant group. A search task was used in these studies which had Ls and Ts as distractors and targets respectively. Experiment 4.1 looked at the effect of three square configurations (closed square, homogeneous and heterogeneous configurations) on search performance when a target appeared outside these configurations. The results did not show any evidence for attentional capture which might have been due to the target being always outside the configuration. Hence, Experiment 4.2 looked at whether having the target inside these configurations (on half the trials) changes their influence on search performance. Experiment 4.3 explored effects of density around the target on the configural effects.

EXPERIMENT 4.1: Configural coding based on different grouping principles: Effects of closure, similarity and location grouping in search

Method

Participants

Twelve participants (9 females; mean age: 27 years) took part in this study in exchange for course credits. They were all post-graduate students of University of Birmingham. All reported normal or corrected - to - normal vision.

Stimuli

The stimuli were created and presented in Matlab using psychophysics toolbox (Brainard, 1997; Pelli, 1997). Capital Ls and Ts were used and the capital letter L was rotated 0, 90, 180, 240 degrees to create different distractors. The target was either an upright capital T or an upside down T (0.57° x 0.57°). Each line was 2 pixels wide. The letters were drawn in black on a gray background.

Three different square configurations were created from the distractor Ls: (i) a closed object (Figure 4.1A) (ii) a heterogeneous configuration (Figure 4.1B), and (iii) a homogeneous configuration (Figure 4.1C). The heterogeneous condition was designed as a baseline for the other configural conditions.

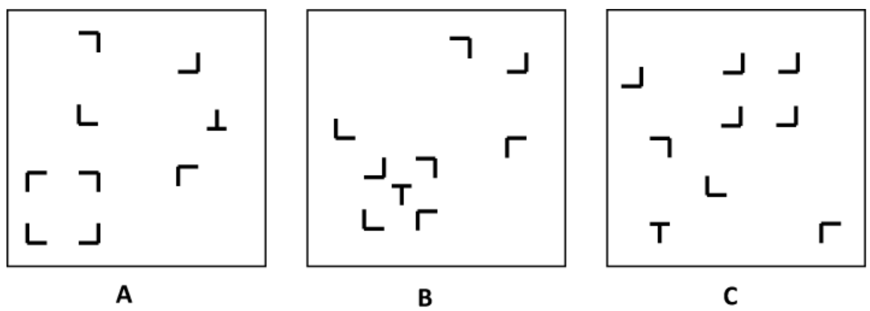

Figure 4.1: *Example displays used in Experiment 1 (target always appeared outside the configuration: A and C) and Experiment 2 (the target appeared inside the configuration on 50% of the trials: B). (A) Closed configuration (target-outside trial); (B) Heterogeneous configuration (target-inside trial); (C) Homogeneous configuration (target-outside trial).*

Each display contained 9 items. Each distractor was repeated twice (once in the configuration and once in the remaining distractor group) in the closed and heterogeneous conditions. Since the homogeneous configuration was made up of identical distractors, only one distractor type occurred in the configuration on any one trial (other distractors were varied, see Figure 4.1C), but the identity of the repeated letter was counterbalanced for the different letter shapes across the block.

Procedure

Each trial started with a fixation cross presented for 500 ms. The search display then followed for 200 ms. Participants were asked to fixate and report the identity of the target (an upright T or an upside down T) - both accuracy and speed being emphasised. The subsequent trial started after an interval of 1000 ms. Participants pressed the “X” key on the keyboard for an upright T and the “M” key for an upside down T. The experiment consisted of 960 trials presented in 10 blocks (96 trials in each). Each block contained an equal number of trials for the three trial types and both target types. Participants completed a block of 30 practice trials before completing the main experimental session.

Results

Incorrect RTs were removed from the analysis. The error percentages were 10.68%, 12.34%, and 11.07% for the closed, heterogeneous and homogeneous conditions respectively. An ANOVA on these errors did not reveal any effect of configuration [$F(2,22) = 2.613$, $p = 0.096$].

RTs less than 200 ms and more than two standard deviations away from the mean were excluded and resulting mean RTs were analysed in a one-way repeated measure ANOVA with the factor of configuration display type (closed, homogeneous and heterogeneous). There was a main effect of the type of configuration [$F(2,22) = 4.921$, $p < 0.05$]. Planned comparisons (in t-tests) revealed that participants were faster when the distractors formed a closed or a homogeneous configuration compared to heterogeneous configurations [closed vs. heterogeneous: $t(11) = -2.917$, $p<0.01$ – 1-tailed; homogeneous vs. heterogeneous: $t(11) = 2.882$, $p<0.01$ – 1-tailed]. RTs on the closed and homogeneous configuration trials did not differ [$t(11) = -0.188$, $p=0.427$ – 1-tailed] (see Figure 4.2).

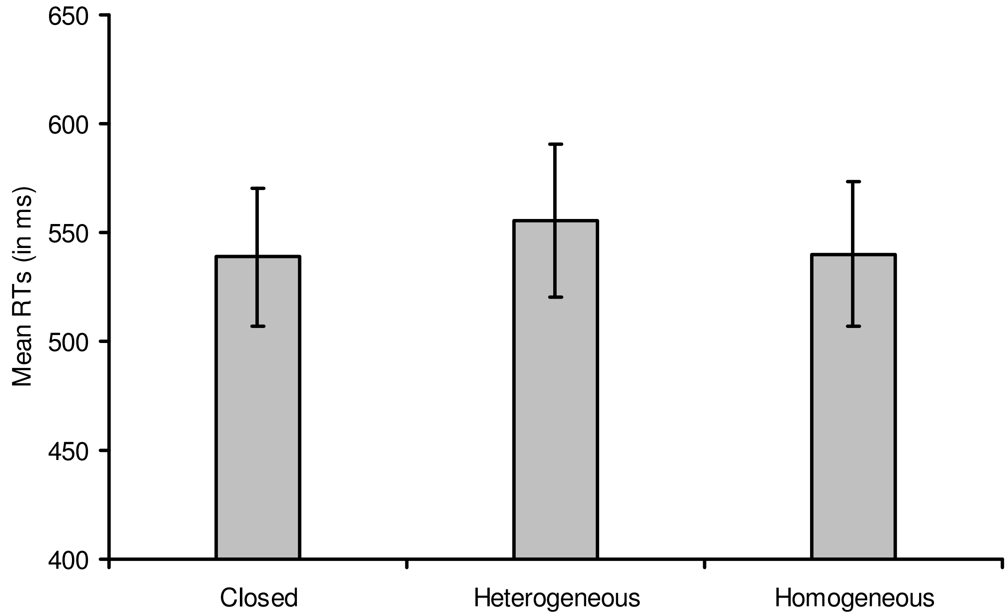

Figure 4.2: *Mean RTs shown for each configural type (Experiment 4.1).*

Discussion

The results showed that the three configurations influenced search differently. Participants were less efficient in discarding distractors in the baseline heterogeneous condition compared to when the distractors formed homogeneous and closed configurations. Kimchi et al. (2007) and Yeshurun et al. (2009) found that closure captured attention and slowed the response when the target was outside the configuration. The current data appear to contrast with this, since performance appeared better with a stronger configuration (with the closed and homogeneous displays, compared with the heterogeneous displays). However, in the present study the target always appeared outside the configuration rather than sometimes falling inside and sometimes outside (as in Kimchi et al. 2007; Yeshurun et al. 2009). Hence, it is possible that strong configurations captured attention but participants might have quickly disengaged attention, since they knew that it would not pay to scrutinise the display.

Alternatively, the configuration might have been computed but suppressed as never containing the target. At least some theories of search suppose that participants can code an inhibitory template which can be used to filter out matching distractors (e.g., Watson and Humphreys, 1997; Treisman and Sato, 1990; Dent, Humphreys, and Braithwaite, 2011). The application of an inhibitory template here could lead to improved selection. To assess whether a disengagement or suppression strategy was adopted, Experiment 4.2 used similar displays but presented the target inside the configuration on half of the trials. If closure captures attention automatically, and attention is then engaged there (as the target could be present), it follows that RTs to targets inside the configuration should be faster rather those to targets outside the configuration. This effect may be stronger with closed and homogeneous configurations than with heterogeneous configurations. Capture may then slow RTs to closed and homogeneous configurations relative to heterogeneous displays, when the target is outside rather than inside the configuration. That is, there may be opposite patterns of configuration effects for the target inside and outside conditions.

EXPERIMENT 4.2: Target location uncertainty and its effect on capture by configuration

Method

Participants

Fourteen participants (10 females) in the age range of 16-37 took part in the study (mean age: 21 years). They were post-graduate students from University of Birmingham and student volunteers from Cadbury College, Birmingham. All of them reported normal or corrected to normal vision. Students from University of Birmingham received course credit for their participation.

Stimuli

The stimulus details remained similar to Experiment 4.1 except that half of the trials now contained the target inside the configuration (Figure 4.1B). Each configuration type had an equal number of target inside / outside trials and both target types (an upright or an upside down T) appeared equally often within these trial types.

Procedure

The procedure also remained the same as in Experiment 4.1. Each block contained 96 trials split equally among the six trial types (3 configuration types x 2 target locations). Participants completed five blocks giving 480 trials in total.

Results

Errors were entered into a 2 x 3 repeated measures ANOVA with target position (inside / outside) and configuration type (closed, heterogeneous and homogeneous) as the two variables (see Table 4.1). The analysis revealed main effects of target position [$F(1,13) = 6.556$, $p < 0.05$] and configuration type [$F(2,26) = 3.846$, $p < 0.05$]. Errors were greater when the target was presented outside the configuration compared to when the target appeared inside the configuration. Errors also seemed to be greater in the heterogeneous condition compared to closed and homogeneous conditions. The interaction between target position and configuration type did not reach significance [$F(2,26) = 1.636$, $p=0.214$].

Table 4.1 *shows percentage errors in each condition for Experiment 4.2*

	Target position	
Configuration	Inside	Outside
Closed	9.91	13.93
Heterogeneous	15.09	15.63
Homogeneous	12.86	14.55

Analysis on the mean RTs revealed the same pattern as errors. Participants were quicker to respond to the target when it appeared inside the configuration than when it appeared outside of it [$F(1,13) = 94.264$, $p < 0.001$; see Figure 4.3]. Participants were also quicker to respond when the disrtactors formed either a closed or a homogeneous configuration compared to heterogeneous configurations [main effect of configuration: $F(2,26) = 15.095$, $p<0.001$]. There was no interaction between target position and configuration type [$F(2,26) = 2.486$, $p = 0.103$].

Target outside trials from Experiments 4.1 and 4.2 were compared to assess whether the uncertainty of the target position had an effect on performance (Figure 4.4). A mixed ANOVA was performed with Experiment (4.1 and 4.2) as a between-subject variable and configural type (closed, homogeneous and heterogeneous) as a within-subject factor. This analysis revealed a main effect of configuration [$F(2,48) = 12.046$, $p<0.001$]. This factor did not interact with Experiment [$F(2,48) = 1.916$, $p = 0.158$]. The main effect of Experiment was also not significant [$F(1,24) = 0.163$, $p = 0.690$]. Planned comparisons revealed that participants were slower to reject the heterogeneous displays compared to closed [$t(25) = -4.815$, $p<0.001$, 1-tailed] and homogeneous [$t(25) = 3.402$, $p<0.003$, 1-tailed] displays. However, closed and homogeneous conditions did not differ from each other [$t(25) = -1.162$, $p = 0.128$, 1-tailed].

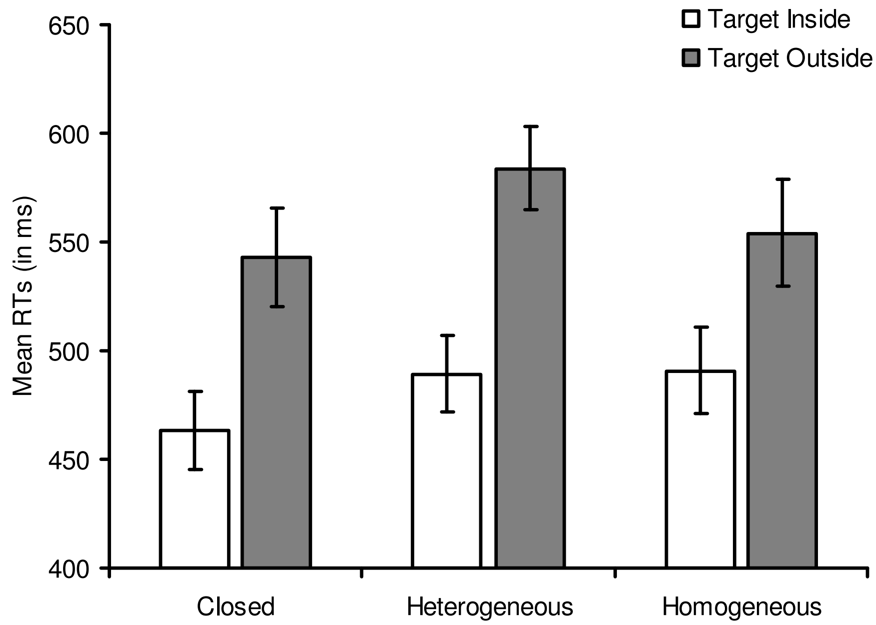

Figure 4.3: *Mean RTs plotted for the three configural types and two target positions. Empty bars indicate target inside trials and filled bars show data from target outside trials.*

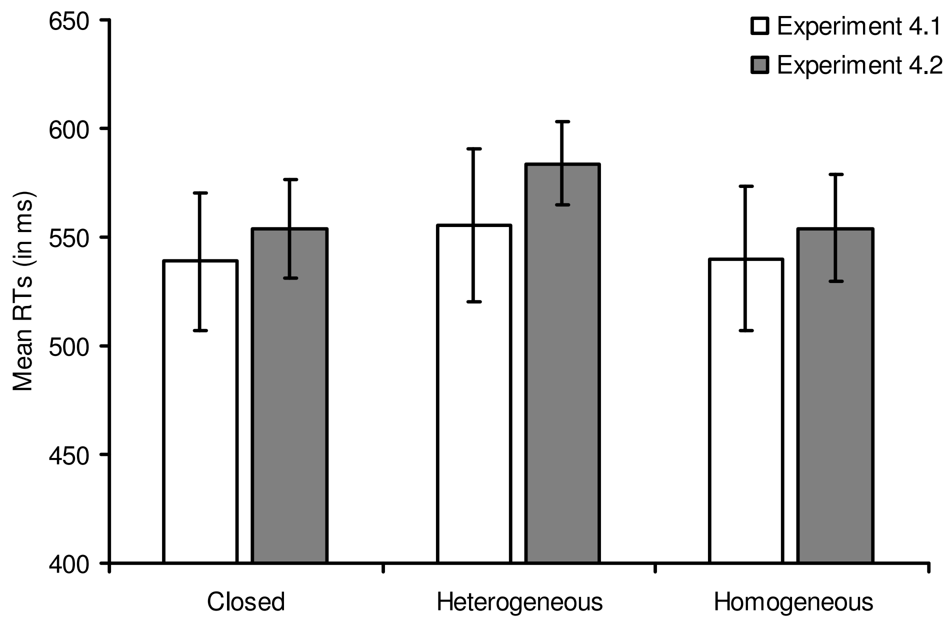

Figure 4.4: *Mean RTs plotted for the three configural types for target outside trials. Empty bars show data from Experiment 4.1 and filled bars show data from Experiment 4.2.*

Discussion

Experiment 4.2 replicated the main result found in Experiment 4.1: homogeneous and closed configurations facilitated target detection compared to heterogeneous configurations. This result occurred even though participants were not able to adopt a strategy here of suppressing the configuration, given that the target appeared within the configuration on half of the trials. Across the experiments, the effects were strongest with closed and homogeneous configurations relative to the heterogeneous stimuli.

In addition to there being a main effect of configuration, there was also an overall advantage for targets falling inside rather than outside the configuration. This suggests that the configuration tended to capture attention, making targets easier to select in the inside condition. However, even when captured by a configuration, the faster rejection of the configural stimulus would speed RTs when the distractors group strongly relative to when the configuration was more difficult to encode (with heterogeneous displays).

Although the data suggest that displays with heterogeneous configurations were more difficult to encode, there remained an effect of whether the target fell inside or outside the configuration for the heterogeneous displays. This might arise because some configural properties were derived from the locations of the elements resulting in attentional capture even when the configuration had heterogeneous elements (e.g., the configuration could be coded from the locations of the stimuli; see Pomerantz, 1983). Alternatively, the effects could stem from the local density of the stimuli. For example, targets falling inside the configuration could lead to an area of high local density in relation to the configuration, cueing attention to that region of the display. This would lead to faster RTs in the inside condition. Differential density across the configuration could also underlie the contrasting performance observed for closed, homogeneous and heterogeneous displays.

Experiment 4.3 set out to test how the configural properties of the stimuli interacted with the density of the display. In this experiment, the target again fell outside the configuration on half the number of trials while the display local to the target was either dense or sparse. Are effects of the configuration modulated by the density around the target? High local density around the target, for instance, could act against any effect of the different configurations if that too is driven by local density. On the other hand, if the configural effect was due to independent coding of the configuration (based on closure, element similarity or element location), the effects of the configuration should remain unchanged from the previous experiment.

EXPERIMENT 4.3: Does density affect configural coding?

Method

Participants

Fourteen participants (12 females, mean age: 21 years) took part in the study. They were all students of University of Birmingham between the age range of 18-33 years. All of them reported normal or corrected-to-normal vision. Participants received course credits in exchange for their participation.

Stimuli and Design

Stimuli remained same from the previous experiment. The design was modified to assess the influence of density on configural effects. The target was either presented along with one or two distractors in its quadrant ('dense' condition; see Figure 4.5A) or on its own ('sparse' condition; see Figure 4.5B) in addition to the target inside condition (Figure 4.1B). Thus, it was a 3 (closed, heterogeneous and homogeneous) x 3 (inside, outside – dense, and outside - sparse) design. The task was again to report the identity of the target (whether T was upright or upside down).

Procedure

The procedure remained the same from previous experiments.

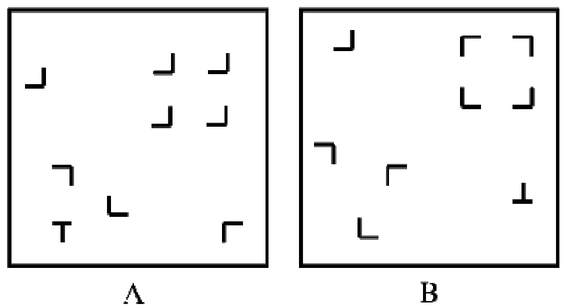

Figure 4.5: *Example displays used in the density conditions of Experiment 4.3 (target always appeared outside the configuration in the (A) dense and (B) sparse displays) and target-inside condition remained the same as in Experiment 4.2*

Results

Since the number of trials was not equal across the conditions, an arcsine transformation was applied on the proportion incorrect data. The resulting values were analysed in an ANOVA with configural type (closure, heterogeneous and homogeneous) and target position (inside, dense or sparse) as two variables. This analysis revealed only a significant effect of configuration [$F(2,26) = 16.971$, $p<0.001$] with the effect of target position [$F(2,26) = 3.095$, $p = 0.08$] and the interaction [$F(4,52) = 0.365$, $p = 0.833$] being non-significant. The main effect of configuration indicated that number of errors was less in the closed and homogeneous conditions compared to heterogeneous condition [$t(13) = -5.151$, $p < 0.001$ and $t(13) = 5.749$, $p < 0.001$ both 1-tailed for comparisons between closed vs. heterogeneous and homogeneous vs. heterogeneous respectively).Closed and homogeneous conditions did not differ from each other in terms of errors [t(13) = -0.478, p = 0.320, 1-tailed].

A repeated measures ANOVA was carried out on the data with configural type (closed, heterogeneous and homogeneous) and target position (inside, outside – dense, and outside - sparse) as the two factors. The main effect of configuration was significant [F(2,26)=7.190, p <0.005]. Heterogeneous configurations (mean RT: 544.43 ms) were harder to reject compared to closed [mean RT: 497.76 ms; t(13) = -3.371, p<0.005] and homogeneous configurations [mean RT: 508.07 ms; t(13) = 2.436, p<0.05] whereas closed and homogeneous configurations did not differ from each other [t(13) = -1.105, p=0.144]. Neither the main effect of target position nor the interaction between configuration and target position reached significance [Fs<1.5] (see Figure 4.6).

