NORMAL AND ABNORMAL ATTENTIONAL DWELL TIME: CONSTRAINS OF TEMPORAL CODING IN VISUAL ATTENTION IN NEUROLOGICAL PATIENTS AND NORMAL INDIVIDUALS

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Abstract

This thesis is concerned with the analysis of constrains of temporal coding in visual selective attention. It is well known that despite the great amount of visual information present in the environment the human visual system is only capable to attend and select some of it. How the brain is able to selectively prioritize relevant information and de-prioritize the irrelevant information in order to guide us through space, has been extensively investigated (Treisman and Gelade, 1980; Posner, 1980). Less is known about how this occurs over time. In the present thesis I investigate the role of temporal limitation of selective attention in brain damaged patients and in normal participants by using a simplified version (attentional dwell time paradigm, Duncan et al., 1994), of the Attentional Blink (AB) paradigm which involves the identification of two or more visual targets when stimuli are presented rapidly in temporal succession always at one location (Broadbent and Broadbent, 1987; Raymond, Shapiro and Arnell, 1992). Within this paradigm I have manipulated different factors which may influence this limitation such as: temporal binding, perceptual similarity among stimuli, task switching, integration of audio-visual information and working memory. In addition, by examining the AB in different brain lesioned groups, this thesis attempts to throws light on the neural mechanisms underlying temporal coding and selection. Evidence was provided of the influence of all these mechanisms in coding, selecting and consolidating visual information over time which suggest a multi components nature of temporal selection as well as possible involvements of a temporo-parietal network (Corbetta and Shulman, 2002) which governs their integration.

A mio padre

(to my father)

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Chapter 1

INTRODUCTION

This thesis attempts to understand and analyse the constraints on temporal coding in visual selective attention in both neurological patients and normal participants, and it attempts to analyse how temporal limitations in processing affect the conscious perception of visual input.

Visuo-spatial attention is one of the most popular subjects of investigation in Cognitive Neuroscience and in the past decade the interest in this topic has grown even more. Among other important aspects of visual attention, the study of its limitations has received particular notice in the literature, being an effective way to understand the different components of the complex architecture of attentional systems.

The amount of incoming information arriving at our perceptual systems is greater than we can fully attend and elaborate. Consequently, relevant information must be prioritized and irrelevant information de-prioritized, to enable limited capacity systems not to be over-loaded (Treisman and Gelade, 1980; Posner, 1980). This prioritization and de-prioritization processes characterise visual selective attention. The primary role which has been given to visuo-spatial attention refers to the fact that it helps the observer to direct his action through space to select the relevant visual information and use it for action (Desimone and Duncan, 1995; Lee et al., 1999; Duncan, 2006). Different attentional mechanisms have been suggested to operate concurrently to unable the efficient selection of relevant stimuli (see Corbetta and

Shulman, 2002, for one summary). Less is known about how visual selection operates over time or about the temporal limitations on information processing. In everyday life we are constantly required to pay attention to different objects or events at the same time. For instance, looking at road signs trying to find a new destination while at the same time, driving and listening to the direction given to you by a friend sitting next to you, is a good example of the demands on attentional resources. Everyday experience suggests that there are costs on processing multiple stimuli and performing multiple actions, implicating disruption of a central capacity system (or central executive) necessary to information processing (Lee, Koch and Braun, 1999). Following the car example, this limitation could affect the ability to detect new visual events taking place while we are busy driving and paying attention to the road. A reduced capacity in visual processing may occur not only when we attend concurrently to multiple events taking place at different spatial locations, but also when these events happen close in time at one location (Lawrence, 1971). The present thesis is concerned with temporal limitations on visual attention. To study temporal aspects of attention, the experiments were based around the Attentional Blink (AB) paradigm which involves the identification of two or more visual targets when stimuli are presented rapidly in temporal succession (e.g., under conditions of rapid serial visual presentation, RSVP). The 'Attention Blink'(Broadbent and Broadbent, 1987; Raymond, Shapiro and Arnell, 1992) is observed when participants are able to identify a single target (T2), but fail to identify the same item when it appears within a time window of approximately 400 ms after the presentation of a first target (T1) that has to be reported. Despite limitations due to its 'artificial' nature, the AB paradigm has provided a powerful means for examining basic attentional limitations influencing the conscious processing of visual stimuli over time. Here a simplified version of the AB procedure is primarily adopted, involving the presentation of only two targets, each

followed by a mask (rather than presenting distracters along with targets; this has been termed the attentional dwell time paradigm; Duncan et al., 1994). This simplified procedure eliminates contributions to the AB from the processes concerned with the rejection of distracters, and it is also particularly amenable to studies involving brain lesioned patients, while maintaining limitations in the temporal selection of multiple targets. This Introduction will first present a classification of different theories of the AB and their underlying theoretical assumptions, using data on temporal limitations in information processing in normal individuals and in neurological patients. In addition, my review will cover factors explored in this thesis in order to understand additional constraints on temporal selection, namely: temporal binding, the effects of feature repetition, task switching, working memory (WM) load, and the role in selection that may be played by cross-modal signal integration. Finally the reduced AB procedure will be used to probe the nature of the selection deficit in a patient with a spatial bias in selection and the clinical symptoms of unilateral neglect, to assess whether spatial problems in consolidation or in attentional disengagement best characterise the disorder. A specific focus will be on the idea that temporal coding of visual information is constrained by a number of different processes which need to be teased apart to understand how temporal selection operates in vision.

"Bottle-neck", "temporary loss of control" and "boost and bounce": why the Attentional Blink occurs?

A conspicuous amount of literature on the AB has been produced over the past twenty years. The AB effect has been measured using a wide range of different procedures (visual or auditory detection, identification, visual search, task switching etc.), and a

wide variety of different stimuli have been used (colours, letters, digits, orientation, bright lights, sounds, pictures etc.). For the purpose of this thesis I have divided the literature on the AB into three main conceptual frameworks: (1) so called bottle-neck or limited capacity accounts, (2) the 'temporary loss of control' theory and (3) the 'overinvestment' theory. However it must be noted that, despite the attempts to explain the AB effect using different theoretical accounts, almost all of these theories include the notion that the effect stems from critical capacity limitations in information processing.

Capacity limitation or bottle-neck theories

The very first attempt to demonstrate temporal constrains on visual attention can be attributed to Lawrence (1971) who presented a single target among distractors within a rapid serial visual presentation (RSVP). Participants found it more difficult to detect one target rapidly followed by a complex stream of stimuli compared to when it was presented alone. Different theoretical accounts of the underlying attentional mechanism characterising temporal limitations in information processing have been put forward by different authors (e.g. Reevs and Sperling, 1986; Weichselgartnes and Sperling, 1987, Kanwisher and Potter, 1989), who commonly attribute the effect to a depletion of attentional resources when multiple stimuli must be processed under time-limited conditions. Broadbent and Broadbent (1987) extended Lawrence's RSVP paradigm, showing for the first time the poor report of multiple targets. These authors demonstrated how interference caused by the detection of a first target (T1) impaired the correct report of a second target (T2) appearing within 500 ms. Raymond, Shapiro and Arnell (1992) systematically investigated this phenomenon further, manipulating the number of post target items presented and the difficulty of the task. Similarly to

Broadbent and Broadbent, these authors observed that, when participants had to report two targets under conditions of rapid serial visual presentation (RSVP), they are typically able to identify a single target (T2, e.g. a black X), but fail to identify the same item when it appears within a time window of approximately half a second after the presentation of a first target (T1, e.g. a white letter 'A'). The limitation on reporting T2 was not present, though, when T1 did not have to be reported – demonstrating an effect on attentional processing and not (simply) visual masking of T2 by T1. Moreover Raymond et al. also found that, if T1 was immediately followed by a blank, the effect disappeared. In analogy to an overt blink of the eye in which visual information is missed, this temporal limitation of visual attention was named the 'attentional blink' (Raymond et al., 1992). Raymond and colleagues developed this concept further (Shapiro and Raymond, 1994, Shapiro et al., 1994) and attributed the AB effect to interference produced by the competition between T1 and the post-T1 items to be consolidated into visual short term memory (VSTM). A further development of the limited capacity account was provided by Chun and Potter (1995). These authors put forward a two-stage account of the AB which posited that all the items embedded in the RSVP stream can reach an initial level of representation that is quite vulnerable to interference from subsequent processing. In order to be consciously reported the stimuli have to reach a second stage of processing in which their sensory representation must be transferred to and consolidated in WM, a process that is assumed to draw on attentional resources (Duncan, Ward and Shapiro, 1994). If processing resources are allocated to consolidate T1, depending how severely masked it is by following items, fewer resources are left to consolidate T2. As a consequence, T2 may not be encoded in WM and is thus missed. According to this 'bottleneck' account, the early stages of processing have a high processing capacity and are devoted to the identification and selection of potential targets. A later, central, and

capacity-limited stage processes the items selected so that they can be available for output. The AB deficit is caused by a limitation in the central stage(s) of processing of T1, which produces a delay in the central processing of T2, while T1 is still being elaborated by the central processing mechanisms. Similar accounts have been put forward by Jolicoeur and colleagues (1998a, b, 1999, 2001) who particularly focused on the effect that Task1 associated with the first target (T1) had on report of T2 (Task2). The manipulation of task difficulty did not limit the availability or the quality of the visual information contained in T1, but rather affected how efficiently the information contained in T2 could be used by later, central stages of processing.

Finally, but still related to the limited-capacity model of the AB, Bowman and Wyble put forward a computational model of the AB (Wyble et al., 2004; Wyble and Bowman, 2005; Bowman and Wyble, 2007) in which temporal binding is proposed to be a crucial element in consolidation. It is well known from the literature that binding features together leads to the formation of object tokens which are defined by their spatio-temporal continuity (e.g. Treisman, 1996; Kahneman et al., 1992). Bowman and Wyble have claimed that the AB effect is a hallmark of the limitation in the temporal resolution of binding *types* (perceptual representation of an object) into WM *tokens* (episodic representations of an object) for their conscious report. That is in order for an item to be successfully encoded in WM, its distributed neural representation needs to be bound episodically into a coherent unit. This process takes time and occurs serially. Different characteristics of T1 are bound together as a result of attentional enhancement operated by a 'blaster' which can accidentally bind two items to the same token. Bowman and Wyble proposed that T2 consolidation is suppressed in order to prevent interference with T1 binding as only one token can be bound to its type at a time.