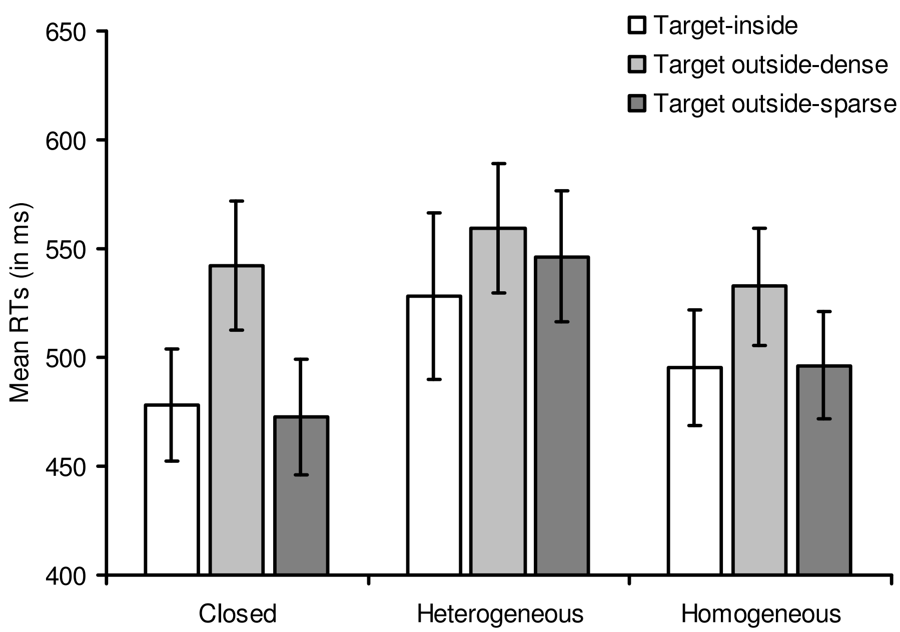

Figure 4.6: *Mean RTs plotted for each configural type. Empty bars represent target inside trials. Grey bars represent target outside–dense trials and black bars show data from target outside- sparse trials.*

Density did not affect the pattern of configural effects found in the previous experiments. Closed and homogeneous configurations continued to facilitate distractor rejection more efficiently compared to heterogeneous displays.

Discussion

The results indicate that, irrespective of the local density of the stimuli, there remained a benefit for targets in closed and homogeneous displays compared with when there was a heterogeneous display. In this study the benefit for targets falling inside the grouped array was not reliable overall though there was a clear trend (Figure 4.6). To provide more power for the analysis, the data for Experiments 4.2 and 4.3 were combined (omitting data from the sparse display condition). There was an overall effect of target position [$F(1,26)=12.729$, $p<0.01$] which did not interact with experiment as a factor[$F(1,26)2.271$, $p=0.144$]. There was also a reliable main effect of configuration [$F(2,52)-12.730$, $p>0.001$] which did not interact with the other factors [largest $F(2,52)=1.24$, $p>0.29$]. The data point to both main effects being robust. The lack of a density effect here makes the results for this factor difficult to interpret, since the manipulation might just have been too weak. Alternatively the result indicates that the configuration effect was independent of density. The additive relation between configuration and target location would then suggest that there is an effect of the configuration (speeding RTs to targets inside relative to outside the configuration) even for heterogeneous displays, and this is not due to confounding by density.

General Discussion

The data across 3 experiments indicate that the presence of both closed and homogeneous configurations can speed search for targets, compared to when the displays contain a configuration of heterogeneous elements. This result occurred when targets were always outside the configuration and when they were equally likely to be inside and outside the configuration, and the size of the configuration effect was not modulated by sometimes presenting the target inside. This in turn suggests that the configuration effects occurred automatically, since any strategic allocation of attention to the configuration should have increased when it could sometimes validly cue the target.

The fact that RTs were speeded by the regular configuration when the target fell outside the shape suggests that, even if a regular configuration attracted attention automatically, it could efficiently be discarded to enable the target to be selected elsewhere. There was no evidence for the cost to performance observed by Kimchi et al. (2007). Whether costs or benefits of a configuration emerge might depend on the difficulty of discriminating the target per se. If the target is easy to discriminate (as in Kimchi et al.'s study) then the configuration might generate a cost to performance since it might compete with selection for the otherwise salient target, slowing RTs to the target. On the other hand, as here, a relatively low salient target may be difficult to select, so that the opportunity to reject a number of distractors together (when they form a regular configuration) boosts performance even if attention is directed to the configuration prior to the target.

Across all three types of configuration the data revealed that RTs were faster to 'inside' than 'outside' targets. This was not modulated by increasing the local density around the target (Experiment 4.3). Rather than variations in local density then, the results indicate that there was some configural coding in all the configuration conditions, so that attention was drawn to the configuration, facilitating RTs when the target fell inside. The speed with which attention capture happened was slower for the heterogeneous configuration relative to the closed and homogeneous displays, but the effect still occurred. This is consistent with configural coding based on the positions of the elements even when the local constituents of the configuration do not group. This would fit with Pomerantz's argument for a position-based coding of a configuration (type P; Pomerantz, 1983).

Finally, the configural effects from homogeneous stimuli were as strong as from closed stimuli. As noted in the Introduction, there is evidence for efficient search of homogeneous displays (Duncan & Humphreys, 1989; Humphreys et al., 1989). The present data suggest that the grouping of homogeneous elements into a configuration can attract attention automatically.

CHAPTER 5

CONFIGURAL PROCESSING AFTER DORSAL DAMAGE: A CASE STUDY

Abstract

Chapter 4 demonstrated the effect of different configuration types on search performance in the normal population. The three configural types tested in Chapter 4 occupied regularly formed positions (square-like) but differed in how they were defined (closure, heterogeneity, and similarity). The results revealed that target detection was more efficient when the distractor configurations were defined by closure and homogeneity compared to heterogeneous configurations even though the elements in all these configurations occupied the same locations. One question that arises from this is whether the configuration was coded automatically without attention, or whether configural coding was influenced by attention. To address this issue, Chapter 5 focused on the effect of closed, homogeneous and heterogeneous configurations on target search in a patient with a spatial bias in attention following damage to the left intra-parietal sulcus (IPS). The data showed that the patient, MH, was sensitive to configural information in his ipsilesional field, but not in his contralesional field. He also showed a selection bias to targets on the right side. Eye-movement data supported the finding that MH was sensitive to configural information in his ipsilesional field. The introduction of colour differences between elements was shown to reduce grouping between homogeneous form elements and to make closed forms difficult to reject. The implications for understanding the effects of attention on configural coding are discussed.

Introduction

Previous studies have shown that some perceptual groups capture attention (Kimchi et al. 2007; Yeshurun et al. 2009). For instance, the presence of an irrelevant group of distractors (a salient configuration) can make participants inefficient at detecting a probe in another location in a search display (Kimchi et al., 2007). Three different conditions were compared in Kimchi et al.'s study; with the probe dot either presented inside or outside the configuration, or no configuration was present. Compared with the no-configuration baseline there was a benefit to performance when the probe fell within the configuration and a cost when the probe fell outside of the configuration. Kimchi et al. (2007) suggested that the configuration captured attention automatically and hence RTs were speeded when the probe appeared within this stimulus. The cost when the probe fell outside reflects the need to reorient attention from the configuration to the probe.

In Kimchi et al. (2007), the configuration took the form of a closed shape. Although closure is an important principle which defines an object, Chapter 4 showed that perceptual groups defined on the basis of similarity (element homogeneity) and location (regularly positioned heterogeneous elements) could also capture attention. Participants were more efficient in responding to the target when it was presented within a closed or a homogeneous configuration compared to a heterogeneous configuration, but for all the different configurations performance was also better than when targets fell inside rather than outside the stimuli. Thus effects of configuration emerged in each case, though there were overall benefits for the closed and homogeneous stimuli.

In Kimchi et al. (2007) the presence of the configuration disrupted performance for 'outside' targets, consistent with the configuration being computed automatically (when it would have been beneficial to not compute it). However, does this mean that formation of the configuration was not modulated by attention? This result cannot be concluded from Kimchi et al.'s study. Note that participants had to detect the probe at any display location and so should have distributed their attention broadly so that, even though irrelevant to performance, any configuration may still have been attended. On the other hand, there is research indicating that configural coding can take place without attention (Vuilleumier and Landis, 1998). Some of the strongest arguments for this come from studies using neuropsychological patients who are impaired at attending to one side of space following a brain lesion. There is evidence, for instance, that patients who neglect or show extinction on one side of space (and so would be unaware of a stimulus falling on the side contralateral to their lesion) are nonetheless sensitive to the grouping of elements in contralesional space (e.g., Gilchrist et al., 1996; Mattingley et al., 1997; Ward et al., 1994) or are only aware of stimuli whose elements group (Humphreys et al., 1994). On the other hand there is also evidence that such patients show a weaker than normal neural response to contralesional stimuli that group (Han and Humphreys, 2007). Hence, while aspects of grouping may take place in patients with impaired spatial attention, it does not mean that the grouping effects are normal or that attention has no effect.

The current study tests the relation between grouping and attentional processes in a patient with biased spatial attention following damage to the left intra-parietal sulcus (IPS). Patient MH has previously been reported as having difficulties with perceptual judgements and actions to line orientations and locations (Riddoch et al. 2004). Riddoch et al. also found that MH's ability to detect and localise a target was severely compromised when the oriented lines grouped together. In the acute stage post-lesion MH showed some symptoms of right-side neglect (Humphreys and Heinke, 1998), but this has subsequently resolved into a bias against his right visual field under conditions of bilateral stimulus presentation (e.g., Kitadono and

Humphreys, 2007). In addition to this MH presents with optic ataxia; he has difficulty in reaching to objects by visual guidance, particularly with his right hand into the right visual field (Kitadono and Humphreys, 2007). Posterior parietal cortex (including IPS) has been shown to play a role in the top-down control of attention (Corbetta and Shulman, 2002; Dent, Lestou and Humphreys, 2010; Friedman-Hill, Robertson, Desimone and Ungerleider, 2003). MH's lesion and his specific impairment in the tasks involving orientations (Riddoch et al., 2004) make him a special case to study attentional capture / inhibition of the configurations as the stimuli used in the study comprised of configurations defined by oriented stimuli. The experiments used the stimuli from Chapter 4 and assessed whether the patient, MH, showed equal capture from configural stimuli in his contra- and ipsilesional field, and whether any effects depended on the type of configural information present (e.g. closed forms vs. homogeneous elements vs. heterogeneous items falling in regular spatial locations).

EXPERIMENT 5.1: Configural coding in dorsally damaged patient MH

Method

Case history

Patient MH is a 57 years old male who suffered anoxia at the age of 42 which left him with primary damage to the posterior left parietal sulcus (see Figure 5.1 for an MRI scan).

10 age-matched neurologically healthy controls (mean age: 59 years) were also tested.

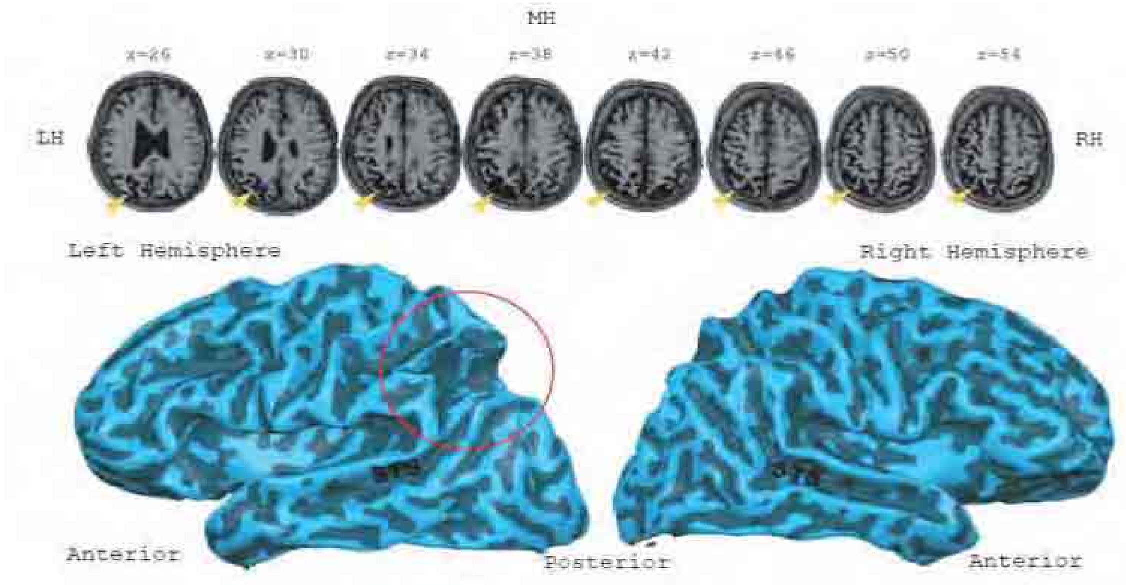

Figure 5.1: *The scans showing the damage resulting from anoxia in MH*

Stimuli

The stimuli were identical to the ones used in Chapter 4. Examples can be seen in Figure 5.3.

Design

Half of the distractors formed a square-like configuration and the remaining four distractors were randomly assigned to different locations (never inside the configuration). The target was presented in one of the two possible positions: on the same side as the configuration (same-field condition; Figure 5.2a and c) or in the opposite visual field (different-field condition; Figure 5.2b and d).

The visual field in which the configuration was presented (ipsi and contra), the type of configuration (closed configuration, heterogeneous and homogeneous) and the target position in relation to the configuration (same field or different field) yielded 12 different conditions. In addition, a baseline condition (Figure 5.3D) was also included where the elements were randomly positioned on the screen. Type of target and field were counterbalanced across trials so that each target appeared in each field equally often.

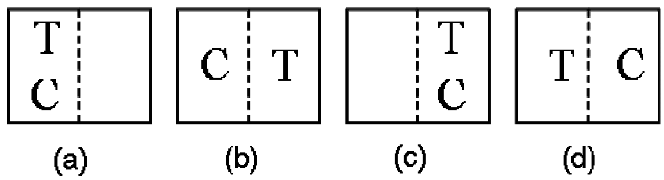

Figure 5.2: *The general design used in experiments in this chapter is depicted here. (a) and (b) represent same-field and different-field conditions respectively when the configuration was presented in the left visual field (ipsilesional field for MH). Segments (c) and (d) represent same-field and different-field conditions when the configuration appeared in the right visual field (contralesional field for MH). Only configuration (C) and target (T) are indicated here to make clear the experimental conditions. In the actual experiment there were other distractors distributed randomly (see Figure 5.3 for specific examples).*

Procedure

Each trial started with a fixation cross ('+') presented for 1000 msec. The search display then followed for 200 msec. The experimenter made sure that MH faced the centre of the screen and fixated on the cross at the start of every block. MH responded with his left hand (middle finger for 'upright T' target and index finger for 'upside down T' target). There was a 2000 msec interval after each response. Each block consisted of 96 trials (24 trials in baseline condition).

The controls responded with their forefingers from each hand, using the 'X' key for an upright target (T) and the 'M' key for an upside down target. Accuracy and RT data were collected but only accuracy data were further analysed to allow comparison with MH's results. MH performed below chance level in some of the conditions and hence accuracy data was chosen as a better indicator of the effects.

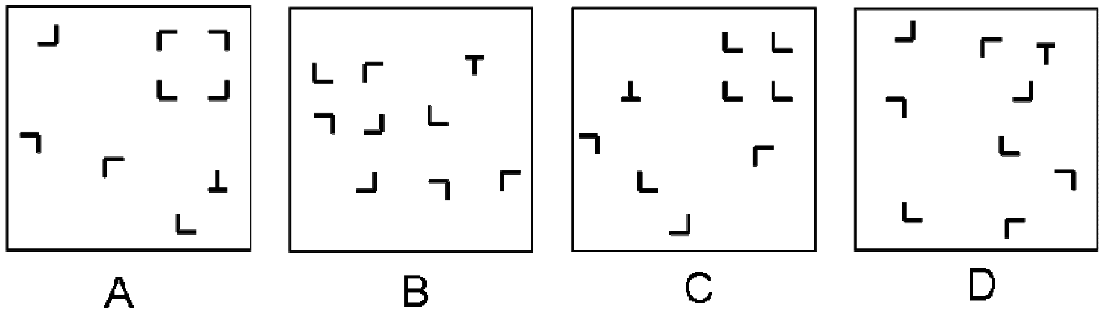

Figure 5.3: *Examples of displays used in Experiment 5.1 and 5.2 (elements were coloured in Experiment 5.2). (A) Closed configuration in the contralesional field (same-field condition); (B) Heterogeneous configuration in the ipsilesional field (different-field condition); (C) Homogeneous configuration in the contralesional field (different-field condition) ; and (D) Baseline condition (no configuration).*

Results

Controls

The data were entered into a three way repeated measures ANOVA with the following variables: field in which the configuration was presented (left / right), configuration type (closed / heterogeneous / homogeneous), and target location (same field / different field). Controls' performance in the baseline condition (where no configurations were present) was 0.76 (proportion correct).

The analysis on the configuration conditions revealed a significant effect of target position [$F(1,9)=10.555$, $p<0.05$]. Accuracy was higher in the different-field condition compared to when the configuration and target appeared in the same field (Figure 5.4). There was no effect of the field [$F<1$] or configural type [$F(2,18)=2.405$, $p=0.382$]. The interaction between configural type and target position failed to reach significance [$F(2,18)=2.402$, $p=0.119$]. All other interactions also failed to reach significance [$Fs<1$].

Controls failed to show any effect of configural type (but see Appendix 2) though there was an effect of target position. Target detection was much better when the configuration and the target appeared in the two different hemifields compared to when both were presented in the same hemifield.

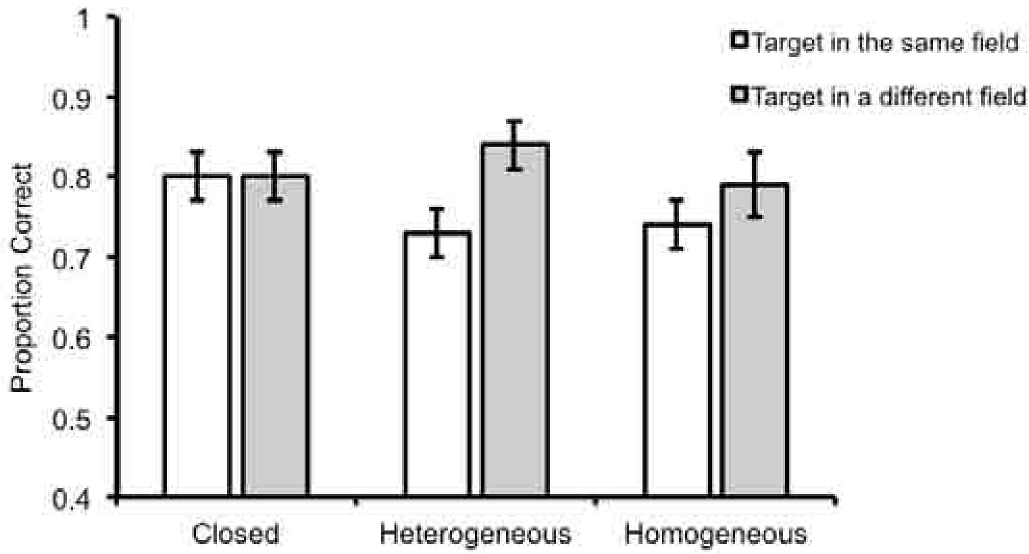

Figure 5.4: *Accuracy data from age-matched healthy controls for Experiment 5.1. The data presented were collapsed across left and right visual fields as there was no reliable effect of field. Configural types are depicted along the x-axis. Empty bars represent the trials where configuration and the target were presented in the same visual fields whereas filled bars represent data from trials where configuration and the target were presented in separate visual fields.*

MH

The proportions of correct responses from the baseline condition (where no configurations were present) were entered into a t-test which revealed no significant difference between the accuracy across the two visual fields [$t(2) = -0.832$, $p = 0.493$; mean proportion correct: ipsi: 0.59, contra: 0.65].

Data from the configuration conditions were entered into a log linear analysis (see for an example Gillebert and Humphreys, 2008). Log linear analysis is typically used where one finds categorical data for example, correct or incorrect as response variable and left or right field as explanatory variable. These variables are nominal and there is no ordering between them. Log linear analysis looks for association between the variables in the context of categorical data. Since the data obtained with MH was categorical in nature, a log linear analysis was carried out with the following variables: field in which configuration was presented (ipsi and contra), type of configuration (closed configuration, heterogeneous, and homogeneous), target position in relation to configuration (same field / different field) and accuracy (correct or incorrect). This analysis gave a best fitting model [$\chi^2(8) = 6.570$, $p = 0.584$] that included two interactions: (i) field in which the configuration was presented x type of configuration x accuracy [$\chi^2(2) = 8.867$, $p < 0.05$] and (ii) field in which the configuration was presented x target position x accuracy [$\chi^2(1) = 58.623$, $p < 0.001$]

Separate three-way (type of configuration, target position in relation to configuration and accuracy) log linear analyses were performed for each visual field, to break down the interactions.