In conclusion these theories (the interference theory, the two-stage theory or the capacity limitation/bottle-neck/temporal binding theory) attribute the AB to a temporal limitation in consolidating (binding) the visual information into WM and attribute a crucial role to the disruptive/misguiding effect of distractors (see below).

Temporary loss of control theory (TLC)

Di Lollo and colleagues have attempted to put forward an alternative account to the limited-capacity accounts of the AB (Di Lollo, Kawahara, Gorashi and Enns, 2005, Kawahara, Enns and Di Lollo, 2006) denying that a lack of resources, induced by the processing of T1, is responsible for the AB effect. These authors have used triplets of stimuli embedded in a RSVP stream of distractors. In one condition the triplets consisted of two targets and one distractor (i.e. T1, D, T2). As expected, there was a drop of performance in reporting T2 after T1, providing a basic AB effect. Surprisingly however, in a second condition in which the triplets consisted in three successive targets (i.e. T1, T2, T3), in which the last target (T3) was in the same exactly temporal position relative to T1 as was the last target in the previous two-target condition, the authors found that detection accuracy of T3 did not differ from that of T1. That is, no AB effect was found, and indeed there was better report of T2 than the other targets (lag-2 sparing). These authors argued that the AB is not caused by capacity limitations in processing T1 and then in consolidating T2. Instead they suggest that the AB is due to a temporary disruption of endogenous attentional control settings. These authors propose that the initial processing of incoming visual information is governed by an input filter which is configured to pass target items but not non-target items into a higher stage where information is consolidated for subsequent report. This filter is maintained by signals sent by a central processor

which is crucial for the consolidating the visual input into WM. This central processor can perform only one function at a time and as soon as a first item appears (T1) from the target set the filter is opened; however, if the post-T1 item has similar perceptual characteristics to T1, then the filter becomes vulnerable to stimulus disruptions and there is 'temporarily loss of control'. As a consequence of this, targets will no longer be allowed in and the time taken by the central control to restore the attentional set will produce a delay in processing further stimuli until the system is fully restored. In conclusion, Di Lollo et al. explain the AB as a temporary loss control (TLC), during the process of target identification, over the system configuration which is no longer available to govern the input of incoming stimuli competing for selection. However because Di Lollo and colleagues still attribute the missed detection of T2 to the fact that the central executive is occupied in processing T1, then these authors do not avoid the resource depletion argument.

The boost and bounce theory (overinvestment hypothesis)

In contrast with the above theories of the AB, Olivers and colleagues (Olivers, van der Stigchel and Hulleman, 2005, Olivers and Meeter, 2008) deny that a lack of resources in processing T1 is responsible for the AB effect and reject a limited capacity theory to account for the AB. Instead they propose what they call "boost and bounce" theory of temporal attention (Olivers and Meeter, 2008). Instead of assuming a long-lasting reduced attentional control over the incoming visual information, Olivers and colleagues propose quite the opposite interpretation: the AB reflects an overwhelming control (over-investment) of attentional resources over incoming new information. According to this view the incoming visual input is filtered or gated by working memory which is set for targets against distracters. Working memory enhances the control over the incoming visual input and suppresses the processing of post-T1

distractors. The period of suppression induced by working memory control recovers across a relatively long time interval of a few hundred milliseconds, affecting the processing of T2 if it occurs within this time gap. WM control is proposed to operate through a gating system (Reeves and Sperling, 1986) which overinvests attentional resources in 'boosting' the processing of T1 and, as a consequence of this, a strong inhibitory process (bounce) will trigger the closure of the attentional gate which temporarily stops T2 from being processed further. For this model the role of post-target distractors is critical to the AB, since it is to protect WM from these items that the attentional gate is recruited. This has been corroborated by previous studies in which the blink was not found if in a sequence of target-distractor-target stimuli (T-D-T), the distractor was substituted by another target (T-T-T) (Di Lollo et al., 2005; Olivers et al., 2007). Despite Olivers and Meeter denying that capacity limitations are a core feature of the AB, they still admit the occurrence of a capacity limitation in working memory and also in the rapid reconfiguration of an attentional set, to enable a second target to be identified immediately after the rejection of distracters (for which the attentional gate is recruited).

An alternative to distractor based-accounts?

A main tendency among all the above mentioned theoretical accounts of the AB is to attribute a fundamental role to distractors for the occurrence of the AB, although for different reasons. For instance Chun and Potter (1995) proposed that distractors following the T1 and T2 stimuli are important to create the interference conditions that generate the AB. Also Raymond et al., (1992) and Olivers and colleagues (2005, 2008) attributed to post-T1 distractors the role of triggering a suppression mechanism aimed to inhibit their selection which inadvertently affects the processing of a shortly following second target. Moreover Di Lollo and colleagues also attribute a functional

role to post-target distractors in their model. These authors propose that a central executive is temporarily engaged in processing T1 and consequently loses its control over a pro-target attentional set. The temporary disruption of this set, triggered by the distractor following the target, causes the attentional set to be reconfigured and the AB to occur.

In contrast to these interpretations however, Nieuwenstein and colleagues (2006, 2009a, b) have recently reported an AB both when T1 (black letter) was masked by distractors (digits) before the appearance of T2 as well as when distractors were replaced by two blanks. They proposed an account on the AB which focuses on the effect of engagement/disengagement of selective attention suggesting that the cause of the AB lies in the difficulty of attending and processing two discrete target events regardless of whether they are intermingled by perceptually different distractors or just blanks. In conclusion these authors denied a capacity limitation account of the AB due to a disruptive effect caused by distractors and suggested that the AB reflects the struggle of selective attention to engage twice (once to identify T1 and a second time to identify T2) within a short period of time.

Simple is better (?)

As noted above, for many of the different accounts of the AB the presence of distracters is vital. However, temporal limits on visual processing have also been reported in simplified versions of the AB procedure where only two targets are presented (plus masks). Duncan et al. (1994) used a so-called 'attentional dwell time' paradigm comprising of two targets followed by two masks. The critical measurement in this paradigm is how long the first target continues to interfere with the second

target. They found that there was poor report of T2 following the report of T1 when the interval between the stimuli was less than 500ms or so. This drop in reporting T2 did not arise when T1 had to be ignored. They argued that the temporal profile of performance in this paradigm reflected the time to consolidate visual information in working memory (the dwell time needed for attentional consolidation). To that extent that this procedure minimizes processes concerned with distracter rejection and/or any additional noise created by distractors, then it may provide a 'purer' means to examine temporal limitations on processing.

Due to the possible 'purer' nature of the procedure, the dwell-time paradigm has been adopted in this thesis. In addition one further advantage is that the dwell-time procedure is simpler to perform for individuals with cognitive limitations. A substantial part of this thesis is concerned with the effects of brain lesions on temporal attention and the dwell-time procedure is somewhat easier to adopt with brain lesioned patients for whom the distinction between distractors and targets is not always readily apparent.

By excluding the effects of distractor competition by using the attentional dwell-time procedure I also aimed to carry out more selective tests of various factors on the temporal limitations in visual processing. These additional factors were: temporal binding, feature similarity, task switching, cross modal integration and working memory. Work on these different factors will now be considered.

Temporal binding

It is well known in the literature on visual attention that the processes involved in binding together different features of objects provide an important limitation on visual processing (Treisman and Gelade, 1980) – an example being the apparently serial

(attention-dependent) visual search required when targets are defined by a conjunction of features. Based on such findings, the influential feature integration theory proposes that focal attention is required to conjoin or bind correctly together multiple features into a single object. A visible outcome of the withdrawing of attentional resources is that errors occur for binding relations between features – so-called "illusory conjunction" errors (Treisman and Schmidt, 1982). Treisman and colleagues (Kahneman, Treisman and Gibbs, 1992) distinguished between different types of binding (e.g. property binding, part binding, conditional binding etc.). For the purpose of the present study only temporal binding is considered, in which successive states of the same object have to be bound to the time interval at which they occurred.

As mentioned earlier, temporal binding has been described as a crucial element for consolidation of the visual input into WM (Bowman and Wyble, 2007). Wyble et al. distinguish two aspects of the binding mechanism: binding of the different features of a stimulus and the binding of these items in their correct temporal order. Theories of binding have classically focused on the first issue (Treisman and Gelade, 1980). However the second is also crucial for the AB, as in the absence of temporal binding the temporal order in which the two targets are encoded into working memory can be lost. For this reason is quite common to observe the occurrence of temporal binding errors when normal participants perform an AB task. These errors are thought to be differentially distributed within the RSVP stream, depending on the nature of the stimuli or the task to be performed (Chun, 1997). In addition, if perceptual features are shared between targets and distractors (e.g., in the AB procedure) then failure to code the temporal positions of stimuli can lead to target colour or shape being inappropriately combined across stimuli so that illusory conjunction results (see Sperling and Weichselgartner, 1995). In early work by McLean et al. (1983), using

rapid serial visual presentations, these authors report that errors were often temporally displaced (e.g. when asked to report the red item, subjects often reported items following the red item) – which was assumed to be due to slow selection of the second attribute after detecting the target's colour. However this phenomenon can also reflect poor temporal coding in which the temporal order of different stimuli is not preserved. (see Chapter 2, Error analysis and Discussion). In Chapter 2 of this thesis temporal binding will be particularly analyzed in the context of the analysis of limitation of temporal coding in brain damaged patients. Prior work has demonstrated that brain damaged patients can have impaired spatial binding of features – with conjunction search being slowed and abnormally high numbers of ICs reported when targets and distracters are distributed across space (Friedman-Hill, Robertson and Treisman, 1995; Humphreys et al., 2000) Interestingly, poor spatial binding of features has been noted particularly after damage to posterior parietal cortex (e.g., when compared to patients with frontal lobe lesions; see Humphreys, Hodsoll and Riddoch, 2009). In contrast, temporal binding has rarely been explored in patients. This was examined here.