Configuration in the ipsilesional field (LVF): The best fitting model [$\chi^2(4) = 2.030$, $p = 0.730$] revealed by the log-linear analysis involved two separate interactions: configuration x accuracy [$\chi^2(2) = 14.704$, $p < 0.01$] and target position x accuracy [$\chi^2(1) = 52.333$, $p < 0.001$]. MH was more accurate in finding the target when closed and homogeneous configurations were present compared to heterogeneous configurations [configuration x accuracy: $\chi^2(1) = 8.599$, $p < 0.01$ and $\chi^2(1) = 12.735$, $p < 0.001$ respectively for closed and homogeneous conditions in comparison with heterogeneous condition]. The closed and homogeneous conditions did not differ from each other [$\chi^2(1)<1.0$; Figure 5.5]. The target position x accuracy reflected that, with the configuration in his ipsilesional field, MH was more accurate at finding a contralesional target (the different field condition) than an ipsilesional target (same field condition) as shown in Figure 5.5.

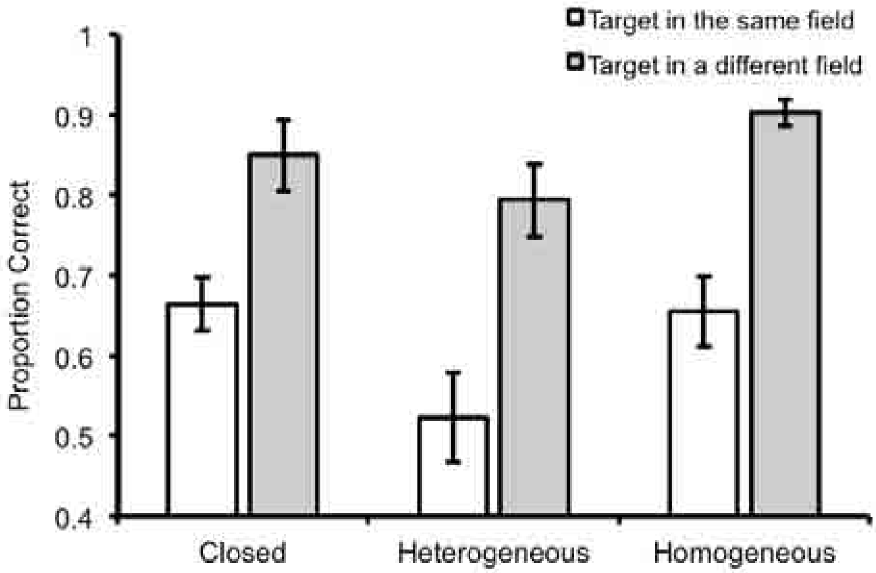

Figure 5.5: *Proportion correct data from MH in Experiment 5.1 for each configural type (on the x-axis) and the two target positions when the configurations were presented in his ipsilesional field (LVF). Empty bars represent trials where target was also presented in the ipsileisonal (same-field) and filled bars represent data from trials when the target was presented in the contralesional field.*

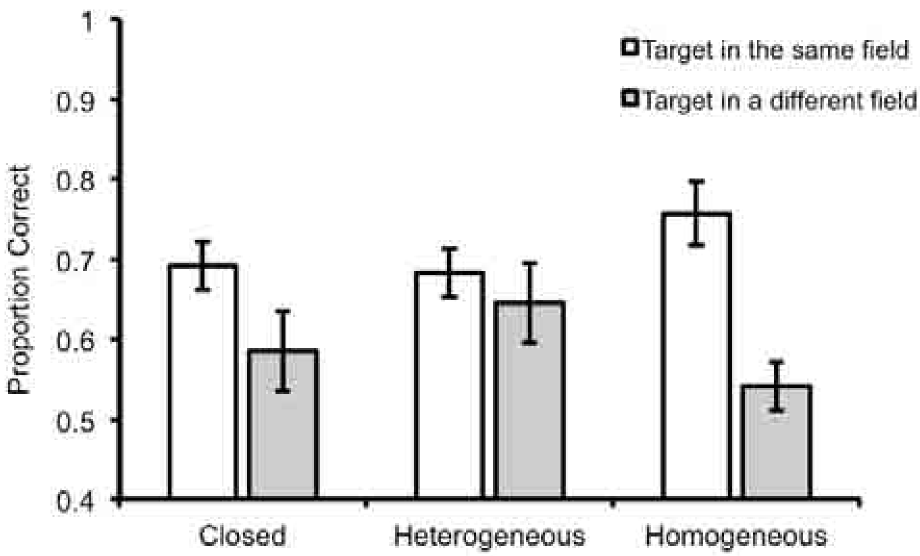

Figure 5.6: *Proportion correct data from MH in Experiment 5.1 for each configural type (on the x-axis) and the two target positions when the configurations were presented in his contralesional field (RVF). Empty bars represent trials where target was also presented in the contralesional field (same-field) and filled bars represent data from trials when the target was presented in the ipsilesional field.*

Configuration in the contralesional field (RVF): The best fitting model included an interaction between target position and accuracy [$\chi^2(8) = 4.957$, $p = 0.762$]. MH was more accurate when both the configuration and the target appeared in the contralesional field (in the same field condition) compared to when the target was in the ipsilesional field [$\chi^2(1)=11.797$, $p<0.01$]. Configural types did not influence his performance (Figure 5.6).

The results showed that MH was more sensitive to the configurations in his ipsilesional field. MH was more accurate in finding the target if the configuration presented in his ipsilesional field was either closed or homogeneous. However, no such sensitivity was found for configurations in his contralesional field. Also, there was a benefit for targets appearing in the contralesional field. To further test whether configural effects found in MH's results were significantly enhanced compared to controls, a modified F test (Hulleman and Humphreys, 2007) was applied. This test has been shown to be more effective while comparing a single case to a group of controls. It adjusts the confidence level and F values to account for the differences in the variance of a single case and that of a group of participants. Accuracy difference between the configurations where best and worst performance was found was calculated (closure – heterogeneous and homogeneous – heterogeneous since MH was better with closed and homogeneous compared to heterogeneous configurations) for MH and the controls. The difference in the scores was significant [$F(1,9)$ adjusted $= 1.55$, $p<0.05$, two tailed] between MH and the controls when the difference between homogeneous and heterogeneous configurations was considered in the ipsilesional field (configurations appeared in the left field and the target appeared in the right field; see Figure 5.2b). MH showed an increased sensitivity to homogeneous configurations compared to controls in this condition. Comparisons in the other experimental conditions proved to be non-significant [$Fs<1$].

Eye-movements

In addition to the experiment described above, eye-movement data were collected from MH. MH was surprisingly better at detecting the right field targets despite it being his contralesional side where he shows extinction under brief exposures. Nevertheless, MH remained sensitive to the configural information only in his ipsilesional field. Hence, eye-movements were collected for the same experimental conditions described above to see if the pattern of eye-movements could explain some of the results.

Equipment and Procedure

An EyeLink 1000 (head supported) eye-tracker (SR Research - Eyelink©), was used to run the experiment. The experiment was written and presented using MatLab and Eyelink Toolbox extensions (Brainard, 1997; Pelli, 1997; Cornelissen, Peters & Palmer, 2002; see http://psychtoolbox.org/). Data were collected in several short blocks to avoid fatigue and calibration was done before the beginning of each block. Stimulus presentation details remained the same as before.

Results

Data for the direction of the first fixation on a trial were analysed to see if MH showed a bias to the contralesional space (right field) as a compensatory mechanism to deal with his impairments. The results indicated that MH did show a tendency to look towards the contralesional space first but to some extent this behaviour was influenced by what was present in the visual field. Details are discussed below. Dwell time (average fixation duration) on the configuration was also computed to see whether dwell time differed for the different configurations and visual fields. Finally the average number of fixations was also looked at to supplement the results from other measures.

Analysis of direction of first fixation

MH was more accurate when the target was in his right field in spite of it being his contralesional side as seen in the previous results section. One explanation for this could be that he has developed a strategy to compensate for the impairments in his contralesional field by directing his eye-movements to this field. Hence, the direction of first fixation for each trial was analysed. Direction of first fixation data in the baseline condition (where no configurations were present) revealed that MH indeed showed a bias to the contralesional side [$\chi^2(1) = 47.320$, $p<0.001$] irrespective of the target position (ipsi / contra). Data from configuration conditions were then analysed to see if his bias was influenced by configuration and the target position. Three-way log-linear analysis was carried out with the following variables: field in which configuration was presented (left / right), target position (same field as configuration / different) and type of configuration (closed, heterogeneous, homogeneous). This analysis revealed a significant two-way interaction between field of configuration and target position [$\chi^2(1) = 17.225$, $p<0.001$]. Analysis on the same-field trials revealed a difference between the directions of fixation across the two fields. There were more first fixations to the ipsilesional field when the configuration and the target appeared in the ipsilesional field compared to when configuration and the target appeared in the contralesional field [$\chi^2(1) = 43.464$, $p<0.001$]. However, there was no difference in the directions of fixation on the different-field trials. First fixations were largely directed to the contralesional field [$\chi^2(1) <1$] (see Figures 5.7 and 5.8).

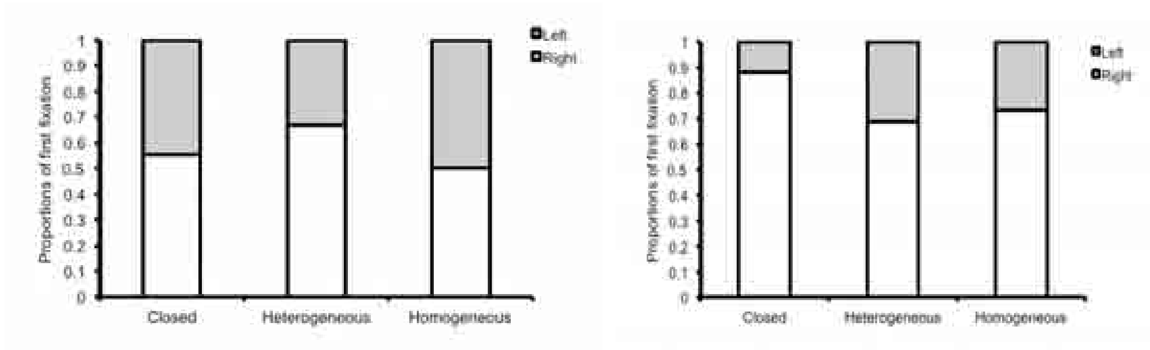

Figure 5.7: *Proportions of first fixations to the ipsilesional field (indicated by darker bar) when the configuration was presented in the ipsilesional field while the target position varied. Left segment shows data when the target was also presented in the ipsilesional field and right segment shows data when the target was presented in the contralesional field.*

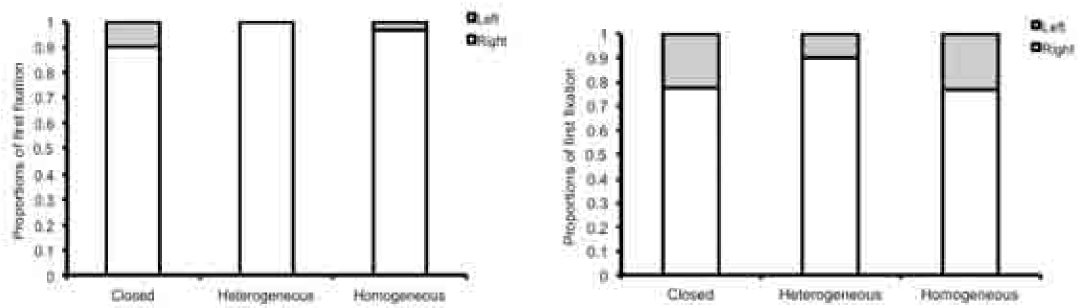

Figure 5.8: *Proportions of first fixations to the ipsilesional field (indicated by darker bar) when the configuration was presented in the contralesional field while the target position varied. Left segment shows data when the target was also presented in the contralesional field and right segment shows data when the target was presented in the ipsilesional field.*

Dwell time analysis

Each dwell time was treated as a separate subject (Young et al., 1987). A between-subject ANOVA was carried out on this data which revealed a significant main effect of field [F(1,261) = 21.043, p<0.001]. Dwell times on the configuration were longer in the ipsilesional field (232 ms) compared to contralesional visual field (200 ms). Field also interacted with target position [F(1,261) = 3.760, p=0.05]. This interaction was analysed further by comparing the two fields (ipsi / contra) on the same-field trials and different-fields separately. These analyses revealed a difference between the fields under both the conditions (same-field condition [$F(1,140) = 4.470$, $p<0.05$]; different-field condition [$F(1,129)=15.842$, $p<0.001$]). On different-field trials configurations in the ipsilesional field captured attention compared to configurations in the contralesional field (dwell time- ipsi: 239 ms compared to dwell time-contra: 194 ms; see Figure 5.9 and 5.10). The capture was less strong on the same-field trials (dwell time-ipsi: 225 ms compared to 207 ms in the contralesional field; see Figure 5.9 and 5.10). Longer dwell times in the ipsilesional field might relate to MH being more sensitive to the configurations in his ipsilesional field. It could be that to ignore or reject the distractor configuration it first needs to be attended (Humphreys et al., 2004b; Tsal and Makovsky, 2006). Thus longer dwell times may indicate that configurations were first attended before being rejected or ignored. However, the results did not show any differential dwell time across the different configurations.

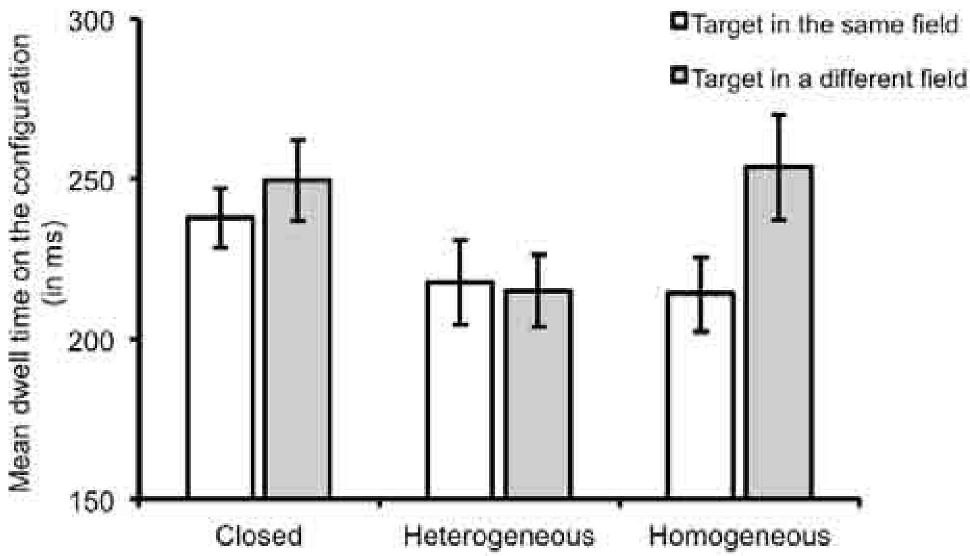

Figure 5.9: *Average dwell times on the configurations when presented in the ipsilesional field*

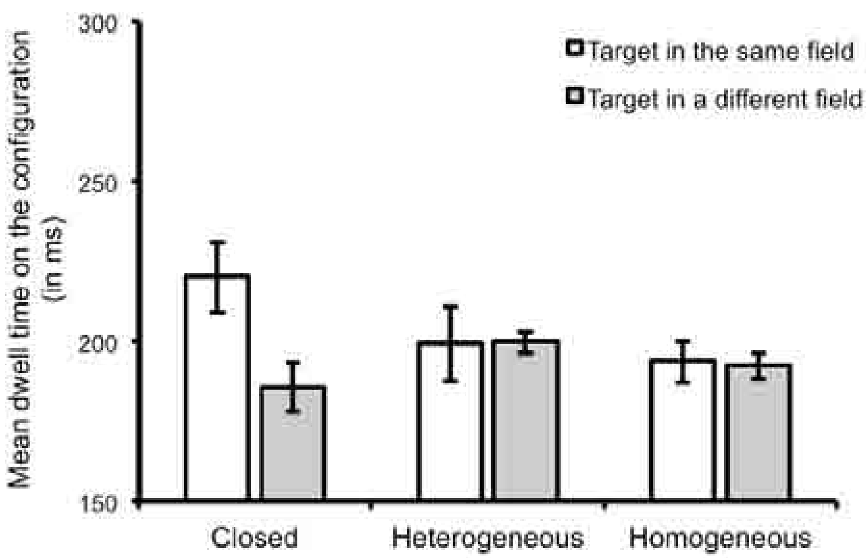

Figure 5.10: *Average dwell times on the configurations when presented in the contralesional field*

The average number of fixations was also greater in the ipsilesional field compared to contralesional field [$F(1,261)=4.339$, $p<0.05$; see Figures 5.11 and 5.12].

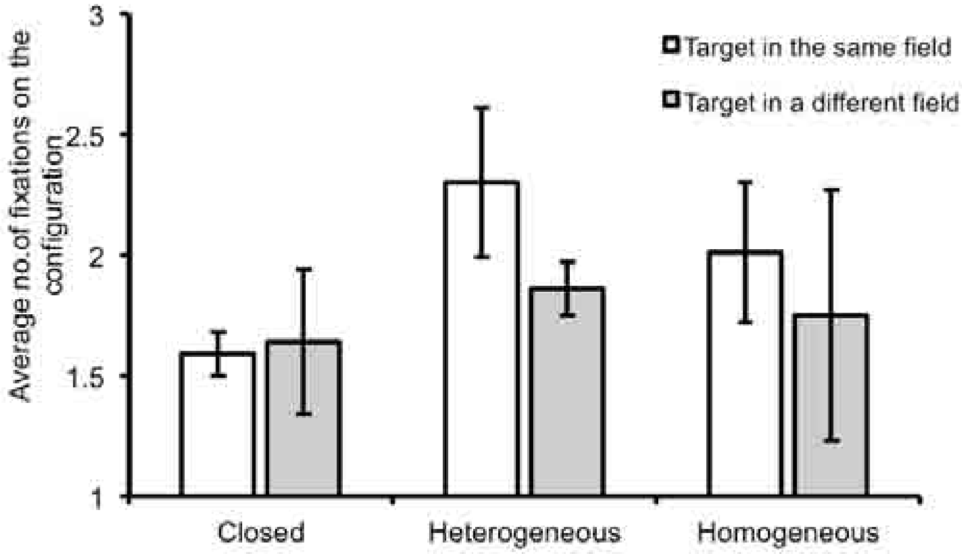

Figure 5.11: *Average number of fixations on the configurations when presented in the ipsilesional field*

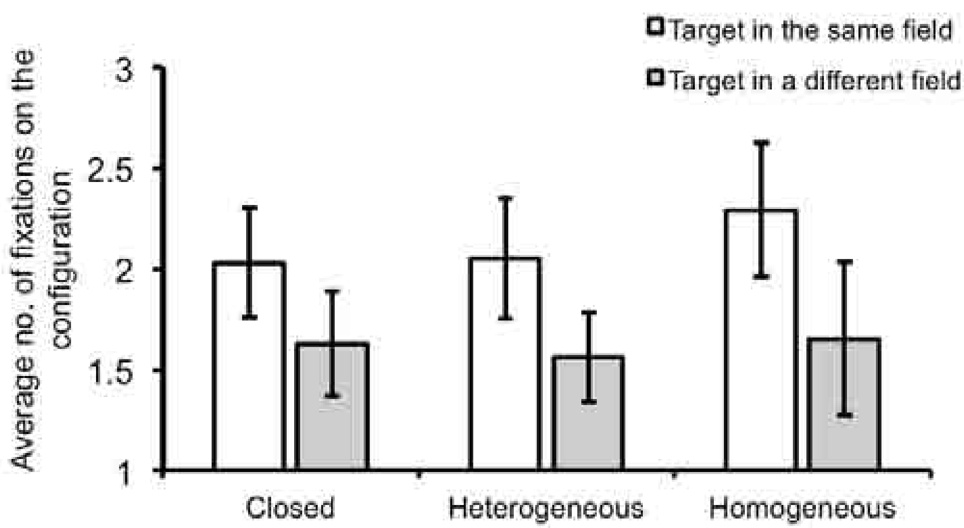

Figure 5.12: *Average number of fixations on the configurations when presented in the contralesional field*

Discussion

Experiment 5.1 revealed the following important findings. Firstly, MH's performance was affected by distractor configurations in his ipsileisonal field. He was more accurate in finding the target when half the distractors formed either a closed configuration or a homogeneous configuration compared to a heterogeneous configuration in his ipsilesional field, and this affected performance irrespective of the target position (same or different field). The better performance when a 'good' configuration was present (and even in the opposite field to the target) suggests that the configuration effect reflected the ease of rejecting distractors. 'Good' configurations were easier to reject than 'poor' configurations, and hence he was better able to select the target. This is consistent with the advantage for configural coding of closed and homogeneous displays arising when stimuli were attended (on the ipsilesional side). However, when compared against controls' performance MH showed an enhanced sensitivity to homogeneous configurations compared to heterogeneous configurations in his ipsilesional visual field (the target was presented in the contralesional field).

Configurations did not influence MH's performance when they were presented in his contralesional field.

Secondly, controls were good at detecting the targets on different field trials (configuration and target presented in different hemifields) compared to same field trials (see Figure 5.4). This result was true of MH but only when the configuration was presented in the ipsilesional field and the target in his contralesional field. This pattern of same versus different field flipped when the configuration was presented in his contralesional field. He was more accurate in finding the target if it was presented in the contralesional field (along with the configuration) as opposed to when it was presented in a different field (ipsilesional field). These results likely arose because MH showed an advantage for detecting a target in his contralesional visual field, perhaps reflecting a bias in MH's overt visual attention due to the reduced covert attention on the contralesional side. Eye-movement data were collected to see if truly this was the case and also to test whether configural effects reflected any pattern of eye-movements.

MH indeed showed a biased preference to look at the contralesional field first as revealed by the direction of first fixation analysis. This bias was present when no configurations were present. The presence of configuration and target in the ipsilesional field attracted more number of first fixations to the ipsilesional side indicating that his strategy to direct his eye-movements could be influenced by the nature of stimuli presented in his good field. MH also showed longer dwell times on configurations in his ipsilesional field for both same field and different field conditions compared to contralesional field conditions. Though dwell times were longer in the ipsilesional field for both types of trials (same field and different field), dwell times on the configurations were longer on the different field trials than same field trials. This relates to MH's results discussed earlier where he was more accurate on the different field trials compared to same field trials when the configurations appeared in the field. Finally, average number of fixations was also greater in the ipsilesional field.

These results show that even though MH's first fixations were mainly directed towards the contralesional field, his strategy could be influenced by the stimuli. Also, in spite of first fixations being largely directed to his contralesional field, configural effects arose only in the ipsilesional field. Further measures such as dwell time and number of fixations strengthened this finding. Longer dwell times and more number of fixations in the ipsilesional field might indicate the need to attend to the configurations before discarding them from search the ability to do which is intact only in his ipsilesional field. This might explain why configural effects were found only in the ipsilesional field.

Experiment 5.2 assessed the generality of these data by testing MH and control participants when the elements had different colours. Elder and Zucker (1993) found that grouping based on closure was disrupted when elements carried the opposite contrast polarities. Thus it is possible that introduction of colours might bring about the same effect for MH here. When the elements have different colours, form-based grouping may reduce in strength – do configural effects still arise?

EXPERIMENT 5.2: Configural coding in MH when colour grouping is weak

Riddoch et al. (2004) reported that MH was relatively good at visual search for colour, consistent with him being able to segment visual elements differing in colour. Colour differences were introduced in Experiment 5.2 between the elements and it was assessed whether these differences disrupted the grouping effects apparent in Experiment 5.1. In Experiment 5.2 each element in the array was a different colour.

Method

Participants

MH was tested in 6 sessions. 4 new age-matched and neurologically healthy controls (3 females; mean age: 58 years) completed the experiment in a single session.

Stimuli and Procedure

The stimuli and procedure remained the same as in Experiment 5.1 except for the introduction of colour to the elements. Nine different colours (yellow, magenta, cyan, red, green, blue, white, black, and darker gray) were used for the nine elements in display. These colours were randomly assigned to the elements on every trial to avoid any guidance by colour association. A baseline condition where no configurations were present was also included as before.

Results

Control data

The data from control participants were entered into a repeated measures ANOVA with the following variables: field (left/right), configuration (closed, heterogeneous and homogeneous) and target position (same-field / different-field). This revealed a significant effect of target position [$F(1,3)=15.681$, $p<0.05$]. Other main effects and interactions did not reach significance [$Fs<1.5$]. The data again showed some similarity to what was found with MH in Experiment 5.1. Controls and MH (in his ipsilesional field) performed more accurately when the configuration and the target were presented in two different hemifields (Figure 5.13). However, once again configural types did not affect the controls' performance; this was contrary to MH who clearly was influenced by the nature of the configuration.

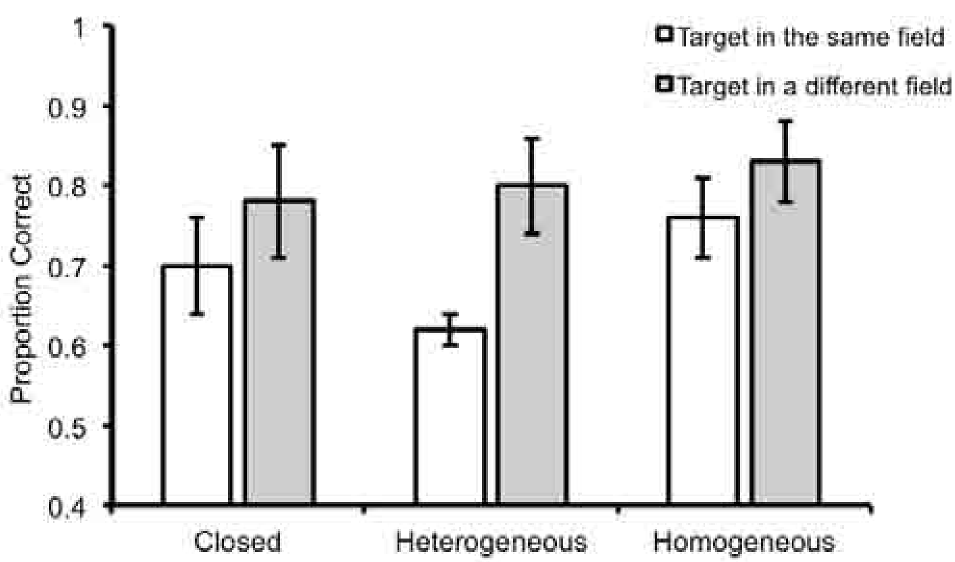

Figure 5.13: *Proportion correct data for controls from Experiment 5.2 for each configural type (on the x-axis) and the two target positions.*

MH

The accuracy data on baseline trials (where no configurations were present) revealed better performance for targets appearing in the contralesional field compared to targets appearing in the ipsilesional field [$t(5)= -8.199$, $p<0.001$; proportions correct: LVF: 0.56, RVF: 0.71].

Data from the rest of the conditions were treated in a four-way log linear analysis with the following four variables: field in which configuration was presented (ipsi/contra), configural type (closed, heterogeneous and homogeneous), target position (same field as configuration or opposite to the configuration field) and accuracy (correct/incorrect). The resulting best fitting model [$\chi^2(8)=5.169$, $p=0.739$] included two interactions: field x configuration x accuracy [$\chi^2(2)=6.824$, $p<0.05$] and field x target position x accuracy [$\chi^2(1)=30.267$, $p<0.001$].

These higher order interactions were broken down by analysing the data for each field (in which configuration appeared) separately with the following variables: configuration type (closed, heterogeneous, and homogeneous), target position (same field as configuration or opposite to the configuration field) and accuracy (correct/incorrect).

Configuration in the ipsilesional field (LVF): The best fitting model [$\chi^2(4)=2.057$, $p=0.725$] included two interactions: configuration x accuracy [$\chi^2(2)=8.192$, $p<0.05$] and target position x accuracy [$\chi^2(1)=35.435$, $p<0.001$]. MH was less accurate when the closed configuration was present compared to when a heterogeneous [$\chi^2(1)=6.392$, $p<0.05$] or a homogeneous [$\chi^2(1)=19.574$, $p<0.001$] configuration was present in the display (Figure 5.14). Performance did not differ across heterogeneous and homogeneous conditions ($\chi^2<1.0$). MH was also more accurate in reporting the target when the configuration appeared in the ipsielsional field and the target in the contralesional field (Figure 5.14).

Configuration in the contralesional field (RVF): Analysis on the data for configurations in the contralesional field did not reveal any significant effects (Figure 5.15).

Similar to previous experiment an adjusted F test was run to compare the performance of MH and the controls. Accuracy differences were again calculated for each condition for MH and controls, for closed – heterogeneous and closed – homogeneous displays. When closed and heterogeneous comparisons were considered (configuration and the target appeared in the left field; see Figure 5.2a), MH tended to be less sensitive to closed configuration in his ipsielsional field compared to control participants [$F(1,3)$ adjusted = 3.24, $p=0.06$, two tailed]. No other differences were reliable.

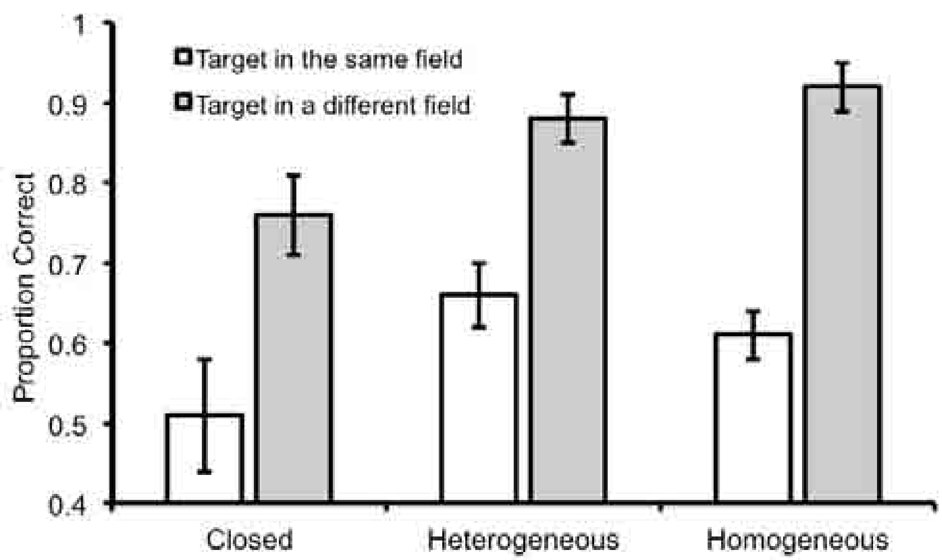

Figure 5.14: *Proportion correct data from MH in Experiment 5.2 for each configural type (on the x-axis) and the two target positions when the configurations were presented in his ipsilesional field (LVF). Empty bars represent trials where target was also presented in the ipsilesional (same-field) and filled bars represent data from trials when the target was presented in the contralesional field.*

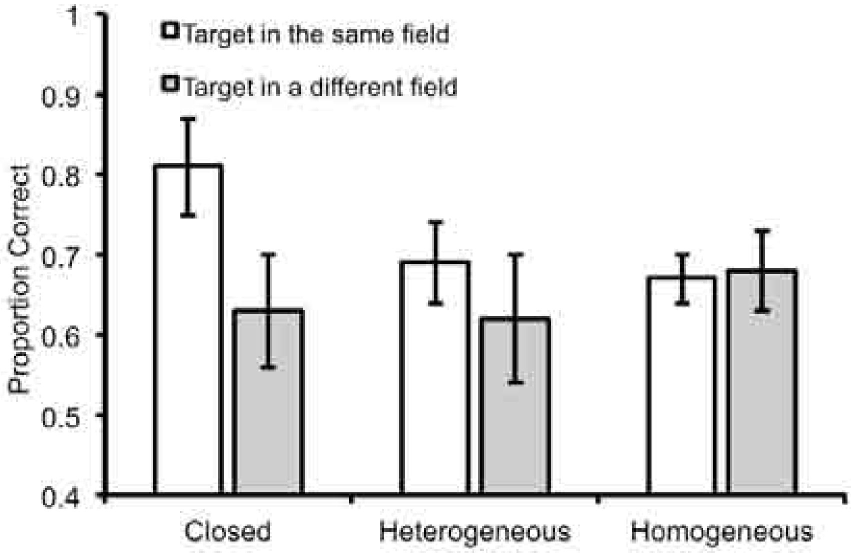

Figure 5.15: *Proportion correct data from MH in Experiment 5.2 for each configural type (on the x-axis) and the two target positions when the configurations were presented in his contralesional field (RVF). Empty bars represent trials where target was also presented in the contralesional (same-field) and filled bars represent data from trials when the target was presented in the ipsilesional field.*

A log-linear analysis on the data across Experiments (5.1 and 5.2) involving experiment as an additional factor revealed the best fitting model [$\chi^2(18)=11.743$, $p=0.860$] involving a significant interaction between experiment, field of configuration, type of configuration and accuracy [$\chi^2(2)=11.967$, $p<0.005$]. This interaction with experiment suggested an effect of stimulus manipulation on the configural effects observed in the two experiments. I will discuss this result in the section below.

Discussion

In both experiments MH was sensitive to the type of configuration in his ipsilesional field, but not in his contralesional field, and, when the configuration was in his ipsileisonal field, MH performed better with a contralesional target rather than an ipsilesional target. This is consistent with his performance reflecting the ease of rejecting the configuration. Unlike

Experiment 5.1, though, performance in Experiment 5.2 was less accurate with a closed configuration than with the heterogeneous and homogeneous configurations, and these latter configurations did not differ. The lack of difference between the heterogeneous and homogeneous configurations suggests that any additional grouping between the homogeneous elements (relative to the heterogeneous configurations) was lost when the elements had different colours. This is consistent with the homogeneous elements grouping on the basis of monochrome texture in Experiment 5.1, which was no longer consistent when the configuration was multi-coloured (in Experiment 5.2). The closed configuration did differ from the other configurations though. This shows that shape configuration based on closure was still computed even when the elements differed in colour. However, the closed configuration in MH's ipsilesional field also disrupted his performance relative to when the items only occupied regular locations (in the heterogeneous and homogeneous conditions). This contrasts with Experiment 5.1, where MH was helped by the presence of a regular, closed configuration compared to a heterogeneous configuration. These results suggest that when the closed configuration also had elements with the same colour, it was easy to reject in search. With heterogeneous colours, it appears that the closed configuration was less easy to reject than the heterogeneous and homogeneous configurations, perhaps because it contained an emergent property (closure; Pomerantz and Pristach, 1989) that competed to hold his attention against the disparate colours. Whatever the case, the data indicate that the closed configuration in MH's ipsilesional field was computed despite the colour differences. As in Experiment 5.1, performance was best when the target and the configuration were in opposite hemifields.

The other major result to note is that, as before, MH was insensitive to configural information in his contralesional field. Although there was some suggestion of the effect of the closed configuration (Figure 5.15), this was not consistent across sessions and was not reliable. The data again highlight the contrast between the computation of configural information in MH's ipsilesional and contralesional fields.

General Discussion

Firstly, the data showed that MH was sensitive to configural information in his ipsilesional field but not in his contralesional field. These data indicate that the left IPS may play a necessary role in configural processing since configural processing appears to be disrupted when the configuration falls in his contraleisonal space. This supports recent work by Lestou, Kourtzi and Humphreys (submitted) with MH. Lestou et al. reported that, relative to control participants and also an agnosic patient with ventral visual damage, MH was impaired at discriminating global glass patterns (e.g., dots configured in concentric rings). Moreover, brain regions that normally respond to such global patterns (e.g, area V3b) were not activated in MH, despite being structurally intact. Lestou et al. proposed that the left IPS damage suffered by MH prevented attentional feedback from parietal cortex to the ventral visual stream, which would normally contribute to the perception of global pattern. In the present study it was found that MH retained sensitivity to global configurations when they were presented in his ipsilesional field, but not in his contralesional field, providing direct evidence of the causal role of the left IPS in global pattern processing in the right visual field. It may also be noted that, when the configuration fell in his ipsilesional field, MH showed stronger effects than the controls. This may reflect the bias in covert attention, with items in MH's contralesional field competing less for attention.

Secondly, MH was sensitive to various kinds of configural information in his ipsileisonal field. In Experiment 5.1, there was better performance with closed and homogeneous displays than with heterogeneous stimuli. This demonstrates coding based on closure and on the textural similarity of form elements (with homogeneous displays). Even with heterogeneous stimuli MH demonstrated improved performance when the target was in the other field, suggesting some sensitivity to the locations of the elements. This point is reinforced by the data from Experiment 5.2. In Experiment 5.2 performance with the heterogeneous stimuli did not differ from that with the homogeneous elements, and both were better than with closed forms in the ipsilesional field. It is suggested that mixed colours in Experiment 5.2 disrupted texture-based grouping of the form elements, eliminating any contrast between homogeneous over heterogeneous displays. In this case, effects of the regular locations occupied by the elements remained. The worse performance with closed configurations in Experiment 5.2 is consistent with these configurations still being computed, but, in this case, they may compete with the multi-coloured letters, distracting attention from the target.

Thirdly, when the configuration was in MH's ipsilesional field, he performed better with a target in the opposite rather than the same hemifield. This occurred even when the distance between the target in the same and different hemifield conditions was equated, by only comparing search when the target was in the aligned spatial region (target and configuration aligned horizontally or vertically). It also occurred despite the right field being MH's worse side (where he showed no sensitivity to the configuration). Controls also showed better performance when the configuration and the target were separated by the hemifield compared to when they were present in the same field. One account of these data is that, when the stimuli are in opposite hemifields, there is parallel processing of the configuration and the target. Previous studies involving split-brain patients (Luck, Hillyard, Mangun and Gazzaniga, 1989) and normal participants (Alvarez and Cavanagh, 2005) suggest that multiple attentional systems could exist thereby facilitating independent processing in the two hemifields. In the current experimental context, this might enable configured distractors to be rapidly coded and rejected, facilitating the detection of the target in the opposite hemifield. In contrast, when the target and the configuration were in the same hemifield they may both compete for a common selection process, slowing down target selection.

All of this brings to the front the topic of the role of attention in grouping processes. The present study suggests that configural grouping cannot take place without attention being deployed to the stimuli. This is further reinforced by the eye-movement results where longer dwell times on the configurations were observed only in the ipsilesional field of MH. Dwell times did not vary across the configurations suggesting that all types of configuration required attentional resources to bind them though this needs further evidence. However, this is at odds with what Kimchi et al. (2007) proposed in their study. Kimchi et al. concluded that perceptual groups (a diamond formed by the line stimuli) capture attention automatically. The current data show that configural processing is not fully automatic in that there was clear modulation of processing due to MH's lesion, which unbalanced the attentional resources he could deploy. It is also possible that attentional effects on grouping might depend on the complexity of the task - a relatively easy task might allow more resources to be available compared to a hard task where attentional resources are not available for grouping. Kraft et al. (Kraft, Muller, Hagendorf, Schira, Dick, Fendrich and Brandt, 2005) presented data which showed that the ability to split attention across space depends on task difficulty. They found that presenting the stimuli across the two hemifields always gave rise to a bilateral advantage in a difficult task. The task tested in the current study was a difficult one as finding L or T among similar form distractors typically conforms to effects found in conjunction search (Julesz and Bergen, 1983), and in addition, the presentation time was very brief. This might lead grouping to be resource-sensitive. In contrast, the stimuli in Kimchi et al.'s (2007) study were different in nature (distractors were differently oriented Ls) and the task was to describe the feature of a distractor indicated by a probe. This may have allowed sufficient resources to be available in all cases for grouping to take place.

Also, it was found that introducing colour heterogeneity to the distractors in the configuration made it difficult to form the configuration quickly. Though other features like closure and similarity were still present in the configurations, colour dissimilarity reduced their grouping strength making it harder to reject.

CHAPTER 6

PERCEPTUAL GROUPING UNDER REDUCED ATTENTION IN PATIENTS WITH SPATIAL AND NON-SPATIAL BIASES IN VISUAL SELECTION

Abstract

The previous chapters assessed effects of the relations between grouping and attention. The chapters mainly demonstrated that 'good' (configural) patterns facilitate distractor inhibition in search, when target detection was the priority. With the normal participants, the configurations fell in areas of the display where targets could be attended. Therefore it is not known whether attention would be required for those grouping effects to arise. Work with patient MH (Chapter 5) showed that attention might be required for grouping (configural grouping in this case). Chapter 6 explores whether simpler forms of grouping than configural grouping might take place without attention. In this chapter I present data on the effects of grouping between elements that fall in the background of displays and so should not fall in attended regions. The effects of these background elements were examined in control participants and neuropsychological patients with a perceptual bias to their ipsilesional field. RH patients were slowed when the left and right field stimuli did not group. Given the right field (ipsilesional field to the RH patients) bias shown by these patients when explicit judgements were required, the slowed responses may arise because the patients are biased to the right when the background stimuli do not group across the fields. Left hemisphere patients and controls showed the opposite result: they were slowed by grouping across the fields. With grouping, attention may be attracted to the background in individuals without a strong attentional bias as the RH patients. Both patient groups, though, remained sensitive to grouping in the contralesional field. The data showed primitive forms of grouping (such as grouping by similarity of brightness) could be intact under reduced attention.