Feature similarity and repetition blindness

Another factor which could influence the correct coding of visual information over time is stimulus similarity. The effect of target/non-target feature similarity has been extensively investigated in the context of visual search (e.g. Treisman and Gelade, 1980; Duncan and Humphreys, 1989; Treisman, 1991; Wolfe, 1994; Proulx and Egeth, 2006) where the perceptual relationships between targets and distractors have been manipulated in order to understand the nature of visual selection. These studies have shown that normal participants produce more errors and take longer to select

targets among perceptually similar distractors compared to when the targets do not share such characteristics.

Other evidence for a detrimental effect of feature similarity on selection has been reported in brain damaged patients. For example, Baylis, Driver and Rafal (1993) studied the effect of feature similarity in patients with visual extinction (the poor report of multiple items relative to when single items are presented). Baylis et al. found that extinction was greater when patients were presented with two stimuli simultaneously that had the same to-be-reported features than when the stimuli had different to-be-reported features. Thus extinction was more pronounced for pairs of stimuli sharing colour or shape when the task was to report that attribute, while repetition on the irrelevant dimension had no effect on performance. These data on the effects of feature similarity on extinction are reminiscent of data on so-called 'repetition blindness' (RB) with normal participants. RB was shown for the first time by Kanwisher (1987), who demonstrated how the repetition of two identical items within a RSVP stream is not perceived correctly – with participants being worse at reporting the second of two repeated items than two non-repeated stimuli Kanwisher and her colleagues (1987, 1990, 1994) attributed this effect to a disruption of type/token binding. They assume that visual recognition takes place with the binding of a type (object perceptual category) recognition to a token (object temporal location) formation. These authors propose that type/token binding is more difficult when stimuli are identical; when binding is challenged under short presentation conditions, so report is worst for repeated stimuli.

As noted by Chun (1997) RB and the AB share some important common features which merit mention. Firstly, both paradigms use RSVP procedures and reflect a temporal limit in information processing, and both occur with the prerequisite being

that T1 needs to be attended first. However while the RB is strictly linked to the manipulation of the perceptual identity of stimuli (i.e., their perceptual similarity), this is not necessary for the occurrence of the AB, although feature similarity can be an important factor. For this reason the effect of stimuli similarity have been extensively investigated in the context of the AB. A number of studies have demonstrated that the AB effect is increased if the distractors are similar to T1 and/or T2 (e.g. Chun and Potter, 1995; Raymond et al., 1995; Maki et al., 2003; Olivers and Watson, 2006) and it occurs on a perceptual as well as a semantic level. In most AB interpretations the similarity between targets and distractors affects their concurrent activation by increasing perceptual interference and this, results in a deeper AB. In the context of this thesis target feature similarity was manipulated as a factor which could have an effect on temporal selection. Differently from previous studies of the AB which varied the perceptual similarity between target and distractors or among distractors, here I have manipulated the perceptual similarity between targets (T1 and T2). The manipulation was close to the study of Baylis et al. (1993) with neuropsychological patients showing extinction in that participants could respond selectively to colour or shape (in different conditions), which the colour and/or shape of the targets was varied. Does the AB in patients reflect visual extinction, with their being poor report of a repeated feature that has relevant to the task?

Task switching

A third factor manipulated in the present thesis is task switching (Chapter 3). The ability to switch between different cognitive tasks is part of everyday life, as when we are working on a PC in our office and unexpectedly the phone rings and a friend reminds you that it's lunch time and you were meant to meet to have a quick bite

together. You will have to save the document on which you were working on, remember to sign the birthday card you need to give to your friend, take your wallet and coat and walk to the café around the corner to meet her/him. All these activities require the correct configuration of multiple task-sets and their correct temporal execution. Hence efficient task switching is intrinsically necessary for productive and effective behavior. In complex environments, task switching not only requires the subject to set a goal for his or her action but also to select and perform a small set of simple sub-tasks which may need to be ordered by 'executive' mechanisms over time and space. Prior work indicates that successful task switching is affected by a number of different factors which can be controlled by our intentions ('endogenous control') or are influenced by external factors and not under direct control ('exogenous control') (Goscke 2000). In many cases, the ability to switch between different processes and/or tasks depends on endogenous attentional mechanisms which exert 'executive control' over ongoing processing.

The first experimental study to be published on task switching has been credited to Jersild in 1927. Jersild asked his students to time themselves in either adding or subtracting the number 3 from a list of numbers. In separate blocks the students either just performed one task or they alternated between subtracting and adding the digits. The students showed a dramatic decrease in performance when they had to alternate the two tasks compared to when they repeated the same task. Jersild's paradigm was further developed in the early 70's and again in the middle 90's by other authors (e.g. Spector and Biederman, 1976; Allport et al., 1994), with participants typically having to alternate between two tasks on successive trials and with performance (RTs and errors) being recorded on each trial in relation to when no alternation is required. Again costs of task switching have been observed. Subsequent work has sought to

tease apart the different factors that contribute to the costs of task switching – including factors such as having to remember two sets of task instructions, having to re-configure the task set (when the set changes) and so forth (e.g. 'alternating task paradigm', Roger and Monsell, 1995; pres-determined task sequence approach, Allport and Wylie, 1999; 'task cueing paradigm', Sudevan and Taylor, 1987; for a general review see Monsell, 2003).

Although task switching has not always been independently analyzed as an intervening factor in studies of the AB, it may be a contributory factor in some studies. For example, consider the case where participants are required to report the identity of a first target (T1) in the form of a white letter and subsequently detect the presence of a second target (T2) in the form of a black 'X'. In this case subjects are required to switch from one perceptual identity set (e.g. 'search for a white letter and ignore digits') to another ('search for a black X') (Raymond et al., 1994). Hence the worse report of T2 following the report of T1, relative to when T2 only is reported (the AB) may be due (in part) to participants having to switch task sets from T1 when they code T2 (no switch would be required when only T2 has to be reported). Chun and Potter (2001) in an extensive review of the AB in the context of task switch theories suggested that some AB effects found in the literature (e.g., with cross-modal AB) can be attributed to task switching rather that a pure capacity limitation mechanism - though they excluded a direct causal link between the two phenomenon because the AB can also be observed when T1 and T2 belong to a similar (but not identical) perceptual category (e.g. Chun and Potter, 1995; T1 and T2 are two black letters to be identified among digits).

Interestingly, at least some piece of evidence indicating that there is a more pronounced AB in brain damaged patients with visual neglect, relative to controls

(e.g. Husain et al., 1997), may be attributed to task switching. For example, in Husain et al. (1997) patients had to switch from selecting a letter defined by its colour for the report of T1 (e.g. a white T) to selecting a letter defined for its shape for the report of T2 (e.g. a black X, so that the 'set' for T1 report differed from that for T2. Problems in task switching in the patients could contribute to their abnormal deficit. The role of task switching in the AB, and whether switching exacerbates the deficit for brain lesioned patients, is explored in Chapter 3 of this thesis.

Cross modal Integration

Although we tend to think of different sensory modalities operating in isolation from one another, this is not the case (e.g. Bermant and Welch, 1976; Bertelson, 1998) and there are numerous examples of cases where perception in one modality is modulated by stimuli presented in another modality. One example of this is the 'Ventriloquist illusion', where an auditory voice is perceived as originating from the mouth of a speaker, even when it comes from a different location (Bertelson et al., 2000). Cross-modal interactions can affect visual processing as well as audition. For example, visual perception can be improved by presenting auditory stimuli before or simultaneously with a target. Such effects could occur for various reasons. There might be an increase in general alertness brought about by the auditory stimulus (Postner et al. 1976) or there could be enhancement of signal processing due to multisensory integration (e.g. Stein, 1984; 1996). An interesting example of apparent multisensory integration has been reported by Van de Burg et al. (2008). These authors demonstrated that a simple nonspatial auditory signal, presented along with a switch

in the properties of a visual target, drastically reduced reaction times to detect the target. These authors suggested that the benefit in performance produced by the auditory stimulus was not due to a general alertness effect as the same sound did not produce any beneficial effect if presented non-concurrently with the switch in the target properties, nor did top-down cueing seem critical as the benefit still occurred when the beep was synchronized with the onset of distractors. Van de Burg et al. proposed that the improvement they observed was due to temporal synchronization of the sound with the visual event, with this integrated event being more salient that other stimuli. Van de Burg et al. (2010) have further proposed that the benefit of auditory stimulation increases visual search efficiency only if the auditory cue is synchronized with an abrupt, transient visual stimulus. Ramped, sinusoidal stimulation did not produce the same effect.

These data suggest that synchronization of an auditory stimulus with a target in an RSVP stream could help the target 'pop out' from the background. If the target is the second of two to-be-reported stimuli (T2), then the AB could reduce. This is exactly what was found by Vroomer and de Gelder (2000) when presenting a meaningless (not containing any information about the perceptual nature of the targets) auditory cue with the occurrence of a target (high tone) within an auditory stream. Cross-modal effects under AB conditions have been reported by Olivers and Van de Burg (2008) (for a detailed description of this study see Chapter 4). These authors showed that the synchronization of a non-specific sound with T2 (under AB conditions) eliminated the blink. A beneficial effect was also found if the sound was synchronized with distractors suggesting an automatic component of the effect, however these authors excluded the hypothesis of an alerting effect as no beneficial effect on the detection of T2 was found if the tone was presented immediately before T2 presentation.

To test for a potential (beneficial) effect of cross-modal integration on temporal selection, in Chapter 4 of this thesis I examined effects of auditory cues on brain damaged patients, using an uninformative tone coincident with either T1 or T2 (both of which were compared against a further a no-sound condition). Contrary to the idea of automatic cross-modal integration, my data suggest that the extra (auditory) stimulus induced an additional processing load which interfered with performance but highlight the role of processing load on the AB.

Working memory (load)

Finally one last factor manipulated here was the level of resource available through working memory (WM).Working memory (WM) has been granted with the important role of promoting and maintaining efficient task-based control over behaviour (for a review see Baddeley, 2003). WM has been classically described to be multi-componential in nature. For example, according to the framework put forward by Baddeley (2003), WM comprises a visuospatial sketchpad (dedicated to the visual input), an episodic buffer (for integrating information across modalities), a phonological loop (dedicated to the verbal input) and a central executive that imposes top-down control over other cognitive systems (Baddeley and Hitch, 1974; Miyake and Shah, 1999; Cowan, 2005). One overriding characteristic of WM is that the information that it deals with is retained only temporarily, enabling WM resources to be rapidly deployed to other tasks (Baddeley, 1997).