Introduction

There is continued debate over the nature of the representations involved in visual selection. For example, space-based theories assume that selection operates on the spatial locations of visual elements, and it may only be after spatial selection that the elements are grouped into organised forms (Treisman, 1998). In contrast, object-based accounts assume that integrated object representations are selected, so that grouping of elements operates pre-attentively (e.g., Duncan, 1984). These accounts are not mutually exclusive though. For example, spatial and object-based selection processes may be interactive – with spatial attention biasing selection to elements in the attended region while object-based coding biases spatial selection to spread across grouped forms (Humphreys and Riddoch, 1993).

Consistent with the object-based and interactive accounts there is evidence that visual information is organised to some extent even without full attention (Kimchi and Razpurker-Apfeld, 2004; Lamy, Segal and Ruderman, 2006; Moore and Egeth, 1997). For example, Kimchi and Razpurker-Apfeld (2004) presented a target matrix at the centre of a display along with background stimuli that were coloured dots which grouped either into columns or rows or which were randomly positioned. Two successive displays were presented on every trial and the target matrix either remained the same or was altered across these successive displays. In addition, the background organisation either remained the same or changed independent of the alteration to the target matrix. Kimchi and Razpurker-Apfeld (2004) found that grouping of the background stimuli (whether the organisation remained same or changed) had an impact on the target matching task. Importantly, changes to the shape information in the background stimuli did not influence performance on the central task. From these data they argued that simple operations like grouping dots into rows and columns could be achieved without attention when attention was engaged in a difficult central task, whereas grouping processes like shape or configural grouping could not be performed when attentional resources were scarce. Kimchi and Razpurker-Apfeld (2004) suggested that a continuum of grouping processes exists, some of which can be achieved without attention (such as grouping by similarity into columns and rows) whilst others require attentional resources. Recently, this paradigm has been extended to studying patients with hemispatial neglect (Shomstein, Kimchi, Hammer and Behrmann, 2010). Shomstein et al. (2010) presented grouping stimuli in the neglected hemifield and the target stimuli in the intact hemifield. The changes in the grouping stimuli were accompanied by changes in the target stimuli on some trials and not on others, thus giving raise to congruent (grouping stimuli and target stimuli both changed together or both remained same across the successive presentations) and incongruent conditions (one of the two stimuli sets changed while the other remained same). Shomstein et al. found congruency effects with both the hemispatial neglect patients and controls and suggested that perceptual grouping in the patients was achieved pre-attentively. One problem with this study, though, is that the dots appeared near to the midline and so may have gained some attention since neglect may be graded across the field rather than being a step function across the midline (see Milberg and McGlinchey, 2010). Also no direct measure of perceiving the contralesional stimuli was taken. Other data though suggest that forms of grouping may be achieved unconsciously in patients with spatial biases in attention (Conci, Bobel, Matthias, Keller, Muller and Finke, 2009; Gilchrist, Humphreys and Riddoch, 1996; Mattingley, Davis and Driver, 1997). Most notably, there are studies demonstrating that patients with neglect and/or extinction fail to perceive contralesional stimuli unless they group with stimuli on the ipsilesional side. For example, when asked to judge whether one or two items are present, such patients may only report two items when there is grouping across the fields, with effects based on collinearity, shape similarity, contrast polarity and even familiarity being reported

(Gilchrist, Humphreys and Riddoch, 1996; see Humphreys, 1998 for a summary). However, it is also possible in such cases that grouping is induced by the ipsilesional item and it does not mean that there is normal grouping for stimuli; just on the contralesional side. There is also evidence however that grouping may not be normal after parietal lesions which lead to biases in spatial attention. For example Han and Humphreys (2007) recorded the visual evoked response to stimuli grouped by proximity and similarity. In normal participants there were larger P1 and N1 responses induced by grouped relative to random elements. In two patients with parietal lesions these early effects on ERP were diminished, consistent with feedback from parietal cortex being necessary to reinforce the grouping mechanisms.

In the present study I report data using a similar procedure to that of Kimchi and Razpurker-Apfeld (2004) to examine grouping in the contralesional field of patients showing asymmetric biases in attention after damage to posterior parietal cortex (PPC). Unlike the earlier studies, however, single displays were used on every trial, avoiding any influence of attention on the comparison between displays. Participants made a shape discrimination response to an item at fixation. At the same time either unilateral or bilaterally presented background stimuli appeared and I assessed whether the central discrimination task was modulated by whether the ipsilesional or contralesional items grouped, and on bilateral trials, what the grouping relation was between the stimuli (both grouped, neither grouped, left field only grouped, right field only grouped). In cases of extinction, the report of a contralesional item is disrupted by the simultaneous presentation of a stimulus on the ipsilesional side (e.g., Karnath, 1988). Here I ask whether grouping on the contralesional side might be disrupted by presentation of a randomly organised array on the ipsilesional side. In addition, a test of explicit discrimination of contralesional stimuli was included, to test if grouping effects did arise implicitly, without explicit awareness. Experiments 6.1 and 6.2 present the data from the explicit task.

Experiments 6.3 and 6.4 then address the question of whether grouping effects arise implicitly.

EXPERIMENT 6.1: Explicit effects with unilateral stimuli

This experiment was run in order to investigate whether the patients showed a spatial bias and thus if there was reduced attention to one of the fields. This would help in understanding any grouping effects that arise implicitly.

Method

Participants

12 patients (DT, JB, MaH, MC, MH, MP, PF, PJ, PM, RH, RP, SB) all with chronic brain lesions and a stable neuropsychological condition (Table 6.1) took part in this study. Seven of the patients (5 males) showed a bias favouring the right after right hemisphere lesions and five of them (all males) showed a bias favouring the left after left hemisphere lesions. Patients showed a unilateral bias that was more than 2 standard deviations away from the mean performance of control participants on measures of spatial attention from the Birmingham University Cognitive Screen (BUCS; www.bucs.bham.ac.uk). In particular, all the patients showed visual extinction (a larger contralesional drop on bilateral relative to unilateral trials under confrontation testing conditions). 8 patients also showed visual neglect (an abnormal spatial asymmetry on the apple cancellation task from BUCS). Clinical details are presented in Table 6.1. The patients were in the age range of 55-77 years (mean age: 69 years). 9 age-matched (7 males; mean age: 67 years) neurologically healthy participants served as controls. These controls were matched over the group for age and educational qualifications.

Table 6.1 *presents the patients' details*

Main Lesion Site	Patient	Gender	Age	Major Clinical Symptoms	Aetiology
Left	MH	M	57	Right extinction, optic ataxia	Anoxia
Left	RH	M	77	Right neglect in reading, right extinction, aphasia	Stroke
Left	DT	M	69	Right extinction	Stroke
Left	DB	M	75	Right extinction, word finding problems	Stroke
Left	PJ	M	77	Aphasia, right visual extinction	Stroke
Left	MaH	M	78	Aphasia, letter by letter reading, right extinction	Stroke
Left	FL	M	77	Right neglect, amnesia	Anoxia
Bilateral	PM	M	69	Mild simultanagnosia, impaired verbal STM, word finding problems, left extinction	Stroke
Right	SB	M	67	Left neglect	Stroke
Right	TM	M	73	Left neglect	Stroke
Right	JB	F	75	Extinction, left neglect, dyslexia	Stroke
Right	RP	M	55	Left neglect	Stroke
Right	MP	M	63	Left neglect and extinction, impaired number skills	Stroke
Right	MC	M	76	Left neglect	Stroke
Bilateral	PF	F	62	Left extinction, dysgraphia	Stroke
Bilateral	AS	M	75	Left extinction	Stroke

Stimuli

The stimuli were arrays of black and white filled circles (9 each). The stimuli were generated and presented using MatLab and Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Each circle measured 0.7^{o} (on the diameter) of visual angle and the unilateral background display measured 4.2^{o} of visual angle from a viewing distance of approximately 57 cm. The circles were either grouped into alternating rows of black and white or positioned randomly (Figure 6.1). A random noise square patch was presented at fixation and measured 0.8^{o}. The target (when present) was a digit (9) on this patch of random noise. The random noise patch and number stimuli were kept here only to keep the stimuli identical across the conditions. These stimuli were related to the central task in the later experiments and will be explained in more detail where appropriate.

Design

The two main factors, visual field in which the background stimuli were presented (left or right) and grouping (grouped or random), resulted in four conditions: (i) left grouped (ii) left random (iii) right grouped, and (iv) right random (see Figure 6.1 for examples).

Procedure

Each trial started with a fixation dot presented for 1000 ms and the display then followed for 100 ms. The four grouping conditions (see Design) were randomised within a block. Patients were encouraged to focus at fixation. The task for patients was to detect the presence or absence of a pattern presented either to their left or right (alternating rows of black and white). This pattern was printed on a paper and shown to the patients before starting the session. A practice block containing 10 trials was run before the experiment proper. Instructions were repeated and any doubts were clarified before proceeding to the main block.

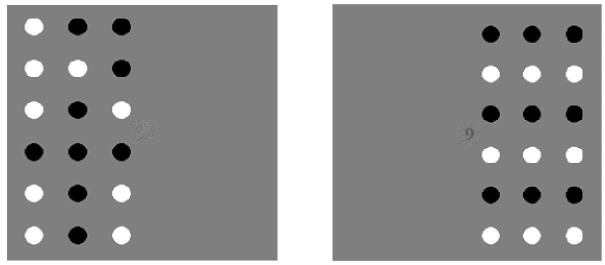

Figure 6.1: *Example displays used in Experiment 6.1 and 6.3. On the left is a display for a random (LVF) target absent trial and on the right is a display for a grouped (RVF) target present trial.*

Each subsequent trial was started by the experimenter after making sure the participant was ready. Each block contained 40 trials (10 trials per condition). Participants were reminded of the instructions at the start of every new block. Participants pressed "left arrow key" if the pattern was present and "right arrow key" for its absence. The experimenter responded on behalf of two patients (SB and PM). SB was in a wheelchair and could not access the keyboard easily and PM got distracted with keyboard use during the practice session. These two patients were asked to respond verbally and the experimenter blinded to the stimuli, coded the responses with key-presses.

Results

Accuracy was measured and analysed to look at the effect of any spatial bias in judging the presence or absence of grouping. Mean percentages from the correct trials for the grouping present conditions were entered into a mixed ANOVA with the following within-subject variable: field in which grouping was present (ipsilesional / contralesional) as a within-subjects factor and patient group (left bias / right bias) as a between-subject factor. The mean percentages from the correct trials for the conditions when grouping was not present are presented in Table 6.2.

Table 6.2: *Mean correct percentages for the grouping absent conditions across both the fields for each patient group.*

	Ipsilesional	Contralesional
Patients with left bias	64	67
Patients with right bias	74	78

An ANOVA on the grouping present conditions produced a main effect of field [F(1,10)=6.105, p<0.05]. Patients were more accurate in judging the presence of the pattern in their ipsilesional field compared to contralesional field (Figure 6.2). There was no interaction between field x patient group [F<1]. The two patient groups did not differ from each other as indicated by a non-significant main effect [F<1].

These results show that patients indeed had a spatial bias while reporting the presence of grouping. Both the groups performed worse when grouping was present in their contralesional side. Therefore any implicit grouping effects reported are unlikely to be due to attention sparing on the contralesional side.

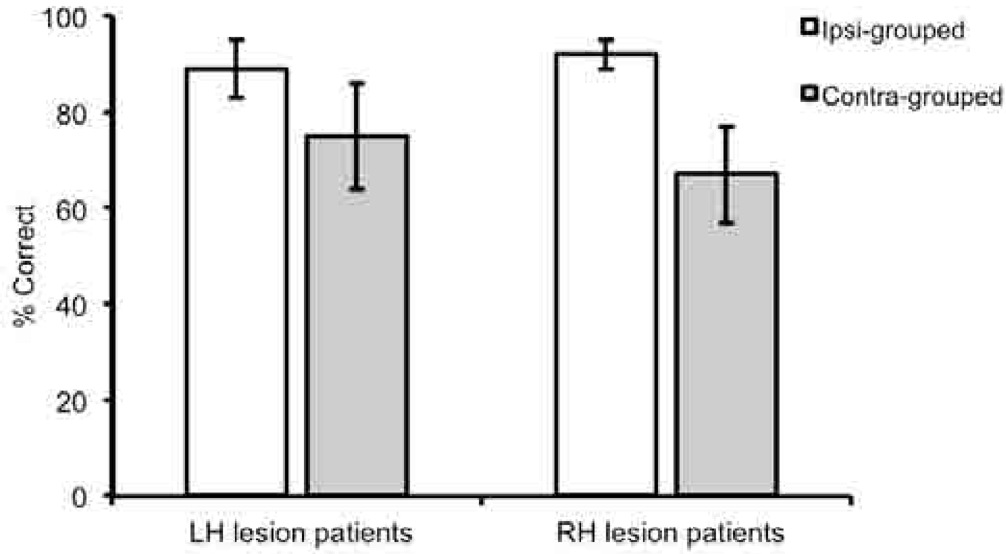

Figure 6.2: *Percent correct data for the grouped conditions is shown for the two groups of patients (along the x – axis)*

EXPERIMENT 6.2: Explicit effects with bilateral stimuli

Since one of the objectives was also to look at the effect of implicit grouping under bilateral stimulus conditions, an explicit task on the bilateral stimuli was also run in order to be able to interpret any effect of implicit grouping from the bilateral background stimuli.

Method

Stimuli and Design

The stimuli were the same as in the previous experiment except that the background stimuli were presented bilaterally (Figure 6.3). There were four experimental conditions: (i) both fields grouped (ii) ipsilesional grouped – contralesional random (iii) ipsilesional random – contralesional grouped and (iv) both fields random.

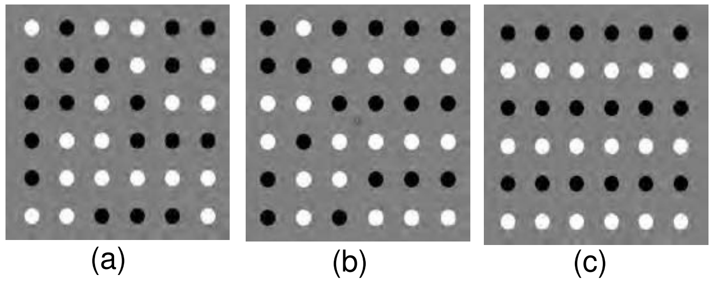

Figure 6.3: *Depicts 3 example displays from Experiment 6.2. (a) both random (b) left random – right grouped and (c) both grouped.*

Procedure

The procedure remained the same except for the following change. There were 60 trials in each block (30 trials where no grouping was present and 10 trials each in the three conditions where grouping was present either in half field or in both). Participants were again instructed to look for the presence of a pattern either in the half-field or in full.

Results

Mean correct percentages from the grouping present conditions were entered into a mixed ANOVA with patient-group serving as the between-subject factor. There was a main effect of grouping [$F(2,22)=56.665$, $p<0.001$]. This main effect was qualified by an interaction between grouping and patient group [$F(2,22)=6.435$, $p<0.01$]. This interaction was broken down by running paired t-tests between the grouping conditions for each patient group separately.

Patients with left bias: As is evident from the figure (Figure 6.4 – left segment), patients with a bias to the left were more accurate when both the fields grouped compared to when only ipsilesional [$t(5)= -5.423$, $p<0.005$] or contralesional [$t(5)= -14.968$, $p<0.001$] field contained grouped stimuli. There was also a significant difference between ipsilesional and contralesional fields with accuracy being higher in the ipsilesional field [$t(5)= -2.098$, $p<0.05$].

Patients with right bias: Patients with a bias to the right side were also more accurate when both the fields grouped compared to when only ipsilesional [$t(6)= -1.988$, $p<0.05$] or contralesional [$t(6)= -7.178$, $p<0.001$] field contained grouped stimuli. There was also a significant difference between ipsilesional and contralesional fields with accuracy being higher in the ipsilesional field [$t(6)= -3.912$, $p<0.005$] (see Figure 6.4 – right segment).

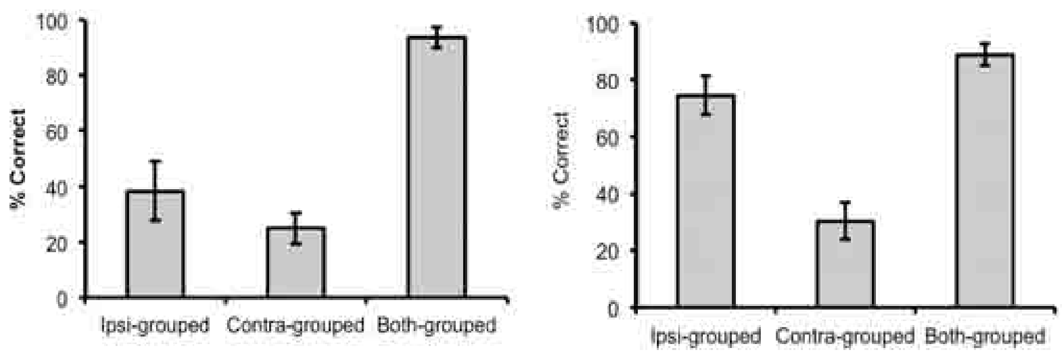

Figure 6.4: *Percent correct data for the grouping conditions (along x – axis). Data from patients with a left bias are presented to the left and data from patients with a right bias are presented on the right.*

EXPERIMENT 6.3: Implicit effects with unilateral stimuli

Experiments 6.1 and 6.2 established what patients could report explicitly from the current displays. Patients were better able to report the presence of a pattern in their ipsilesional field compared to their contralesional field thus confirming that the contralesional field received reduced attention. This then enables the study of what grouping takes place implicitly. This was tested in the next two experiments, where I tested for implicit grouping processes in patients with spatial bias who show reduced attention to one of the fields resulting from their lesions. Here the dot arrays (see Design for complete details) were presented in the background when patients were engaged in an otherwise unrelated task at the centre of the display. Did the nature of the background stimuli modulate responses to central targets?

Method

Participants

9 patients (DT, DB, RH, MH, JB, RP, MP, MC and AS) all with chronic brain lesions and a stable neuropsychological condition (Table 6.1) took part in this study. Five of them (4 males) showed a bias favouring the right after right hemisphere lesions and four of them (all males) showed a bias to the left after left hemisphere lesions. The patients had an age range between 55-77 years (mean age: 69 years). 9 age-matched (mean age: 67 years) neurologically healthy participants (7 males) served as controls.

Stimuli

The background stimuli remained the same as before. A random noise square patch was presented at fixation and measured 0.8^{o}. The target (when present) was a digit (9) presented on this patch of random noise (Figure 6.1).

Design

The two main factors, visual field in which the background stimuli were presented (left or right) and grouping (grouped or random), resulted in four conditions: (i) left grouped (ii) left random (iii) right grouped, and (iv) right random. A fifth condition was also included in which only the target appeared in the central location without the background stimuli. A central target was present in the noise patch on half the trials and it was absent on the other half. The visibility/contrast of the target was individually decided for each participant (see

Procedure). There were two variations in the stimuli: (i) where there was only one grouped pattern present and random patterns were generated on each trial (single grouped pattern condition) and (ii) there were equal number of grouped patterns and random patterns (4 each repeated randomly and equally; will be referred to as multiple grouped patterns). This was done to ensure the grouping effect did not arise as a result of unequal repetitions (as in (i)) but from the absence or presence of grouping. This manipulation was applied only with the patients. Controls performed only under manipulation (i) i.e., single grouped pattern condition. Patient group (left versus right bias) was included as a between-subject factor.

Procedure

Pre-test: Participants took part in a pre-test in which they had to report a central digit presented for 100 ms. Five levels of contrast were used. The contrast at which the participants achieved 80% correct was chosen for the target in the main experiment. This was estimated using linear interpolation curve fitting.

Each trial started with a fixation dot presented for 1000 ms and the display then followed for 100 ms. The five conditions (see Design) and the presence or absence of the target were randomised within a block. Patients were encouraged to focus on the central task ignoring the background distractors. The task for patients was to detect the presence or absence of a target (a pre-specified digit) in the centre and report through a key press on the keyboard (left arrow key for presence and right arrow key for absence). The task was made more difficult for controls to avoid ceiling effects. This was done in order to test whether controls would show effects of grouping under conditions of similar attentional demand to the central task as the patients. Control participants judged whether the target presented was an odd number or an even number (8 single digits were used excluding “1”). Controls pressed the left arrow key if the target was an odd number and the right arrow key for an even number. The next trial was started by the experimenter after making sure the participant was ready. Each participant went through a practice block in the beginning and any doubts were clarified. Each block contained 50 trials (10 trials per condition). Participants were reminded of the instructions at the start of every block.

Results

RT and accuracy data were collected for each participant. Incorrect RTs were excluded from further analysis. Data from the target-only condition were dropped from the analysis since they were included as a control to make sure patients understood that the target in fact appeared in the centre. Generally median RTs (from patients) were numerically longer for the "target-only" condition compared to the grouping conditions. Median RTs were calculated for each session and an average of the medians from all the sessions was computed for each participant. These averages were entered into a mixed ANOVA with the following within-subject variables: grouping manipulation (single versus multiple grouped patterns), background grouping (grouped / random), and visual field (ipsi / contra). Participant group (left bias and right bias) served as a between-subject factor.

There was a main effect of the background grouping [$F(1,7) = 11.542$, $p<0.05$]. Participants were faster in reporting the central target when the background stimuli were grouped compared to when they were randomly arranged. Importantly, this main effect did not interact with the grouping manipulation (background grouping x grouping manipulation: $F(1,7)=2.239$, $p=0.178$). Main effects of field and grouping manipulation were not significant [$Fs<1$]. Two-way interactions between field x grouping manipulation and field x background grouping were not significant either [$Fs<1$]. The three way interaction between field x grouping manipulation x background grouping also failed to reach significance [F<1].

The between-subject factor (patient group) interacted with the grouping manipulation [F(1,7)=6.159, p<0.05]. All other interactions were non-significant [Fs<1].

Since this initial analysis (involving only patients) did not reveal any interaction between grouping manipulation (single vs. multiple) and background grouping (grouped vs. random), the data for these conditions were averaged and then compared to controls. A new mixed ANOVA was carried out with the following within-subject variables: field (left / right) and background grouping (grouped / random). Participant group (left bias, right bias and controls) served as the between subject factor. This analysis revealed a main effect of background grouping [F(1,15) = 11.154, p<0.005]. Patients (Figures 6.6 and 6.7) and controls (Figure 6.5) were faster to respond to the central target when the stimuli in the background grouped compared to when these stimuli were arranged randomly. No other main effects or interactions reached significance.

Table 6.3 *presents a summary of statistics for a comparison between patients and controls (Experiment 6.3). Field and grouping were within-subject variables and participants group served as a between-subject factor. Significant effects are marked with asterisk.*

Effects	F value	p value
Field	F(1,15) = 3.452	0.083
Grouping	F(1,15) = 11.154	0.004*
Participant group	F(2,15) = 2.690	0.082
Field x grouping	F(1,15) = 1.741	0.207
Field x participant group	F(2,15) = 0.852	0.446
Grouping x participant group	F(2,15) = 0.923	0.419
Field x grouping x participant group	F(2,15) = 0.758	0.486

The results showed an effect of the background grouping on a central task even when the background was completely irrelevant to the task at hand. Both patients and control participants were faster to respond to the central target when the background stimuli were grouped compared to when they were randomly arranged. Importantly, this effect was not influenced by whether a single pattern or multiple patterns were presented. Also, the grouping effects arose in both the fields. The results suggest that, for the PPC patients as for the controls, there were effects of grouping of background stimuli. The equality of the effects across the fields suggests that grouping was not affected by any attentional biases produced by the brain lesions. However, Experiment 6.3 used unilateral displays and it is possible that the patients could allocate some attention to the background items on the contralesional side. This may be less likely under bilateral presentation conditions, when other stimuli fall simultaneously in the ipsilesional field. This was tested in Experiment 6.4.

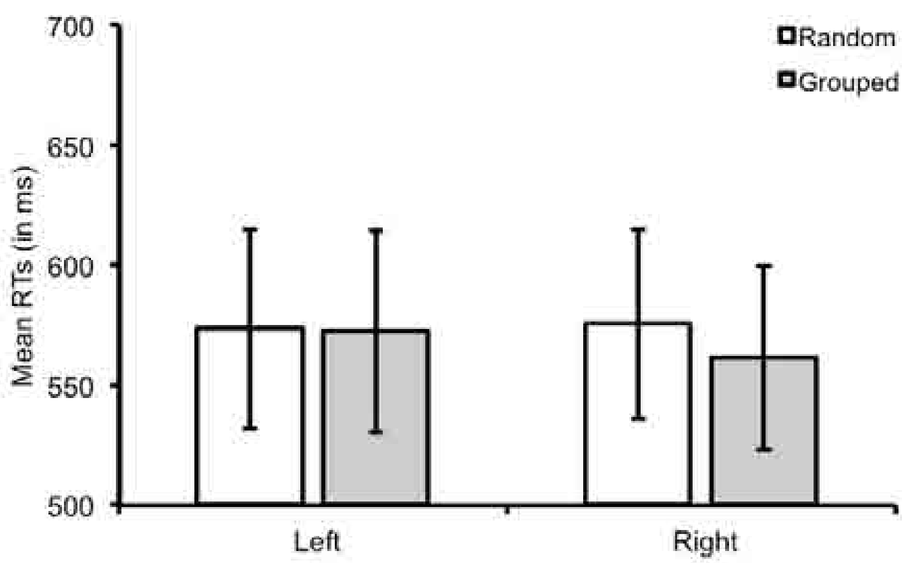

Figure 6.5: *Average RTs (age-matched controls) for the random (empty bars) and grouped (filled bars) background conditions in Experiment 6.3. Visual fields are drawn on the horizontal axis.*

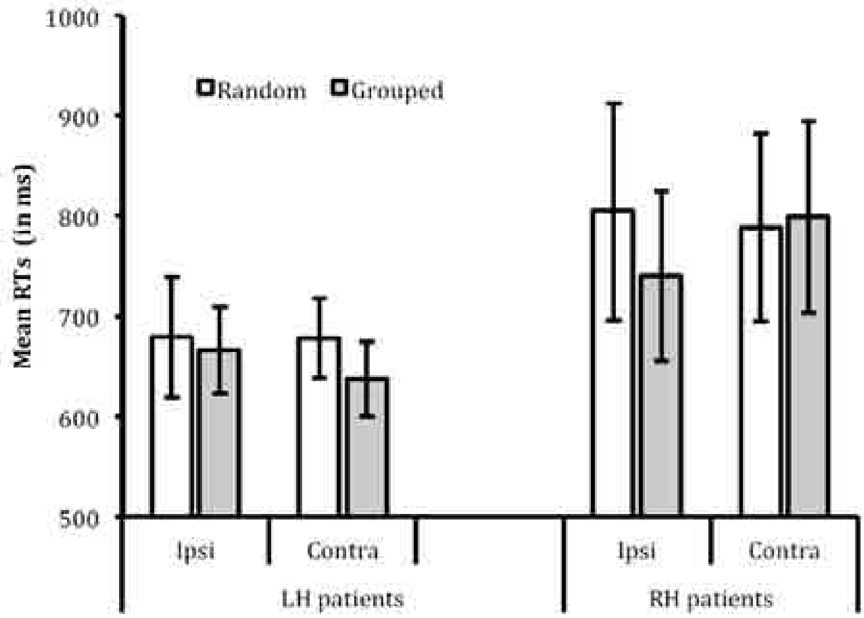

Figure 6.6: *Average RTs for the random (empty bars) and grouped (filled bars) background conditions in single grouped pattern condition of Experiment 6.3. Visual fields and patient groups are drawn on the horizontal axis.*

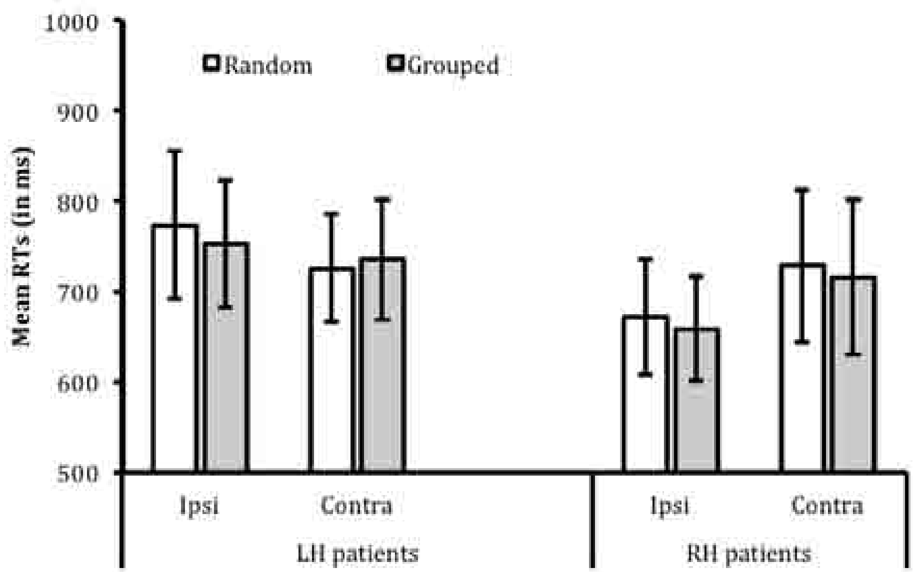

Figure 6.7: *Average RTs for the random (empty bars) and grouped (filled bars) background conditions in multiple grouped pattern condition of Experiment 6.3. Visual fields and patient groups are drawn on the horizontal axis.*

EXPERIMENT 6.4: Implicit effects with bilateral stimuli

Method

Participants

The same 9 patients who took part in Experiment 6.3 participated in this experiment. Seven new approximately age matched (mean age: 67 years) neurologically healthy participants were also tested in this experiment.

Stimuli and Design

The stimuli were the same as in the previous experiment except that the background stimuli were presented bilaterally (Figure 6.3). There were five experimental conditions: (i) both fields grouped (ii) both fields random (iii) ipsilesional grouped – contralesional random (iv) ipsilesional random – contralesional grouped and (v) target - only condition.

Procedure

Procedural details remained the same from Experiment 6.3. The new controls performed the pre-test (see Procedure in Experiment 6.3) prior to the main experiment. The controls completed 320 trials in a single session (64 data points for each condition) in the main experiment.

Results

RTs from incorrect trials (< 4%) and RTs from the target-only condition were excluded from the analysis. Median RTs were calculated for each condition for each session and these medians were averaged across the total sessions completed by the participant. A mixed-

ANOVA was carried out on the data with the following within subject variables: contralesional grouping (grouped / random), ipsilesional grouping (grouped / random). Participant group (patients with left bias and patients with right bias) was a between-subject variable.

The analysis revealed a significant interaction between contralesional grouping, ipsilesional grouping and participant group [$F(1,7) = 5.932$, $p<0.05$]. No other main effects or interactions reached statistical significance [$Fs<1$]. Patients with right bias (right hemisphere patients) were fast to perform on the central task when the both the fields contained same grouping information (both random or both grouped) whereas patients with a bias to the left (left hemisphere patients) were slowed on these trials (both random or both grouped)

In addition each patient group was compared to the age-matched control group.

There was no significant difference between the patients with a left spatial bias (left hemisphere lesions) and the age matched controls (Figures 6.8 and 6.9). Both groups were slowed on the trials when the two visual fields contained either random or grouped stimuli compared to when only one of the fields contained grouped stimuli [$F(1,9)=12.672$, $p<0.01$]. However, patients showing a right spatial bias (right hemisphere lesions) differed from controls (Figures 6.8 and 6.9). While the controls performed slower on the trials when the visual fields consisted of similar grouping stimuli (both random or both grouped), the patients showing a right bias were quicker on these trials [$F(1,10)=7.730$, $p<0.05$, for the interaction of grouping and participant group].

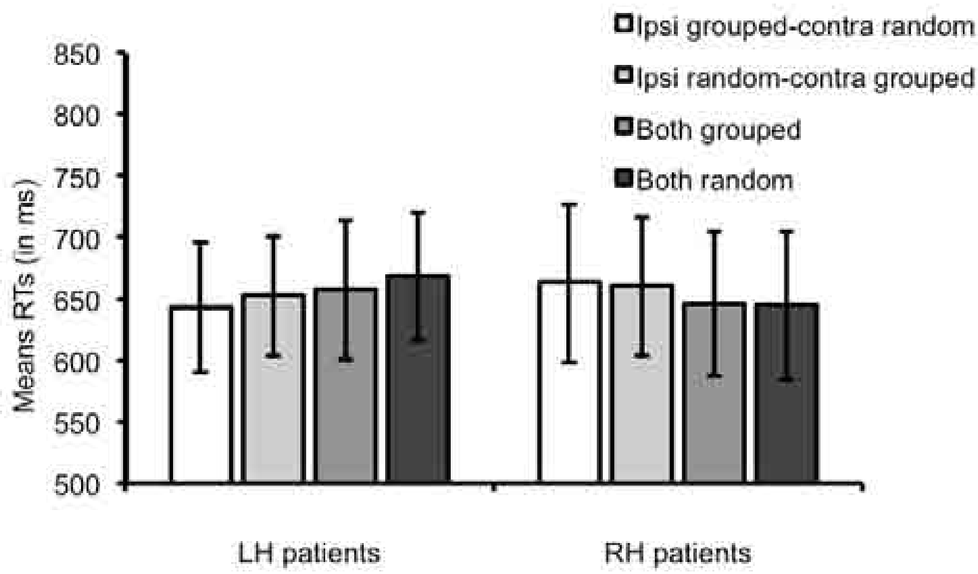

Figure 6.8: *Data showing the mean RTs for the four grouping conditions in Experiment 6.4 with patients grouped along the x-axis.*

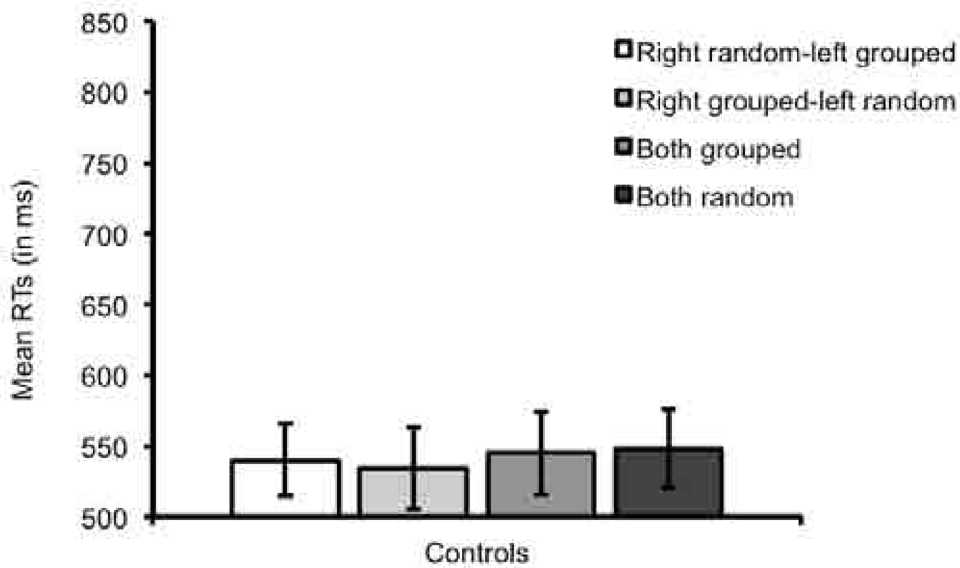

Figure 6.9: *Data showing the mean RTs for the different grouping conditions healthy controls in Experiment 6.4.*

Discussion

The results from this experiment again showed an effect of background grouping on an unrelated central task when the background stimuli were presented bilaterally. In this case, however, grouping of the background stimuli exerted a differential influence on the performance of the two patient groups and the control group. Patients with a bias to the right visual field (after a right hemisphere lesion) were significantly faster on the trials when both the fields contained similar information (both random or both grouped) compared to when the two visual fields carried conflicting information. Age-matched controls and patients showing left spatial bias (after a left hemisphere lesion) showed the opposite effect. They were slowed by similar background information (both random or both grouped) compared to other grouping conditions (when the two fields contained conflicting information).

These effects of grouping with bilateral stimuli suggest that the patients are differentially sensitive to whether the left and right visual fields have similar or different background properties. The data can be understood if the effects of right hemisphere brain lesion lead to a spatial bias in selection, but this is less so for the left hemisphere lesioned patients (and controls). It is well known that spatial biases in selection are stronger after right than left hemisphere lesions (particularly involving the posterior parietal cortex, as in the current patients; see Heilman and Valenstein, 2003). For the right hemisphere patients, there may be increased competition for attention from the right visual field when both fields differ in their grouping characteristics compared with when they have similar properties (both grouped or both random). This spatial competition for selection between the fields may itself disrupt attention to the central target, slowing performance. Interestingly there was no evidence for contrasting effects on trials where the grouping properties differed according to whether the grouped stimuli were in the left or right field – it appears that the difference in the grouping properties, more than the presence of grouping per se, was critical. In contrast to the right hemisphere patients, the left hemisphere patients and the controls may not have a spatial bias in selection. These participants appear equally sensitive to the right hemisphere patients as to whether both the left and right fields have the same grouping properties, but in this case there was a slowing of responses when the grouping properties are the same perhaps because the similarity biases attention to the background (across both fields) compared to the (foreground) target. RTs to targets are then slowed. Experiment 6.2 was run to see if there was such difference in spatial bias across left and right hemisphere patients when they explicitly reported the presence of grouping in the bilateral displays. The results confirmed this speculation. Right hemisphere patients were more accurate when their ipsilesional field contained grouping information in addition to being good at judging the presence of overall grouping ('both grouped' condition) thus showing a right spatial bias. Left hemisphere patients, however, were only good at judging the presence of grouping when both the fields carried grouping information.

General Discussion

This study assessed whether patients with a field bias (after lesions to right or left posterior parietal cortex) would show any grouping effects from the background while performing an unrelated task in the centre. These patients have problems attending to their contralesional space in tasks requiring explicit target identification (e.g., under conditions of visual extinction). The patients showed a difficulty in reporting the presence of grouping in their contralesional field when asked explicitly. Despite this, the patients were influenced by grouping relations between the background stimuli when they were engaged in a central task (Experiment 6.3). All participants (left and right hemisphere lesioned patients and non-lesioned controls) were faster to respond to the target if the background display was grouped compared to when it was random. Under unilateral presentations of the background, there were no reliable effects of field and no interaction between field and group. Importantly these results show that simple forms of perceptual organisation, such as grouping elements into rows and columns by similarity can be achieved under conditions of reduced attention (after lesioning, in patients).

Experiment 6.4 looked at the effect of background grouping when the display was presented bilaterally. Patients with a right bias (after a right hemisphere lesion) responded more quickly when both the fields contained similar information (both grouped or both random) compared to when the field contained conflicting grouping information (one grouped, one random). To account for this, I suggest that there was competition for attention between the visual fields according to whether the grouping properties were the same or different. When they were different, spatial competition favouring the right field would bias patients away from the central target, slowing the central task. Consistent with this argument, in a task requiring explicit judgements of the presence of a perceptual group, the right hemisphere patients were strongly lateralised – detecting perceptual groups in their right but not their left field (Experiment 6.2).

The data from the right hemisphere patients contrasts with those from the left hemisphere patients and the controls. For both of these groups, RTs to the central task were faster when background stimuli in each field differed than when they matched. Here I suggest that these individuals are less sensitive to the spatial properties of the groups, and more to whether there is a uniform pattern across the field (be it grouped or random). When there is a uniform pattern, attention may be attracted to the background rather than the target, so that (for a different reason to the right hemisphere patients), target performance is affected. Again the data from the explicit judgement task fit this proposal. In the explicit judgement task the left hemisphere patients were poor at detecting a unilateral group (when a random pattern was present on one side) but they improved when grouping information was presented bilaterally. This pattern of results is consistent with left hemisphere patients pooling information from across their fields and with their judgements about spatial groups improving when the information is consistent (bilateral grouping) compared with when it is inconsistent (unilateral grouping).

The argument that the left and right hemisphere lesioned patients differ fits with prior neuropsychological studies. There is a substantial literature indicating that right hemisphere patients show a strong spatial bias in visual selection, and are sensitive to the balance of information across their left and right fields (Heilman and Valenstein, 2003). In contrast, patients with left hemisphere lesions have been reported to show non-spatial biases in attention – for instance showing object- rather than spatial disengagement problems (Egly et al., 1994) and showing poor selection in the face of high distractor salience irrespective to the spatial layout (Mevorach, Humphreys and Shalev, 2006). Poor selection based on saliency might be a contributory factor here for the left hemisphere lesioned cases. For example, difficulty in using a saliency signal to select a unilateral group (when a random pattern is on the opposite side) would lead to poor explicit discrimination of a perceptual group, but the patients might fare better when they can pool information from across the field to derive a stronger 'grouping' signal. Note that the left hemisphere patients did show a spatial bias in explicit selection in a letter identification task (used to select the patients in the first place), but the bias may be confined to identification tasks without affecting the underlying computation of grouping in each field.