The AB may reflect limitations in WM and this idea is incorporated into several of the AB accounts. As mentioned above (see earlier sections), WM could be a critical factor in the AB because (i) the amount of information that a central executive can deal with

at a time is limited, so that a second target occurring in a similar period may be missed; or (ii) there may be a finite time to consolidate information in WM, so consolidation of a second target is prevented during the consolidation of T1.

It follows that if the WM is loaded by an additional memory task to be performed while trying to report the two targets (T1 and T2) in the AB procedure, then the blink should increase. Attempts to assess this have been carried out by different authors (e.g. Olivers and Nieuwenhuis, 2006; Akyürek et al., 2007; Visser 2010), but different outcomes have been produced (see Chapter 4). In some cases a memory load has been found to facilitate performance, consistent with the load reducing the over-investment of attention through the 'gating system' over the visual input Olivers and Meeter, 2008). In other cases though, loading WM has had the opposite effect.

In Chapter 5 I attempt to study the effect of a memory load on a simplified AB procedure. This allowed me to analyze more directly limitations in temporal consolidation without being confounded with an effect of distractor interference.

Neuropsychological studies

Rather than directing manipulating experimental factors such as the presence of a memory load or a coincident auditory cue, another way to decompose complex cognitive tasks is to study the effects of brain lesion on performance. If the brain lesion affects a specific process (e.g., WM capacity) the effect of the lesion can provide evidence of the role of that component on performance. As noted above, studies of neuropsychological impairments of the AB have been reported in conjunction with a more prolonged and exaggerated AB effect (e.g. Husain et al., 1997; Shapiro et al., 2002), with the studies focusing on the inferior parietal lobe (IPL), inferior frontal lobe (IFL) and the superior temporal gyrus (STG) as likely

critical sites. These results conform also with some evidence of a temporo-parietal-frontal activation during the AB in normal subjects (e.g. Marois, Chun and Gore, 2000; Kessler et al., 2005).

Husain et al. (1997) conducted a pioneering study in which they assessed non spatial components of visuo-spatial neglect using the AB paradigm. The neglect syndrome is typically caused by damage to the right parietal and/or temporal cortical regions (e.g., see Chechlasz et al., 2010) and its clinical manifestation typically consists in the inability shown by the patient, to orient attention to the side opposite to the location of the lesion (contralesional space). Husain et al. (1997) found that neglect patients showed a worse performance in detecting T2 after T1 compared to a group of patients without neglect as well as an age and sex matched control group. These authors concluded that this neuropsychological deficit can be understood in various ways. Husain et al. proposed that a prolonged temporal consolidation of the visual stimulus into WM caused a bigger 'blink' in these patients. They further suggested that this non-spatial deficit was a contributory factor in the clinical manifestation of neglect which they defined having two components: (i) a spatial bias towards the contralesional side of space and (ii) a deficit in temporal processing. Both deficits would result in clinically poor selection on the affected side of space. To be noted is the fact that Husain et al. (1997) included in their neglect patient group individuals with various lesions locations, focused mainly on the inferior parietal lobe and the inferior frontal lobe.

The relations between the pronounced AB and the syndrome of neglect was examined across several of the chapters here, where, differently from Husain et al. (1997), comparisons were made between patients with damage to posterior parietal cortex (many of whom presented clinical signs of either neglect or a extinction) and patients

with more anterior lesions based in the frontal cortex (who tended not to show symptoms of neglect). In addition, clinical deficits in various aspects of attention were measured in the patients (spatial biases but also measures were also taken of sustained attention, the ability to select targets and not distracters and working memory capacity) in order to assess which of these factors might be critically related to the AB. It should be noted that many of these different aspects of attention can be disturbed in patients with visual neglect (e.g., Manly and Robertson, 1998), and the different factors need to be teased apart to understand why the AB may be pronounced in neglect patients.

Along with problems in sustained attention, selection, spatial orienting and working memory, patients can also be impaired in task switching (e.g. Aron et al., 2004; Shallice et al., 2008). It may be, then, that patients can have problems in switching their task set under AB conditions, and this is a major reason for the pronounced AB in some studies. Differences between parietal and frontal patients in a simplified form of the AB procedure (Duncan et al., 1994) were tested in Chapter 2, and the effects of task switching were evaluated in Chapter 3. These studies should inform us not only about the nature of the factors that generate the AB, but also about factors contributing to clinical deficits such as visual neglect in these patients.

In Chapter 6 I used the AB to examine a further clinical question relating to the nature of unilateral neglect. One classic argument concerning neglect is that it reflects impairments in the processes that orient attention in the environment – most notably, neglect may occur if patients orient to their ipsilesional side but then have problems in disengaging attention from that side. Evidence suggesting a disengagement problem were reported by Posner et al. (1984). These authors found that neglect patients were

able to attend to the contralesional side of space (typically affected by neglect) if cued to that side of space but were impaired in detecting a target in the contralesional side if first cued to the ipsilesional side. Posner et al. attributed this effect to a problem in disengaging attention from the 'good' side (ipsilesional side) and reorient it to the 'bad' side (contralesional side). Another well accepted interpretation of the neglect syndrome identifies the core of this deficit in an attentional bias towards the ipsilesional side of space (e.g. Ladavas et al., 1990, Smania et al., 1998; for a review see Kinsbourne, 1993). According to this theory of neglect patients' deficit in detecting stimuli in the contralesional field is due to an exaggerated engagement of attention towards the ipsilesional side (hyperattention hypothesis). To test the possibility of either these two interpretations of neglect, in Chapter 6 I varied the spatial position of T1 in an AB procedure, with T2 always being presented at fixation. If there is a major problem in attentional disengagement, then patients with neglect should show a pronounced AB when T1 appears in the ipsilesional field (since they should have problems disengaging from that field). In contrast, neglect may be associated with slow consolidation of stimuli in the contralesional field (Husain et al., 1997). If this holds, then the AB in neglect patients might be most pronounced when T1 is in the contralesional field. Results from Chapter 6 disconfirm both hypotheses.

Overview

Overall, this thesis focuses on different mechanisms influencing temporal selection. In Chapter 2 temporal binding and target similarity were investigated as potential contributors to the AB effect in brain damaged patients. Moreover an attempt to correlate the effect to deficit in visuo-spatial attention as well as other cognitive measures was carried out. Contrarily to previous studies conducted on brain damaged patients using the AB paradigm, here a systematic division between frontal and

parietal patients (carried out also in Chapter 3, and 4) was applied to the analysis of the data. The lack of evidence for a significant difference in performance between these two groups of patients suggested a potential involvement of a fronto-parietal network responsible for the integration of the visual information across time. Moreover a significant correlation between clinical sign of neglect and a deficit in temporal coding was excluded. However this effect was positively correlated to deficit in selective attention and poor binding. Finally an effect of target shape dissimilarity was found. In Chapter 3 further investigated the possible contribution of a fronto-parietal network to temporal selection particularly under conditions stressing the role of task switching in the AB deficit. Again no difference was found between the two groups of patient corroborating the hypothesis of a fronto-parietal network involved in temporal selection. Moreover the patients were found to be particularly poor in detecting a second target (T2) following a first one (T1) if they had to switch task set from the report of one and the other. However the switch cost believed to be responsible for a worsened AB in previous studies (Husain et al., 1997) was not correlated with measures of visuo-spatial deficit in the patients.

In Chapter 4 cross-modal integration was investigated as a potential (positive or negative) factor affecting performance in a simplified AB paradigm in neurological patients based on evidence which showed the AB deficit being ameliorated with the presentation of an auditory stimulation concurrent with the visual input in normal individuals (e.g. Vroomer and Gelder, 2000; Olivers and Van de Burg, 2008). Results showed in this chapter did not support the hypothesis of a beneficial effect of a synchronized audio-visual stimulation. In fact a detrimental effect of the auditory tone coincident with target presentation was found, though it might be the case due to the fact that brain damaged patients were tested and not normal participants.

In Chapter 5 the effects of a working memory load as well as temporal binding and target similarity were tested in normal participants to assess the reliability of theories on the AB which linked the deficit in temporal coding to a limitation in consolidating the visual input into WM under rapid visual presentation conditions. The results suggested that a memory load had a detrimental effect on performance and that moreover, binding of targets' perceptual attributes particularly if the targets were perceptually different produced a decrease in performance.

Finally, in Chapter 6 a patient (MP) presenting clinical signs of neglect was tested in a task using a simplified AB paradigm where the position of T1 was varied, in the attempted to test for different hypothesis accounting for the cause of visual neglect while trying to understand if presentation of T1 on different side of the space prior of T2 presentation would have had a probing effect and help identification of the second target. MP results go against both neglect main accounts. Theoretical implications will be discussed.

This thesis should be informative about the different factors that contribute to the AB. In addition, the experiments should throw light on the nature of the clinical deficit associated with spatial biases in attention in neuropsychological patients, and particularly the nature of the disorder of unilateral neglect.

Chapter 2

TEMPORAL CONSTRAINTS IN SELECTIVE ATTENTION IN PATIENTS WITH PARIETAL AND FRONTAL LOBE LESIONS: AN INVESTIGATION USING THE ATTENTIONAL BLINK PARADIGM

Abstract

The Attentional Blink (AB) provides a measure of temporal limitations in visual processing. Previous reports have documented that the AB can be pronounced following brain lesions that are associated with visual neglect – particularly after damage to the inferior parietal lobe. It has also been noted that parietal patients are selectively impaired at binding together colour and form and at identifying multiple items that have the same identity. Here the effects of feature binding and feature repetition on the AB were examined in a simplified version of the AB procedure, using patients with damage focused on either posterior parietal or frontal cortices. Results showed an increased AB effect in both patient groups compared to controls, particularly pronounced when patients had to report the conjunction of colour and shape of T1 and T2. Furthermore both frontal and parietal patients were impaired at temporal binding, showing errors by combining features across stimuli and in reporting the temporal order of stimuli. The deficit correlated with poor selective attention but not neglect. The data suggest that damage to a fronto—parietal network can compromise temporal selection of visual stimuli but this is not necessarily correlated with a deficit in hemispatial visual attention. The implications for understanding visual selection are discussed.

Introduction

Over the past 25 years there has been extensive study of visuo-spatial attention. It is well known that the amount of incoming information that can be processed by the primate visual system is much greater than that which can be fully attended and elaborated. Only part of the information present may be fully processed, while the remaining is filtered from a response (Treisman and Gelade, 1980; Postner, 1980). Visuo spatial attention is thought to have a primary role in guiding the observer through space in order to select the relevant visual information (Desimone and Duncan, 1995; Egeth and Yantis, 1997). A number of different attentional mechanisms are thought to operate concurrently to enable efficiently the selection of relevant stimuli (see Corbetta and Shulman, 2002, for one summary). In contrast, less is known about how visual selection operates over time, or about the neural basis of temporal visual selection.

The 'Attentional Blink' (AB) paradigm provides a powerful means of examining basic attentional limitations on the conscious processing of visual stimuli over time (Broadbent and Broadbent, 1987; Raymond, Shapiro and Arnell, 1992). The AB is observed when individuals have to report targets under conditions of rapid serial visual presentation (RSVP). Typically observers are able to identify a single target (T2), but fail to identify the same item when it appears within a time window of approximately 400 ms after the presentation of an earlier to-be-reported target (T1). In analogy to an overt blink of the eye in which the visual information is missed, this

temporal limitation of visual attention has been named the 'attentional blink' (Raymond et al. 1992).

Husain et al. (1997) first reported that the AB could be greatly increased after brain damage. They examined the AB in patients with unilateral visual neglect following right parietal, frontal or basal ganglia strokes. The patients' awareness of T2, after identifying T1 correctly, was significantly diminished for a period up to three times longer than that for individuals without neglect. Husain et al. interpreted these results as indicating that visual neglect has a temporal as well as a spatial component. Neglect patients have a spatial bias in directing attention plus also a deficit in temporal processing/consolidating stimuli in working memory (Husain, Shapiro, Martin and Kennard, 1997). This last deficit gives rise to the prolonged AB in these patients. Consistent with this, Husain et al. reported a correlation between a clinical measure of neglect and the magnitude of the AB in their patients. Shapiro et al. (2002) further investigated the AB in patients with damage either to the inferior parietal lobe (IPL)/superior temporal gyrus (STG) or the superior parietal lobe (Shapiro, Hillstrom and Husain, 2002). They found that patients with damage to the more inferior regions had a prolonged AB; in contrast, patients with damage to more superior parietal regions did not. This is consistent with the inferior parietal lobe being crucial for modulating the temporal coding of visual stimuli and with this region being linked to unilateral visual neglect (Chechlacz, Rotshtein, Bickerton, Hansen and Humphreys, 2010; Mort et al., 2003; though see Karnath, Ferber and Himmelbach et al., 2001).

Although Husain et al. (1997) reported a pronounced AB in neglect patients it is by no means clear whether poor temporal processing (indexed by the AB) is a necessary component of the neglect syndrome, or whether the AB can be disrupted in patients whose lesions do not necessarily lead to visual neglect. In addition, the reasons for any

enlargement of the AB in neuropsychological patients remain unclear. Previously, investigators have used AB procedures in which participants have to identify a letter defined by its colour and then to detect a particular target shape (what is the identity of the white letter and is there an X present?). Part of the difficulty experienced by patients with such tasks may relate to a difficulty in switching from a first colour-based task (identify the white letter) to a second task based on letter-shape. For example, Sohn et al. (2000) report that deficits in task switching can be found in patients with damage to posterior parietal cortex, and this could be a contributory factor to the observed problems (Sohn, Ursu, Anderson, Stenger and Carter, 2000). In addition, for T1 report participants need to bind the colour of the stimulus to its identity and it could be this requirement for correct spatio-temporal binding (linking the colour and shape in the correct temporal interval) that increases the AB in patients with posterior parietal lesions. Parietal patients are known to be selectively poor in tasks that require spatial binding. For example, such patients can make frequent illusory conjunctions, where they mis-attribute properties of different objects presented simultaneously in the visual field (Friedman-Hill et al., 1995; Humphreys et al., 2000). Baylis et al. (1992, 2001) have also argued that a problem in spatial binding can contribute to phenomena such as visual extinction effects in patients (Baylis, Driver and Rafal, 1992; Baylis and Driver, 2001). Baylis et al. (1992) demonstrated that visual extinction was greater when patients were presented with two stimuli that had the same to-be-reported features than when the stimuli had different to-be-reported stimuli. These authors suggest that the critical features of both stimuli were extracted, but the patients were impaired at integrating 'type' information about which features were activated with 'token' information, binding the features to their locations. They suggested that this process of binding was easier when the stimuli had different attributes than when the same features had to be bound to two different

locations. A problem in binding could be responsible for the poor AB, as standardly measured.

The present study set out to assess the relations between temporal coding, measured through the AB, and neglect and feature binding in patients. Patients were tested whose main area of damage resided either in posterior, inferior parietal cortex or in pre-frontal regions (centered around the middle frontal gyrus). None of the pre-frontal patients had unilateral neglect though 2/6 presented with some evidence of a spatial bias under conditions of extinction. All of the parietal patients (7/7) presented with visual extinction and there were clinical symptoms of neglect in 4 cases. We examined whether the AB was specifically linked to damage to posterior parietal cortex by contrasting performance across these two patient groups.

Unlike prior studies of the AB in neuropsychological patients, a two-target (followed by two masks) procedure was used here (Duncan et al., 1994) in which the same task was performed on both T1 and T2 and no distractors were presented, eliminating any contribution from task switching. The similarity of the to-be-reported features was manipulated, but this time using stimuli presented at the same spatial position over time. If parietal patients have a problem establishing token binding when tokens have the same 'type' identity, and if this occurs in the temporal as well as the spatial domain, then similar similarity effects to those reported by Bayliss et al. should be found. The patients should be poor at reporting both stimuli when they have the same to-be-reported features, relative to when they have different to-be-reported features and this effect will not be associated with an interfering effect of distractors. To the extent that binding is not a problem in patients with more frontal lesions (Humphreys, Hodsoll and Riddoch, 2009), then the featural relations between the stimuli should not contribute differentially to their performance relative to non-lesioned controls. One

other change, relative to prior studies, was that the target exposure time was individually set during the preliminary training session for all participants in order to reach a minimum of 70% of correct responses across the different report tasks. This procedure was carried out to try and ensure that overall performance was roughly equated across the groups, averaging across all the conditions of interest. This in turn means that the main interest focuses on differential effects of a given variable (e.g., the time interval, the report task, the similarity of T1 and T2) on report across the groups. Such differential effects would indicate a qualitative difference between the groups over and above general effects of task difficulty.

Method

Participants

Thirteen patients were tested, seven with their main lesion focused on the posterior parietal cortex (DB, JB, PF, MH, GK, TM, MP) and six with their primary lesion involving the frontal cortices (GA, WBA, PH, AS, DS, PW, all including the middle frontal gyrus). All of the parietal patients showed a clinically apparent lateralized deficit in selection (Table 2.2; see section 5, Results section). The patients' clinical characteristics and lesion descriptions are presented in Table 1. Ten age and sex matched healthy participants (mean age 63.11; SD 11.9) were also tested. All participants were naïve with respect to the experiment and all received a basic color vision assessment consisting in naming the colour of each stimulus presented singularly on the computer screen. If this preliminary test was failed the Ishihara's

Test for Colour Deficiency was used to assess colour perception (Ishihara, 1981). Table 2.1. gives details of the clinical deficits and Figure 2.1. the lesion transcriptions.

Table 2.1. *List of the patients tested, lesion site and clinical details. IPL, inferior parietal lobe; SPL, superior parietal lobe; SMg, supramarginal gyrus; ANg, angular gyrus; ITg, inferior temporal gyrus; MTg, middle temporal gyrus; STg, superior temporal gyrus; IFg, inferior frontal gyrus; MTg, middle temporal gyrus; SFg, superior frontal gyrus.*

Patients	Sex/age/ handedness	Main lesion site	Major clinical symptoms	Aetiology	Years post-onset
Parietal patients					
DB	M/71/R	Left inferior parietal and superior temporal cortex	Right extinction	Stroke	12
JB	F/71/L	Left inferior occipital, lingual and parahippocampal gyrus. Right parietal (ANg,SMg, IPL), temporal (ITg,mtG,STg) and frontal (IFg,MFg)cortex	Left extinction, Left neglect (in reading and writing)	Stroke	10
PF	F/58/R	Left parietal (IPL,SPL,ANg) and right parietal cortex (ANg,IPL,SPL)	Left extinction, Dysgraphia	Stroke	8
MH	M/53/R	Lentiform nucleus, left parietal (SMg, ANg, IPL, SPL),cortex	Right extinction, Dysgraphia	Stroke	10

GK	M/67/R	Right medial occipital cortex (cuneus, lingual and parahippocampal gyri), right parietal cortex (postcentral gyrus), left parietal cortex (IPL,ANg)	Left neglect Left extinction Bàlint syndrome	Stroke	20
TM	M/70/R	Right inferior parietal cortex (ANg, IPL), superior temporal cortex and inferior frontal	Left neglect Left extinction	Stroke	12
MP	M/59/L	Right parietal (SMg,IPL), temporal (MTg,STg) and frontal (IFg,MFg) cortex	Left neglect, extinction, dyscalculia Right hemiplegia	Aneurism	15
<u>Frontal patients</u>					
GA	M/52/R	Bilateral medial anterior temporal lobes, extending into left medial frontal region	Aphasia Amnesia Dysexecutive syndrome	Herpes simplex encephalitis	13
WBA	M/68/R	Right middle frontal gyrus	Aspects of dysexecutive syndrome	Stroke	8
PH	M/34/R	Left medial and superior temporal lobe, left inferior and middle frontal gyri	Right hemiplegia Aphasia Extinction under brief exposures	Stroke	10
AS	M/71/R	Right middle frontal and occipito-temporal cortices	Left extinction	Stroke	6

DS	M/71/R	Left inferior, middle and superior frontal gyri	Right hemiplegia Aphasia	Stroke	14
PW	M/72/R	Right inferior and middle frontal gyri, right superior temporal gyri	Left hemiplegia Dysexecutive syndrome	Stroke	8