In sum, the present data are consistent with some forms of grouping taking place despite the presence of parietal damage in patients. In addition, differences in the strength of a spatial bias might contribute to contrasting performance patterns in left and right hemisphere patients

– with right hemisphere patients sensitive to the competition when stimuli in the left and right fields differ, and left hemisphere patients sensitive to pooling of grouping information across both fields.

CHAPTER 7

GENERAL DISCUSSION

Abstract

In the final chapter results from each of the experimental chapters are summarised and their implications are discussed. The findings are reviewed with a focus on understanding the relations between perceptual grouping and attention.

Summary of Findings

Five empirical chapters have been reported in the thesis, each of which has dealt with the effects of various forms of grouping on visual attention. I review the main results for each chapter in turn.

Chapter 2

Chapter 2 was aimed at understanding the role of configural regularity in search over space and time in normal observers. In addition to the regularity of the patterns, element grouping within regular and irregular configurations was also manipulated. The elements grouped based on their inner / outer orientations (Experiment 2.1) or brightness (Experiment 2.2). Preview search was used to explore the effects of presenting different configurations of distractors across time. A modified version of the preview procedure was also included to investigate the nature of any configural effect (e.g., whether it was confined to the spatial locations of the pattern or transferred across space, in a location-change preview condition). There were a number of important findings.

- Regularity did facilitate search, compared with when irregular configurations were presented. In preview search, presenting regular configurations of distractors in the preview reduced the effect of display size; in contrast to this, presenting one group of distractors with a regular configuration in full-set search affected the overall reaction times but not the slope of the search function.
- Making the external elements of the configuration group by orientation improved search efficiency under preview but not full-set search conditions (Experiment 2.1).

On the other hand, full-set search was improved by having the local members of a configuration group by brightness (Experiment 2.2).

- Results from the location-change preview suggested that configural-suppression was object-based since search was not disrupted by shifting the location of the preview. However, search in the location-shift condition benefited both from grouping items by orientation and by brightness.

Taken together the results support the idea that distractors forming regular configurations can be efficiently suppressed, as proposed earlier by Kunar et al. (2003a) and Watson (2001). The current results extend the literature by showing that regularity and element grouping combine in their contribution to search, and that different grouping cues are used when displays are staggered over time (under preview conditions) and when all the elements appear simultaneously. Orientation grouping between the elements proved to be useful when search was segmented over time whereas grouping based on brightness facilitated search when the display appeared simultaneously. In the location-shift preview condition, effects of both types of grouping were apparent, but this may be because search in this condition was of intermediate difficulty – partly dependent on the efficient rejection of the previewed distractors (hence effects of orientation grouping occurred) and partly on the efficient segmentation of the target from all the distractors in the field (after the onset of the search displays – hence effects of brightness grouping, as in the full-set baseline). On top of this, the location-shift condition was sensitive to the regularity of the configuration, suggesting that distractor rejection was mediated by an object-based representation coded independent of its lateral position in the field.

Chapter 3

Chapter 3 was an extension of the investigation in Chapter 2, but in this case investigating whether the presence of a regular configuration enabled preview search to withstand effects of temporally grouping the preview with the search display, when the preview was blinked off before the onset of the search items. A preview condition with a temporal gap between the preview and the final display (100 ms; produced by a brief blank screen) was compared with a no-gap preview condition. It has been shown previously that such brief offsets can abolish the preview benefit (Watson and Humphreys, 1997). The results revealed that grouping by regularity was not sufficient to counteract the effects of a visual transient. In particular, introducing a temporal gap between the preview and the search display eliminated the preview benefit on search slopes. There remained benefits in terms of overall RTs for preview compared with the full-set displays, and for regular relative to irregular displays.

These data indicate that while there can be effect of regularity and temporal segmentation on RTs, these might reflect factors such as the time to initiate search or to respond; effects of the preview and display regularity on search efficiency, though, arise only when when other factors contributing to the objecthood of the preview display (having a discrete spatio-temporal identity) are also in place. The gap condition disrupts this spatio-temporal identity of the preview by assigning the preview to have a common time-stamp with the search display, and this disrupts the preview effect on search. The data are consistent with the preview effect on search efficiency being dependent on suppression of some form of object-file for the preview based on its spatio-temporal identity.

Chapter 4

Chapter 4 looked at the role of configural grouping in a standard search task (where all the elements appear simultaneously) where the presentation was time-restricted. The stimuli were constructed such that, on some of the trials, there was a globally defined object configuration present (a square made up of differently oriented Ls). Such perceptual objects have been shown to capture attention automatically (Kimchi et al., 2007; Yeshurun et al., 2009; Rauschenberger and Yantis, 2001) but it was not known whether such 'capture effects' could be modulated by top-down goals or task difficulty. In the displays used in Chapter 4, the configuration always formed a distractor-set, so the study assessed if participants could ignore the configuration. The configuration either formed a closed shape, or an open shape with homogeneous elements or an open shape with heterogeneous elements (but falling at the locations of the corners of a square). The main findings were as follows:

- When the target appeared always outside the configurations, participants were able to exclude closed and homogeneous configurations more efficiently compared to heterogeneous configurations.
- Even when the target position was made uncertain (it appeared equally often inside or outside the configuration in a random order), similar configuration effects prevailed. Responses to target-inside trials were generally faster than target-outside trials. This indicated that configurations did capture attention but were also easier to exclude from search when the target appeared outside of them.
- The contrast between performance with targets inside and outside the configurations, even with heterogeneous configurations, suggests that there was some capture of attention by all configuration types, though the effects appeared strongest with closed and with homogeneous configurations. To test if performance with heterogeneous

displays reflected the density of the elements, Experiment 4.3 manipulated the density of the displays by having sparse (zero distractors in the target quadrant) and dense (one or two distractors in the target quadrant) displays. Responses on closed and homogeneous configuration trials remained faster compared to the heterogeneous baseline, irrespective of the density of the display, suggesting that the effects were driven by the configural properties of the displays rather than by variations in density.

These results indicate that attention can be captured by various types of visual configuration, with there being effects based on the locations of elements through to effects based on closure and element homogeneity.

Chapter 5

Chapter 5 focused on configural grouping in a patient, MH, with damage focused on the left posterior parietal cortex. In previous work MH was shown to have specific difficulties in responding to oriented stimuli in the context of other elements that grouped to form a higher-order stimulus (Riddoch et al., 2004). I studied whether MH would be sensitive to / captured by the grouped stimuli and if this would differ across the two visual fields. His eye-movements were recorded to support the behavioural findings. I list the important findings below:

- Performance in age-matched controls was not affected by configuration type. There was an effect of target position, though, with performance being more accurate when the configuration and target appeared bilaterally (in different-fields) compared to when they appeared in a single hemifield (same-field condition).

- In contrast to controls, MH was sensitive to configurations when they were presented in his ipsilesional field. Similar to younger controls in Chapter 4, MH was able to reject the distractors when they formed closed or homogeneous configurations, and performance was then better than when the heterogeneous configuration was present. There was no effect of configuration in his contralesional (right) field.
- MH performed better when the configuration appeared in his ipsilesional field and the target in his contralesional space compared to when both of them appeared in a single hemifield. It is possible that presenting the configuration and the target in the same field gives rise to competition for resources thus affecting the performance. This competition poses less as an issue when the same stimuli are presented across the visual field. This matches data on a bilateral advantage in the literature (Cavanagh and Alvarez, 2005; Sereno and Kosslyn, 1991).
- When one of the grouping cues was made less salient (each element carried a different colour thus weakening grouping by colour), MH found closed configurations difficult to exclude. In this case there was no difference in performance between homogeneous and heterogeneous configurations.
- The effects of visual field on configural coding occurred even though MH tended to make first fixations into his RVF, presumably as an attempt to compensate for a processing deficit there.

Overall, the lack of an effect of configuration type in the contralesional field (in spite of first fixations largely directed there) suggests the involvement of left parietal cortex in grouping processes. These results support the argument that attention is needed to enable grouping to take place optimally, even if the groups are subsequently suppressed as being irrelevant.

Chapter 6

This chapter investigated implicit grouping in patients with spatial and non-spatial biases in visual selection. Patients with either a left bias (after left hemisphere damage) or a right field bias (after right hemisphere damage) were tested along with age-matched control participants on a central target detection task while stimuli (either grouped or random) appeared in the background. The display durations were very brief (100 ms) and participants were aware that the background stimuli were irrelevant to their task. The effects of unilateral and bilateral background stimuli were separately tested in two experiments. Patients also performed in an explicit task where they reported the presence or absence of grouping / pattern in both unilateral and bilateral stimuli.

The main findings were:

- When asked to report explicitly the presence of grouping both groups of patients performed better with unilateral ipsilesional trials compared to unilateral contralesional trials. However, the two groups differed when asked to report the presence of grouping in bilateral stimuli. Patients with a left hemisphere lesion and left bias were only able to report grouping when both the fields contained patterns and performance was below chance when only one of the fields contained a pattern (the other being randomly arranged). Patients with a right hemisphere lesion showing a right bias were more accurate when the ipsilesional field contained a group (bilaterally grouped and ipsilesional grouped trials). Their performance on contralesional group trials was below chance. These data suggest that the right hemisphere patients were sensitive to grouping in the ipsi- but not the contralesional field (on explicit judgement tasks). In contrast, patients with left hemisphere lesions seemed sensitive to the presence of grouping in both field (enhancing judgements when grouping was in both fields).

- In the implicit grouping task (when participants responded to a central target stimulus), both patients and controls showed an effect of grouping when stimuli were presented unilaterally. Responses were speeded when the background stimuli grouped compared to when they were arranged randomly. There was no field effect.
- With bilateral stimuli performance again differed for right and left hemisphere patients. Right hemisphere patients with a right bias were faster on the central task when the bilateral stimuli carried similar information (both grouped or both random) compared to when the fields conveyed conflicting information (e.g., one grouped, the other random). This is consistent with these patients being biased to the ipsilesional field when the grouping status of the background changed across the fields. Exactly the opposite pattern was observed with patients with a left hemisphere lesion and a left field bias. These patients and the controls were slowed on the central task when the bilateral stimuli conveyed similar information (both grouped or both random) compared to when the fields conveyed conflicting information (e.g., one grouped, the other random). The results for left hemisphere patients fit with the idea that there is grouping in both fields but, when the grouping status is the same, attention is drawn to the background, which worsens responses to central targets.

In summary, the results showed that some grouping does occur under reduced attention in both the patients and controls. The study also showed that left and right hemisphere damaged patients differ on how grouping affects their behaviour with left hemisphere patients sensitive to similarity in grouping status, with attention drawn to the background when there is a consistent status across the visual field. In contrast right hemisphere patients show a bias in attention, which is greater when the items in the field have a different grouping status. In this case, cueing attention to the ipsilesional field worsens performance.

Robustness of the findings

The thesis presents a couple of robust findings. The presence of regularity consistently reduced the effect of set size on slope (Chapters 2 and 3). Also, Chapters 4 and 5 demonstrated a consistent pattern of configural effects in search. Both younger controls and MH (in his ipsilesional field) were more efficient in responding to the target when a closed or a homogeneous configuration was present compared to a heterogeneous configuration. This indicated the ease of rejecting 'good' patterns in facilitating search.

Now I discuss some of the overarching issues addressed by the thesis and their implications for understanding of grouping, attention and their interaction.

Attention and grouping

The results from this thesis showed that attention is sensitive to grouping. In visual search grouping distractors into regular configurations facilitated search compared to when the distractors formed irregular configurations (Chapter 2). There were effects of closure, of homogeneity of individual elements and also of positioning elements in regular positions (e.g., on the corners of a square). There is prior evidence for closure and homogeneity facilitating search (Donnelly et al., 1991; Duncan and Humphreys, 1989). Donnelly et al. (1991) showed that when heterogeneous elements were configured into shapes based on closure and good continuation, search was more efficient than when these cue were absent. There are a couple of differences to be noted here. First, in Donnelly et al.'s (1991) study the entire display was a shape formed by closure and/or good continuation and the target (when present) was part of this shape. It is possible that the target was automatically attended in Donnelly et al.'s study as it formed part of the configuration (Duncan, 1984). Alternatively the grouped distractors may have been easier to reject. Hence it is unclear how the benefit found with such displays comes about. This issue was resolved in the experiments I reported as the closed shape always contained distractor elements and even when the target was present inside the configuration it was not a part of it (Chapters 4 and 5). Participants remained faster in the presence of closed configurations thus providing stronger evidence that performance can be facilitated by the rejection of grouped distractors. Alongside this, the prior work on grouping effects on search has not provided clear evidence for effects based purely on the locations of the elements and not their shape properties. The results with heterogeneous configurations here, though indicating that our attentional systems are sensitive to the regularity of local element positions and this may form a basic type of configural coding which is enhanced by grouping between the local elements themselves. The argument for configural coding based on stimulus location matched the proposal from Pomerantz (1981) that there is a type-P (defined by the positions of the elements) form of configural coding, distinct from configural coding based on the identities of the local elements (nature of the elements; type-N).

Perceptual groups can automatically capture attention

The evidence presented here also indicates that there can be attentional capture by grouped patterns (Chapter 4). It has already been shown that perceptual objects such as a square formed by rotated Ls or a Kanizsa square can attract attention (Kimchi et al., 2007; Yeshurun et al., 2009; Rauschenberger and Yantis, 2001). I demonstrated that targets presented inside the configurations were detected more efficiently compared to when they appeared outside these perceptual groups indicating automatic capture (Chapter 4). However, unlike previous studies (Kimchi et al., 2007; Yeshurun et al., 2009) there was no cost to performance when the target appeared outside the configurations. This suggests that initial capture of attention by a perceptual object can be overcome if the task setting is appropriate. I discuss this in more detail in the next section.

Configuration-based inhibition

Chapters 2-5 demonstrated that perceptual groups could be suppressed more easily than non-grouped elements. Such configuration-based inhibition has been reported previously (Kunar et al., 2003a; Watson et al., 2001) but the types of configuration tested in those studies were limited. Here, it was shown that different types of configuration can lead to effective suppression of the irrelevant distractors. I have suggested that object files (Kahneman and Treisman, 1984) mediate this group-based suppression. Object files are temporary representations of objects in the scene which specify the features present, the relations between the features and the spatio-temporal identity of the stimulus (Kahneman et al., 1992). Different elements forming a group based on various Gestalt principles (e.g., similarity, closure, good continuation etc.) can be coded together in a single object file. These object files might help maintain a stable representation even in the occurrence of changes in the context (e.g., occlusion) or the location of the object (e.g., when the object translates across the field). Evidence from Chapter 2 supports this view. Changing the location of a previewed set of distractors did not affect search when the configurations were regular. In this case, suppression of the object file for the regular preview would lead to these distractors still being ignored even when they appeared in new locations in the search display, provided the regular configuration was maintained.

Not all groupings are equal

The thesis also brings out the point that not all groupings are equal. Different grouping principles were explored across the thesis. Chapter two manipulated the regularity of the configuration. The stimuli that made up the configurations were horizontal and vertical ellipses also containing a horizontal or a vertical line in them. Thus there were two levels at which grouping could take place. Under conditions of preview search, orientation-based grouping at the level of the global (preview) shape was dominant and determined the efficiency of visual search. The regularity of a sub-set of the distractors, when the same elements were present in full-set search, had at best only a small effect on performance – presumably because the configural group then competed with other potential groupings between display members. In contrast, full-set search was influenced by brightness-based grouping between the elements. These data are consistent with the view that, in complex displays where all the items appear together, texture-based grouping is influential (Treisman & Paterson, 1984).

Chapters 4 and 5 used configurations defined on the basis of closure, similarity and locations. These configurations shared identical spatial locations but differed in the relations between the form elements making up the displays (closed, homogeneous and heterogeneous items). The work here showed that closed elements were most effective, though effects of both item homogeneity and of the regularity of the locations of the elements were also shown to be important. Alongside this, there was also evidence that the grouping of the form elements making up these displays was modulated by attention. For example, there were minimal effects of form groups that fell in the (impaired) right visual field of a patient with damage to his left posterior parietal cortex (PPC).

Finally, the stimuli used in Chapter 6 were defined on the basis of brightness similarity (black and white dots formed alternating rows). In contrast to the results from Chapter 5 (where there was decreased grouping in a posterior parietal patient), there was evidence here for both left and right hemisphere patients (including patients with damage to the PPC) remaining sensitive to grouping in the contralesional field. For example, right hemisphere patients improved at explicit judgements about the presence of a group when the group fell on the left as well as the right side of space, while their responses to a central target were modulated by whether elements on both sides of the field grouped.

Trick and Enns (1997; see also Kimchi et al., 2004) distinguished between two kinds of grouping: cluster formation and shape formation. Cluster formation serves to pool together information to guide selection. Shape formation is dependent upon the details of the individual shapes. In some situations, cluster formation might be enough to modulate selection, whereas in other cases shape formation may be more critical. The stimuli used in Chapter 6 lend themselves to cluster formation and it is possible that clustering operations are relatively preserved even after damage to the PPC, which would weaken attentional modulation of grouping. Hence PPC patients remained influenced by grouping in the background and this did not differ significantly across the two visual fields even though patients exhibited reduced attention to one of the fields because of their lesions. This is not to state, however, that grouping at the cluster level is impervious to attentional feedback. Han and Humphreys (2007), for example, showed that the neural signals for early basic similarity and proximity-based group were reduced in patients with PPC lesions and reduced attention. The current data show that grouping can still modulate performance in such patients, but this is not to say that the effects were normal. In contrast to the stimuli in Chapter 6, the items in Chapters 4 and 5 were more complex and likely required shape formation – with grouping determined by shape homogeneity and similarity. It is possible that attention is more critical to grouping based on shape similarity than to grouping based on cluster formation, and hence clear effects of PPC lesioning were found on the grouping effect in this case.

Finally, one other type of grouping was apparent in the preview experiments (Chapters 2 and 3). Previous research suggests that attention can be selectively directed to temporally segregated groups (Jiang et al., 2002) just as attention can be directed to spatial groups (Chapters 4 and 5; see also Treisman, 1982). In the preview condition, half the items (previewed or old) appear first and the new items have a different onset. This procedure results in asynchronous temporal groups with attention selectively applied to the new group (Jiang et al., 2002). The results in Chapter 3 though indicated that the preview effect on search efficiency was dependent on previews being coded as discrete spatio-temporal event, when the spatio-temporal identity of the preview was reduced by having the preview onset at the same time as the search display, then the benefit to search efficiency was lost. These data are consistent with temporal grouping taking place between the preview and the search items, when the preview was offset and then re-onset along with the search displays. This temporal grouping was sufficient to overrule effects of configural grouping between the preview elements, so effects of the regularity of the configuration no longer mediated search efficiency.

Factors influencing the interaction between grouping and attention

The findings clearly show that the effect of grouping on visual selection is not an "all-or-none" phenomenon but is dependent on many factors. I highlight some of the key factors that have come up in this thesis.

Spatio-temporal continuity: a role for object files

It is important that a perceptual object (a configuration) maintains its perceptual continuity to avoid confusion with newly emerging objects and to avoid unnecessary processing of the same input twice. Because new objects are ecologically relevant, the visual system is tuned to respond to the cues that signal the arrival of new elements. Object files are representations that help the visual system maintain information regarding an object or a group of objects (Kahneman et al., 1992). Object files may be updated whenever changes occur. When the change is not in accordance with basic laws of spatio-temporal continuity, a new file should be opened to indicate the presence of a new object in the scene. In the gap-preview condition (Chapter 3) the display was offset briefly and was presented with the new set after the offset. This transient disrupted perceptual continuity and old items competed for selection with the new items. For grouping to have an effect, the grouped elements must belong together and adhere to spatio-temporal principles.

Task difficulty

Task difficulty is another important factor that seems to determine grouping effects. Many of the tasks explored in this thesis were relatively difficult – for example, requiring searching for a T among Ls (Julesz, 1983). These more difficult tasks may enable grouping effects to emerge. It would clearly be of interest to examine whether the grouping effects apparent here emerge under conditions in which the key tasks can be carried out more efficiently. It would also be of interest to explore how factors such as task load modulate grouping. According to the load theory of attention (Lavie, 1995), there may be greater processing of distractors under conditions of high rather than low cognitive load, and this might have enabled some of the apparent grouping effects (reflecting coding of the distractors) to emerge.