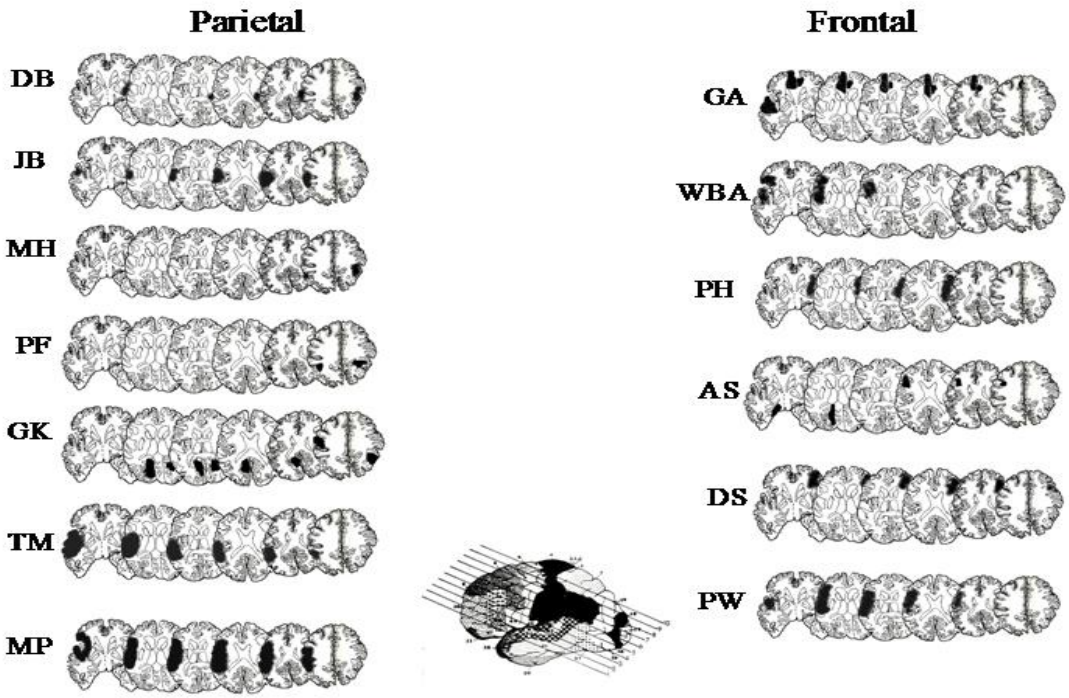


Fig. 2.1. Lesion reconstructions for the patients from MRI scan. Lesions have been drawn onto standard slices from Gado, Hanaway and Frank (1979). The bottom figure shows the 10 slices used. Only slices 3–8 are depicted here. The left of each slice represents the right hemisphere.

Stimuli

The stimuli comprised three different geometrical shapes (triangle, circle and square) in either of three different colours (red, blue and green). Each shape measured (25x25 mm) at its widest points and subtended 2.2° x 2.2° of visual angle. Different permutations of the colours and shapes were generated to create 81 possible combinations for each time interval, and each combination appeared in a single trial in a block. The different combinations led to four different target similarity conditions, which were as follows:

(1) T1 and T2 differed in both perceptual characteristics: shape and colour

(2) T1 and T2 had the same colour but differed in shape.

(3) T1 and T2 had the same shape but had different colours, and

(4) T1 and T2 were identical.

These four target similarity conditions were taken as a single factor with four levels in the third part of the analyses (see below, Results; *3 - Effects of tasks and stimulus similarity*).

Design and Procedure

The experiment used a 3 x 2 x 4 x 4 factors design: 1) target feature report, with three levels (colour, shape and conjunction); 2) target load, with two levels (dual target task and single target task); 3) inter stimulus interval (ISI) with four levels: 50 ms, 150 ms, 450 ms, 1350 ms; and 4) targets similarity, with four levels (see above, *Stimuli*). For the purpose of clarity the following factors were analysed separately (see below, Results; *2) Overall AB effect; 3) Effect of tasks and stimulus similarity).*

The experiment was divided into two sections, separated by a week,, which corresponded to the two target report conditions: 1) dual target task- report (T1 and T2); and 2) single target task- report (T2 only). Each of the two sections was divided into three trial blocks corresponding to the three target feature report conditions: 1) in a first block participants were asked to report only the colour of the two targets T1 and T2 (colour report-single feature search); 2) in a second block they had to report only the shape of T1 and T2 (shape report-single feature search); 3) finally in a third block participants were asked to report both the colour and shape of the two items (conjunction report- conjunction feature search). T1 and T2 were represented by equal numbers of permutations of colour and shape for each time interval (see below).

The experiment was programmed and run using E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002). The stimuli were presented on a gray background (RGB: 190-190-190) on a 17-inch monitor with a 1024 x 768 pixel resolution. All participants viewed the stimuli presented on a Gateway Pentium PC from a distance of approximately 65 cm. A trial was only initiated when the participant reported being fixated on a central cross presented for 2000 ms. After a key press, a sequence of two targets (T1 and T2) followed by two masks was shown at the centre of the screen on a grey background. During the interval between the T1-mask pairing and the T2-mask pairing, a blank screen was presented which lasted alternatively 50, 150, 450 and 1350 ms (ISIs), with the masks and a blank screen following each target, respectively being presented for 50 ms duration (see Fig.2.2.).

No combination of features was repeated within the same time interval within the same trial block. However because the possible permutations of features (number of trials) were greater when T1 and T2 were dissimilar rather than when they were identical, each feature report condition had the same number of trials at each time

interval but not the same number of trials representing the four different target similarity conditions: the first condition (1) in which T1 and T2 were both different in shape and colour [DS_DC] had 44 trials; the second (2) condition in which T1 and T2 had different shapes but the same colour [DS_SC] had 25 trials, the third (3) condition in which T1 and T2 had the same shape but different colour [SS_DC] had 26 trials and the fourth condition (4) in which T1 and T2 were identical [SS_SC], had 13 trials for each block. The target similarity factor was taken into account only in the third part of the Results (see below). For each of the four ISIs there were 81 data points for each report condition (blocks) for the patient group as well as the control group (although patients repeated the dual target report experiment twice, generating 162 data points for each ISI). All patients performed 648 trials divided across two sessions, for the dual-target task (T1-T2) and 324 for the single-target task (T2 alone). Controls performed 324 trials for both target conditions (T2 alone and T1-T2). The time intervals (ISIs) between T1 and T2 were the same for all participants but the presentations times for T1 and T2 varied across patients in order to roughly match performance across the different report conditions. The form of the AB procedure used here mirrors that employed by Duncan et al. (1994). It represents a reduced RSVP procedure, where effects due to masking between similar items (typically encountered with RSVPs of letters and shapes) are minimized because of the absence of distractors. The measure of the AB here may provide a relatively pure index of temporal constraints on visual selection without additional masking components.

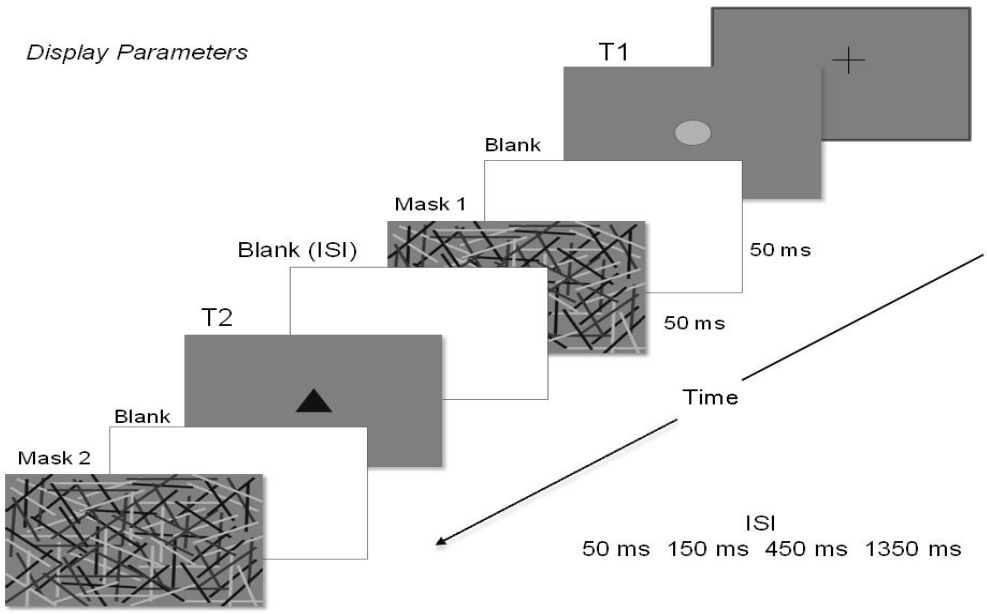


Figure 2.2. Illustration of the sequence of events on a trial. The same display parameters were used for the dual task when participants had to report both T1 and T2, and for the control task, when participants had to ignore T1 and report only T2. Both the after-target blank interval and the following mask lasted 50 ms.

Target exposure time was individually set during the preliminary training session for all participants in order to reach a minimum of 70% correct responses across the different report tasks. Thirty trials were sampled from the different target similarity and ISI combinations, with ten trials for each feature report condition (report colour; report shape; and report both colour and shape). During this practice block participants were trying to report both targets at an initial duration of 50 ms. Typically this short exposure time was not sufficient for most of participants to be able to report both targets correctly. Therefore the exposure time was then increased by 5 ms by the experimenter or until participants were able to identify correctly both targets for at list 2/3 of this initial practise session. This procedure was carried out to try and ensure that overall performance was roughly equated across the groups,

averaging across all the conditions of interest. This in turn means that the main interest focuses on differential effects of a given variable (e.g., the time interval, the report task, the similarity of T1 and T2) on report across the groups. Such differential effects would indicate a qualitative difference between the groups over and above general effects of task difficulty.

The order of the different ISIs was counterbalanced across blocks. The patients all performed the experiment with the same fixed block order for both the dual-target task (T1 and T2) and the single-target task (T2 alone), which was done to facilitate the ability of the patients to perform the experiment by increasing the difficulty of the tasks gradually. In the first block, patients were asked to report only the colour of the two targets, in a second block the shape of the two target (colour and shape feature search) and finally the conjunctions of colour and shape (conjunction search). The block order for the control group was counterbalanced across participants. Subjects received an initial 20 practice trials or until they reported feeling confident with the task. Answers were always recorded manually by the experimenter for all participants. Trials on which the first target was missed or was reported incorrectly (when T2 was not reported contingently on T1) were discarded. All errors were recorded and classified for all participants.

Results

The analyses were divided into five sections:

(1) A first analysis assessed whether there were overall differences in stimulus durations across the groups and whether there were overall differences in performance, averaging across all conditions.

(2) The AB. A second analysis tests whether the overall AB effect differed across the groups, and also whether it differed according to the target report condition (colour vs. shape vs. conjunction). To maximise the data, performance was summed across the different similarity conditions (same colour, same shape etc.). For these analyses, and for the analyses that follow, contrasts were made first between the two groups of patients. When the patients did not differ, their data were then considered together and compared with the results from the control participants.

(3) The third analysis assessed the effects of stimulus similarity on performance. To maximise the data for this, performance was summed across the different time intervals and only the single target report condition was considered.

(4) The fourth analysis was performed on the contrasting error types to assess if there were any differential forms of error, either across the conditions or across the subject groups.

(5) Finally a correlation analysis was performed between measures of the magnitude of the AB (see below) and the performance of all patients on different neuropsychological tests assessing impairments in visual selection and visual attention.

(1) *Overall differences in durations and performance levels*

A first analysis assessed differences in stimulus durations (the target time exposition was varied across participants, please see the *Stimuli and procedure*) across groups in order to assess whether the patients required longer exposures in order to set the average level of performance close to that of the controls. A one-way-ANOVA showed a significant difference in target duration between the groups, F (2, 20) =

12.53, $p < 0.001$ (parietals mean duration: 65.71 ms, frontals mean duration: 51.83 ms, controls mean duration: 23.2 ms). The two patient groups differed significantly from the non-lesioned controls, but they did not differ from one another: parietals vs. frontals: t (11) = 1.06, $p = .825$; controls vs. parietals: t (15) = 5.31, $p < 0.001$; controls vs. frontals: t (14) = 3.91, $p < 0.005$.

Moreover a one-way-ANOVA applied on a measure of overall performance across groups (averaged across the different conditions) showed a significant difference in the overall performance between the three different groups (averaged across all conditions: target feature report, target load, target feature similarity and time interval). A significant difference in overall level of performance was found between the groups, F (2, 20) = 4.36, $p < 0.05$ (parietal mean overall performance = 0.85, SDE = 0.12; frontal mean overall performance = 0.92, SDE = 0.32, control mean overall performance = 0.96, SDE = 0.21). The overall performance of the two patient groups differed significantly compared to the control performance but they did not differ from one another: parietals vs. frontals, t (11) = -1.36, $p > 0.05$; parietals vs. controls, t (15) = - 2.17, $p < 0.05$; frontals vs. controls, t (14) = -2.38, $p < 0.05$.

(1) The overall AB effect

Parietals vs. Frontals. A general AB effect was observed in all groups (see Fig. 2.3. for the parietal patients versus frontal patients, and Fig. 2.4. for the patients considered as a single group versus the controls). Data from the patients only were analysed in a 3 x 2 x 4 ANOVA with the within-subjects factors being: 1) target feature report (colour vs. shape vs. conjunction of colour and shape); 2) target load [dual-target task (T1 and

T2) vs. single-target task (T2 alone)] and 3) time interval (ISIs 50, 150, 450, 1350 ms). The between-subjects factor was patient group (parietals vs. frontals). No overall difference was found in performance across the two patient groups, F (1, 11) = 1.87, p = .199. A main effect of target load (T1 and T2 vs. T2 only) was observed, F (1, 11) = 21.91, p = 0.001, along with reliable main effects of target feature report (colour vs. shape vs. conjunction), F (2, 22) = 6.62, $p < 0.05$, and time interval (ISI), F (3, 33) = 8.90, $p < 0.001$. Identification of T2 decreased following the identification of T1 relative to when T2 was identified alone, and it decreased in the conjunction report task compared with both the shape report, t = 3.37, $p < 0.05$, and the colour report tasks, t = 3.01, $p < 0.05$, colour report: mean= 0.897, SD= 0.35; shape report: mean = 0.894, SD 0.35; conjunction report: mean = 0.82, SD= 0.37. There were interactions between target feature report and target load, F (2, 22) = 13.82, $p < 0.001$, and between target load and time interval (ISI) F (3, 33) = 4.60, $p < 0.05$.

The interaction between target feature report and target load arose because the disadvantage for the conjunction over the single feature (colour and shape) conditions was most pronounced when T2 was reported after T1, compared with when T2 was reported alone (i.e., the AB was stronger in the conjunction condition). When performance with T2 reported alone was considered, there was no effect of feature target reported, F (2, 22) = 1.04, p = .369. In contrast, a main effect of feature target report was found in the dual-target task (T1, T2), F (2, 22) = 10.14, p = 0.001.

The target load x time interval (ISI) interaction arose because the difference between the report conditions with T2 alone and T2 after T1 was greater with a short ISI than with a longer ISI. This reflects the standard AB. There were no interactions with the patient group (all F<1.0). Thus there was no evidence for the parietal group being worse than the frontal group in terms of the time course or the report task on the

AB once overall performance levels were roughly matched. T1 accuracy was above 90% for all the patients.

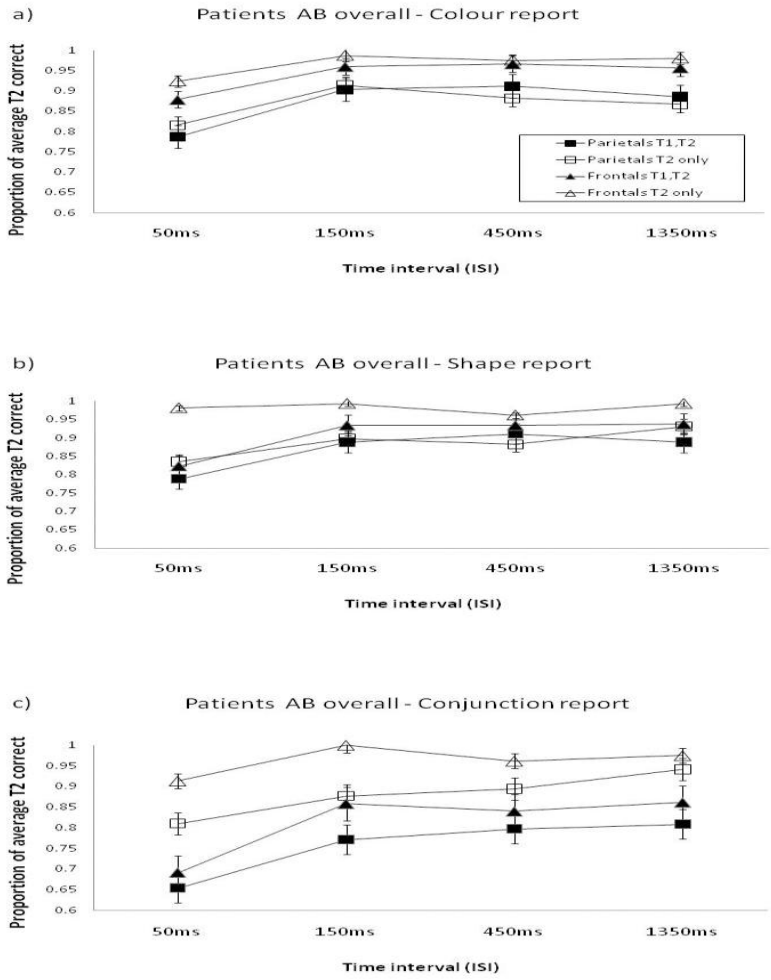


Figure 2.3. Overall AB (report of T2 contingently with T1 correct report) for the parietal and frontal patients in the dual target task (T1, T2) and single target task (T2 alone) for the three different report conditions: a) Report Colour, b) Report Shape and c) Report Conjunction

Patients vs. Controls. Given that the two patient groups did not differ, their data were compared as a single group with the controls using the same design ANOVA as above. A significant difference was found between the patient group and the control

group, F (1, 21) = 4.93, $p < 0.05$. There were reliable main effects of target load, F (1, 21) = 17.509, $p < 0.001$, target feature report, F (2, 42) = 8.26, $p = 0.001$, and time interval (ISI), F (3, 63) = 26.55, $p < 0.001$, (see Fig 3). Moreover a significant interaction between target feature report and target load was found, F (2, 42) = 13.72, $p < 0.001$, where performance accuracy decreased differentially in the dual target report condition (T2 after T1) for the conjunction targets. No significant effect of target load was found for the colour report condition, colour: F (1, 21) = 3.72, p = .067; but there was a reliable effect of load in the shape report condition, F (1, 21) = 7.67, $p<0.05$, and the conjunction condition, F (1, 21) = 22.97, $p < .001$. A three-way interaction was found between target feature report, target load and subject group, F (2, 42) = 6.91, $p < 0.005$. The decrement in performance in the conjunction report condition over the feature (colour and shape) report conditions was more pronounced for the combined patient group than for the controls, for the T1-T2 report condition more than the T2 report only (see Fig. 2.4.) .Finally interactions were found between target load and time interval, F (3,63) = 7.008, $p < 0.001$, which reflects the standard AB effect, and target report and time interval, F(6, 126) = 3.84, $p = 0.001$, which is due to a greater effect of time interval at early lags in the conjunction report condition compared to the other two report conditions. T1 accuracy was above 90% for both the patient group and the control group.