Grouping under reduced attention

The above discussion ultimately leads back to the repeatedly asked question: does grouping require attention? This thesis indicates that the answer to this question is neither straightforward nor simple. First, there are different kinds of grouping effect, and each may not require a similar level of attention. Second, the conditions in which these grouping operations come into play can vary. Therefore, it is crucial that these factors are taken into account before any debate about whether grouping requires attention can be concluded. There is a divide in the literature on this issue with some researchers holding that no grouping takes place without attention (Ben-Av, Sagi, and Braun, 1992; Mack et al., 1992) and others maintaining that grouping (at least some forms of grouping) can occur without attention (Kimchi et al., 2004; Lamy et al., 2006). These contrasting opinions could arise due to differences in the stimuli and tasks in particular studies. To take but one example, when the patients here were asked to explicitly report what grouping was present (Chapter 6), hardly any were aware of grouping taking place. On the other hand, clear effects of grouping were apparent when measured implicitly, via their effects on a central task. Different conclusions about whether grouping survives or is abolished by damage to posterior parietal cortex (and consequent changes in visual attention) would emerge here according to which measure is taken. These observations, in agreement with previous reports, (Moore and Egeth, 1997; Driver et al., 2001) show that grouping information may not be available to explicit report or awareness without attention though grouping itself can happen without attention in some cases. Once grouping provides candidate objects, attention needs to act upon the candidate representations, depending on the observer's requirement. As set out in the beginning of the thesis attention involves 'selection' and 'inhibition' to optimise information processing. Thus it is possible that attention is required when selection or inhibition need to be applied to the grouped object. Patient MH (Chapter 5) showed sensitivity to grouping in his good field but configurations from the contralesional field failed to have any impact on his performance. I suggest that this is due to a failure to apply inhibition to the grouped object that was irrelevant to search. MH suffered damage to left parietal cortex, which plays an important role in attentional processing. It is also possible however that left parietal cortex is important to grouping dependent on shape formation, and so MH showed a reduced effect for this reason. Further work is required to evaluate these points.

Conclusions

The thesis provides a detailed investigation into the role of grouping in attentional selection and inhibition. The thesis specifically contrasted different kinds of configurations and examined how the different configurations interacted with attention. The data indicate that grouping helps attention by facilitating distractor rejection, while attention can modulate at least some forms of grouping in its own right.

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APPENDICES

APPENDIX 1

REPLICATION OF PREVIEW BENEFIT

This experiment was carried out to ensure that the new hierarchical displays used throughout this study produced a preview benefit, and to act as a baseline for the subsequent experiments. The experiment consisted of three conditions: half-set search, full-set search and preview search. In preview condition, the initial (preview) display had randomly positioned elements.

Method

Participants

Thirteen participants (8 females and 5 males) took part in the study for course credits. All were post-graduate students of University of Birmingham in the age range of 23-36 years (mean age: 27 years). All had normal or corrected to normal vision.

Stimuli and design

The stimuli were created with Adobe Flash. The distractors were horizontal and vertical ellipses containing a congruent line (same orientation as the ellipse), for example, a vertical line in a vertical ellipse and that line could either be thick or thin (Figure 1.1). The stimuli measured 1.24º of visual angle on the longer side and 0.76º on the shorter side at a viewing distance of 60 cm. The ellipses were black and the line inside was white. The stimuli were presented on a gray background. The target was always an incongruent item (the orientations of the line and the ellipse were mismatched). The target was a horizontal ellipse with a vertical line. The line in the target could be either thick or thin with p=0.5 (see procedure). A target was present on all of the trials.

The experiment was a within subjects design with two factors: condition (half set, full set, and preview search) and set size (10 and 16). In the half set condition, only distractors from the search display in the preview condition were present. In the full set and preview conditions, both types of distractors shown in Figure 1.1 were present (i.e. preview and search). In the preview, the distractors were horizontal ellipses each with a horizontal line element.

Procedure

Participants had to complete three conditions presented in separate blocks: (i) half set baseline, (ii) full set baseline, and (iii) preview search. The experiment was run in MatLab using Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). A fixation cross appeared at the beginning of each trial for 500ms in every condition. In the half set and full set baseline conditions this was immediately followed by the search display. Participants were instructed to search for the target immediately after the items appeared. In the preview condition, the trial sequence (Figure 1.1) was slightly different. Here one set of distractors appeared first for 1000ms (the preview). The search items then followed with the target in the subsequent search display. In preview search participants were instructed to fixate and ignore the preview items until the search items appeared and to look for the target only when the second set of items appeared. In all the conditions the search items remained on the screen until participants responded.

A compound search task was used in which participants pressed “Z” on the keyboard if the line in the target was thick and “M” if it was thin. The subsequent trial started after an inter-trial interval of 500ms. All participants completed 24 practice trials for all three conditions before the main experiment started. The three conditions were administered in 12 blocks (4 blocks for each search condition) consisting of 544 trials in total. These blocks were counterbalanced across participants.

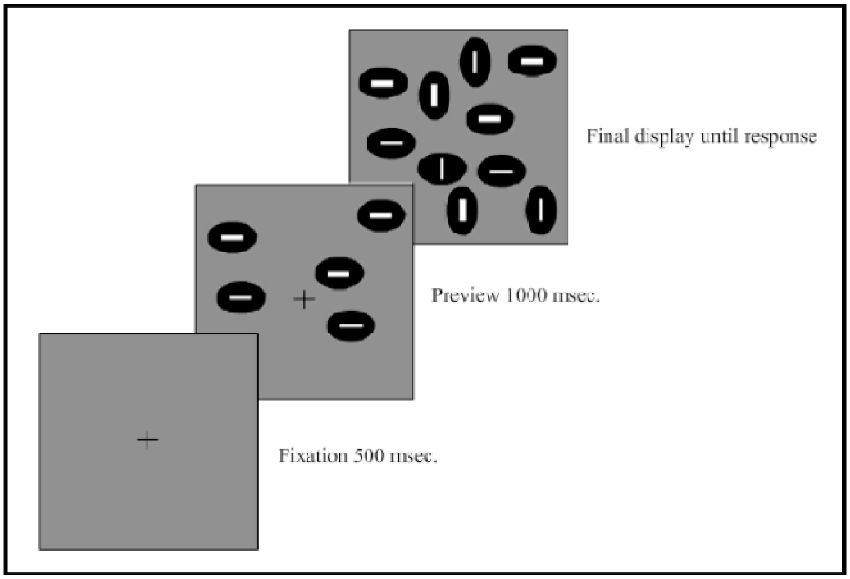


Figure 1.1: *A typical trial from a standard preview search condition. Full-set search (where all the items appeared simultaneously) display resembled the final display shown in the figure*

Results

Accuracy and reaction times (RTs) were recorded for each participant. Incorrect trials were dropped from the analysis (3.4%; see Table 1.1). A two (set sizes 10 and 16) x three (half set, full set, preview) repeated measures ANOVA did not reveal any significant main effects or interactions (set size: $F(1,12) = 3.023$, $p = 0.108$; condition: $F(2,24) = 2.619$, $p = 0.094$; set size x condition: $F(2,24) = 2.599$, $p = 0.095$).

Reaction times greater than two standard deviations away from each participant's mean and RTs less than 200ms were excluded from the analysis. A repeated measures analysis of variance (ANOVA) was carried out with set size (10, 16) and condition (half-set, full-set and preview) as two variables. Significant main effects were found for set size [$F(1,12)=112.357$, $p<0.01$], and condition [$F(2,24)=138.847$, $p<0.01$]. RTs were faster with the smaller display size and increased with more items. The interaction between set size and condition was also significant [$F(2,24)=24.168$, $p<0.01$] (Figure 1.2).

Table 1.1: *shows percent errors for each search condition across two set sizes.*

	Set Size	
	10	16
Half-set	2.12	2.98
Full-set	3.04	2.88
Preview	2.56	5.05

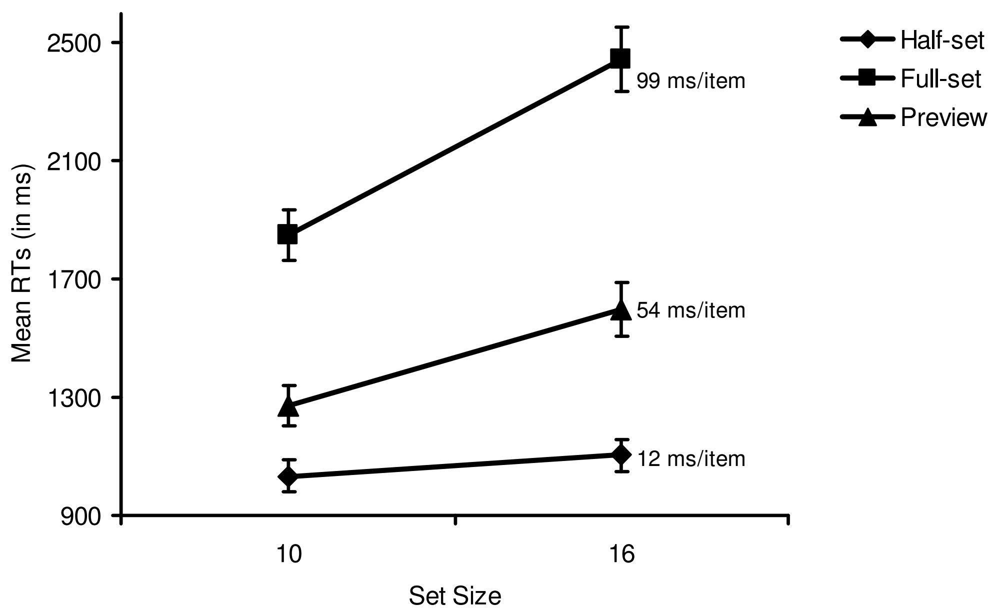


Figure 1.2: *RT slopes for the different search conditions.*

Comparisons were made between different search conditions to reveal the preview effects.

Full-set versus half-set: RTs increased with increasing set size, [$F(1,12)=54.850$, $p<0.01$] and RTs were faster in the half set condition [$F(1,12)=181.303$, $p<0.01$]. The interaction was also significant [$F(1,12)=49.875$, $p<0.01$]. RTs increased greatly with set size in the full set, but not in the half set condition (slopes: 98.92 ms/item and 11.56 ms/item respectively).

Full-set versus preview: All the main effects were significant. RTs increased as a function of set size [$F(1, 12) = 116.531$, $p<0.01$], and RTs were reduced in the preview condition relative to full set condition [$F(1, 12)=102.201$, $p<0.01$]. A further interaction between the two variables was also reliable; there were smaller effects of set size on preview search compared to full set search [$F(1,12)=7.987$, $p<0.05$].

Half-set versus preview: Again all the main effects were significant. RTs increased with the increasing set size [$F(1,12)=77.007$, $p<0.01$]. Faster RTs were observed in half set search compared to preview search [$F(1,12)=82.917$, $p<0.01$]. The interaction between the two variables was also significant [$F(1,12)=26.983$, $p<0.01$]. The effects of set size were greater on the preview than on half set search.

Discussion

We found a preview benefit in this experiment with search performance being more efficient in the preview condition than in the full set search. The effects of set size were larger in the full-set condition. The results showed that the new hierarchical stimuli produced a preview benefit, replicating previous findings (e.g. Watson and Humphreys, 1997).

APPENDIX 2

AGE EFFECTS IN CONFIGURATION PROCESSING: A COMPARISON OF YOUNGER AND OLDER CONTROLS

Participants

Younger participants (n = 14, mean age: 21 years) were students of University of Birmingham and older participants (n = 10, mean age: 60 years) were recruited from the community. Students received credits and older participants received cash in exchange for their participation. All of them reported normal or corrected-to-normal vision.

Method

Stimuli

The stimuli remained the same from Chapter 4 (Ls as distractors and T as a target).

A mixed design was used with the following within-subject variables: configuration (closed, heterogeneous, and homogeneous), target position (inside the configuration, same field as configuration or opposite field of the configuration) and field in which configuration was presented (left / right). Participant group (young / old) was a between-subject factor. A baseline condition was also included where no configurations were presented. The target appeared equally often in the left and right fields.

Procedure

The procedure remained the same from the previous Chapter.

Results

Accuracy and RTs were recorded for each participant. However, only the accuracy data were analysed. Proportion correct for each condition was calculated and entered into a repeated measures mixed ANOVA with the following three within-subject factors: configuration (closed, heterogeneous, homogeneous), target position (inside the configuration, same field as configuration or opposite field of the configuration) and field in which configuration was presented (left or right) and participant group (young / old) as a between-subject factor. This analysis revealed reliable main effects of configuration [$F(2,44)=17.915$, $p<0.001$] and target position [$F(2,44)=13.163$, $p<0.001$] but no effect of field [$F<1$]. The interaction between configuration and target position was significant [$F(4,88)=3.601$, $p<0.01$]. Two-way interactions between field and configuration [$F(2,44)=1.961$, $p=0.153$] and field and target position [$F<1$] failed to reach significance. Three way interaction between configuration, target position and field also failed to reach significance [$F(4,88)=1.059$, $p=0.371$].

The main effect of the between-subject factor (participant group) was significant [$F(1,22)=19.876$, $p<0.001$]. Younger participants were more accurate overall compared to older participants. This between subject factor also interacted with the main effect of configuration [$F(2,44)=8.367$, $p<0.01$]. Finally all of the significant effects observed above were qualified in a significant interaction between configuration x target position x participant group [$F(4,88)=3.041$, $p<0.05$].

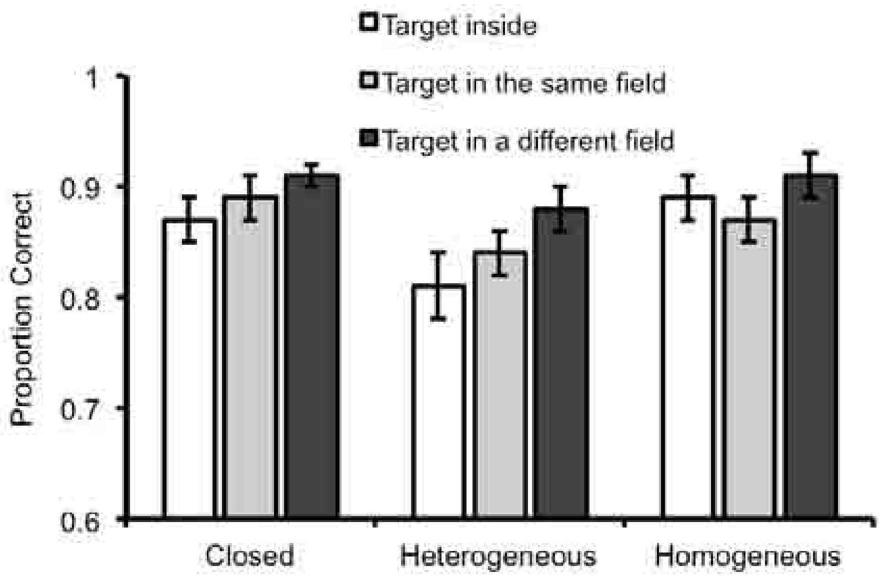
Since there were no effects involving field, the data were collapsed across fields in further analyses. These data were then analysed with configuration and target position as two within-subject factors. With younger participants there was an effect of configuration [$F(2,26)=12.508$, $p<0.001$]. These participants were more accurate when closed [$t(13)=4.868$, $p<0.001$ – two tailed] and homogeneous configurations [$t(13)=-4.430$, $p<0.01$ – two tailed] were presented compared to heterogeneous configurations. Participants performed equally well when closed and homogeneous configurations were presented [$t(13)=0.211$, $p=0.836$ – two tailed]. Younger participants tended to be slightly more accurate on the different-field trials compared to target inside and same-field trials however the effect was not statistically significant [$F(2,26)=3.363$, $p=0.07$]. Two-way interaction between configuration x target position was not significant [$F<1$].

With older participants there were main effects of configuration [$F(2,18)=14.805$, $p<0.001$] and target position [$F(2,18)=8.947$, $p<0.01$]. The interaction between these two factors was also significant [$F(4,36)=4.066$, $p<0.01$]. Follow-up analyses for each of the configural conditions (target position as a factor) revealed that target position did not have an effect on the performance of older adults when a closed configuration was presented [$F<1$]. However, target position had a significant effect on the performance when heterogeneous [$F(2,18)=10.336$, $p<0.01$] and homogeneous [$F(2,18)=9.263$, $p<0.01$] configurations were presented. The effect of target position on heterogeneous and homogeneous configurations was similar. Accuracy was lowest when the target was presented inside the configurations. Performance was better on same-field (where configuration and target were presented in a single hemifield) trials compared to target-inside trials. Older participants were most accurate when one of these configurations and the target were presented in two different hemifields (different-field trials).

Although the effect of target position seemed similar in the younger and older participants, it was significant only in the case of older adults. Closed configurations were immune to the effect of target position in the older adults but target position did exert an influence when a heterogeneous or a homogeneous configuration was presented.

Younger participants performed better on closed and homogeneous configuration displays and the two types did not differ from each other. However, relative to when closed configurations were present, older participants performed worse when a homogeneous configuration occurred, especially when the target was presented inside the configuration.

(A)



(B)

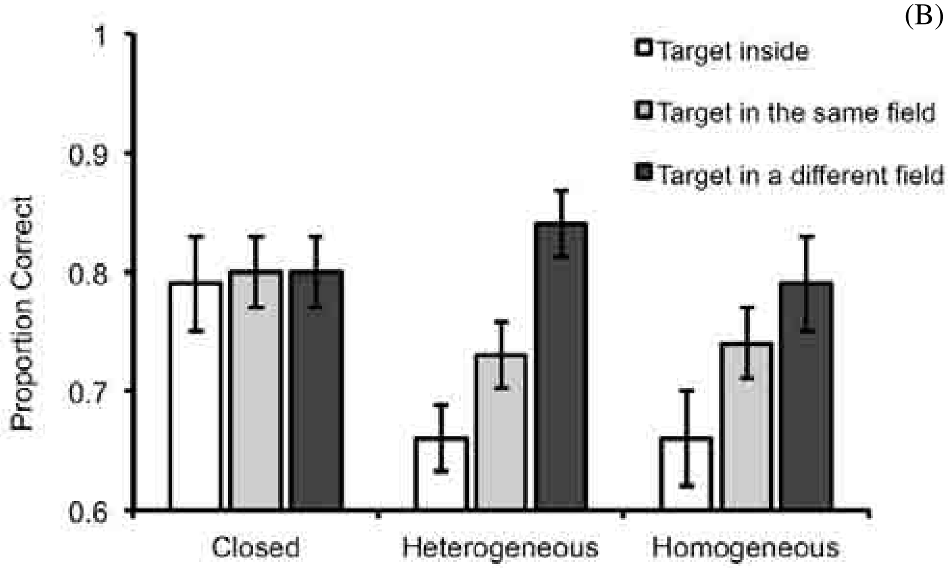


Figure 2.1: *shows proportion correct data for young (A) and old (B) participants for each of the configuration (x-axis) and target position.*

Discussion

There were two main findings. Younger adults performed equally well in the presence of closed and homogeneous configurations. Target detection was difficult when heterogeneous configurations were present. This was not the case with older adults. Target detection was difficult for older adults when the target occurred in the homogeneous as well as the heterogeneous configuration. Target position did not have any effect on the trials where a closed configuration was presented. This difference between the younger and older adults indicates that there might be age-related decline in the configural processing. Habak et al. (2009) showed that processing shape by texture is impaired in older adults compared to younger adults. Here older adults were very efficient when a closed configuration was present. However, the presence of a homogeneous configuration significantly reduced their accuracy and their performance then was no better than when a heterogeneous configuration was present. This suggests that processing shape by closure is unaffected by the age which also finds support from a recent study (Habak, Wilkinson and Wilson, 2009 but see also Del Viva and Agostini, 2007 and Roudaia, Bennett and Sekular, 2008), but processing texture (probably required by the homogeneous configurations) was affected by age.

The second important finding was that both younger and older adults performed best on the trials where the configuration and the target were presented in two separate hemifields (different-field condition). This advantage was found even though the distance between the configuration and the target was matched across same-field and different-field conditions. It is possible that the different-field condition enabled participants to process the distractor configuration and the target independently in the two hemifields. The same-field condition might present itself with the problem of competition for shared resources, as the distractor configuration and the target were present in a single hemifield. In contrast, there may be a benefit for trials where the configuration and the target appear in different fields, as any competition for resources is then resolved. There is evidence in the literature for such independent attentional processing in the two hemispheres (Luck et al., 1989; Sereno and Kosslyn, 1991; Alvarez and Cavanagh, 2005). This study adds to the current evidence on independent attentional processing in the two hemifields.