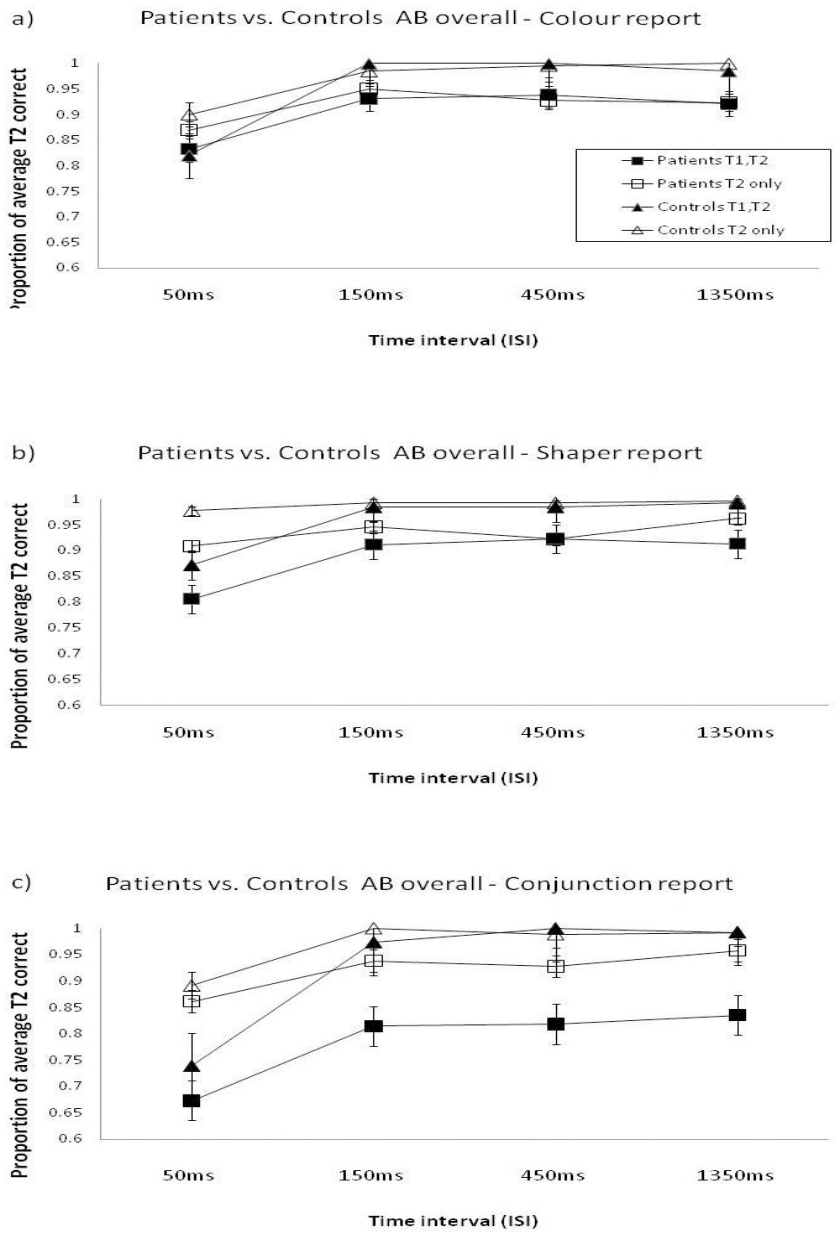


Figure 2.4. Overall AB (report of T2 contingently with T1 correct report) for the patient group and the control group in the dual target task (T1, T2) and single target task (T2 alone) for the three different report conditions: a) Report Colour, b) Report Shape and c) Report Conjunction

(3) *Effects of task and stimulus similarity*

In a second part of the main analysis, the data from the dual target report condition only were broken down into the four target-similarity conditions for each subject group averaging across durations.

Parietals vs. Frontals. In a first analysis the parietal patients were compared with the frontal patients (see Fig. 2.5.). The data were entered into a mixed design 3 x 4 ANOVA with the within-subjects factors being: target feature report (colour vs. shape vs. conjunction) and target similarity (T1 and T2 with different shapes and colours [DS_DC]; with different shapes but same colour [DS_SC], with the same shape but different colours [SS_DC]; and with identical shapes and colours [SS_SC]). Patient group was the between-subjects factor. There was no overall difference between parietal and frontal patients, F <1.0. A reliable main effect was found for the target feature report, F (2, 22) = 12.15, p = 0.001, where performance was worse in the conjunction compared with the colour condition, t (12) = 4.14, p = 0.001, and the shape condition, t (12) = 3.56, p < 0.005. The shape and colour report conditions did not differ, t (12) = .95, p = .357. A significant interaction was found between the feature reported and target similarity, F (6, 66) = 4.69, p < 0.001. This interaction arose because of a more pronounced difference in performance when the shape of both targets was different compared to when was the same, particularly in the conjunction report condition.

In order to understand this 2-way interaction, data from the two conditions where the shape of both targets differed (DS_DC, DS_SC) vs. when they were both the same (SS_DC, SS_SC) where averaged together. This led to a 3 x 2 ANOVA with the within-subject factors being: target feature report (colour, shape and conjunction of colour and shape) and shape similarity (different shape vs. same shape). A main

effect of feature target report was found, F (2, 22) = 12.15, p< 0.001, with performance being worst in the conjunction condition (colour report mean = .886, SDE = .035; shape report mean = .875, SDE = .035; conjunction report mean = .796, SDE = .040). There was also a main effect of shape similarity, F (1, 11) = 9.42, p = 0.01. The conditions where T1 and T2 had different shapes produced lower performance then when the two targets had the same shape (different shape mean = .835, SDE = .035; same shape mean = .870, SDE = .035). These effects did not vary across the patients, F (1, 11) = 1.69, p = .219.

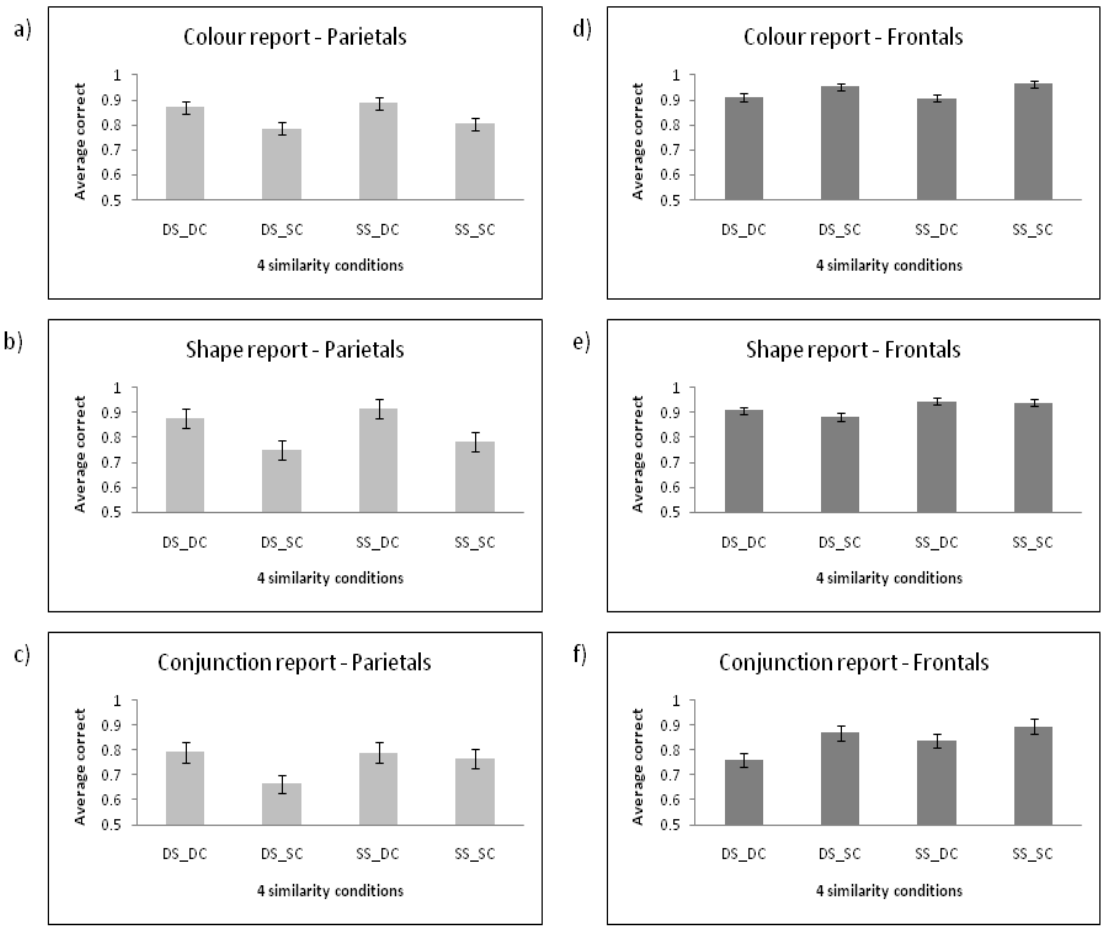


Figure 2.5. Performance of the parietal group and the frontal group showing the effect of feature similarity between T1 and T2 with performance average across duration and feature and conjunction report conditions. DS_DC (colour and shape of T1 and T2 are different); DS_SC (T1 and T2 share the same colour but have different shape);

SS_DC (T1 and T2 share the same shape but have different colour); SS_SC (T1 and T2 have same colour and shape).

Patients vs. Controls. A further analysis compared the patients group with the control group using the same design as before (Fig. 2.6.). A reliable difference was found between the patient group and the control group F (1, 21) = 4.54, $p < .05$. The patient group performed worse compared to controls, patient mean = .849, SDE = .028; control mean = .941, SDE = .032. A main effect of target feature report was found, F (2, 42) = 20.79, $p < 0.001$, and an interaction between target feature report and target similarity was present, F (6,126) = 4.23, $p = 0.001$. Again, in order to understand this 2-way interaction data from the two conditions in which the shape were different (DS_DC, DS_SC) vs. those were shape were the same (SS_DC; SS_SC) were averaged together and analysed as before. A significant difference between patients and controls was found, F (1, 21) = 4.54, $p < 0.05$. Patients performed worse compared to controls, patient mean = .849, SDE = .028; control mean = .941, SDE = .032. There was a main effect of feature target report, F (2, 42) = 20.79, $p < 0.001$, along with a main effect of shape similarity, F (1, 21) = 16.84, $p = 0.001$. An interaction between feature target report and shape similarity arose because report was worse when the two targets had different shapes compared to when they had the same shape, particularly in the conjunction target report condition, colour target report-different shape mean = .913, SDE = .022; colour target report same shape mean = .923, SDE = .020; shape target report-different shape mean = .893, SDE = .023; shape target report- same shape mean = .942, SDE = .022; conjunction target report-same shape mean = .834, SDE = .025; conjunction target report-different shape mean = .863, SDE = .026.

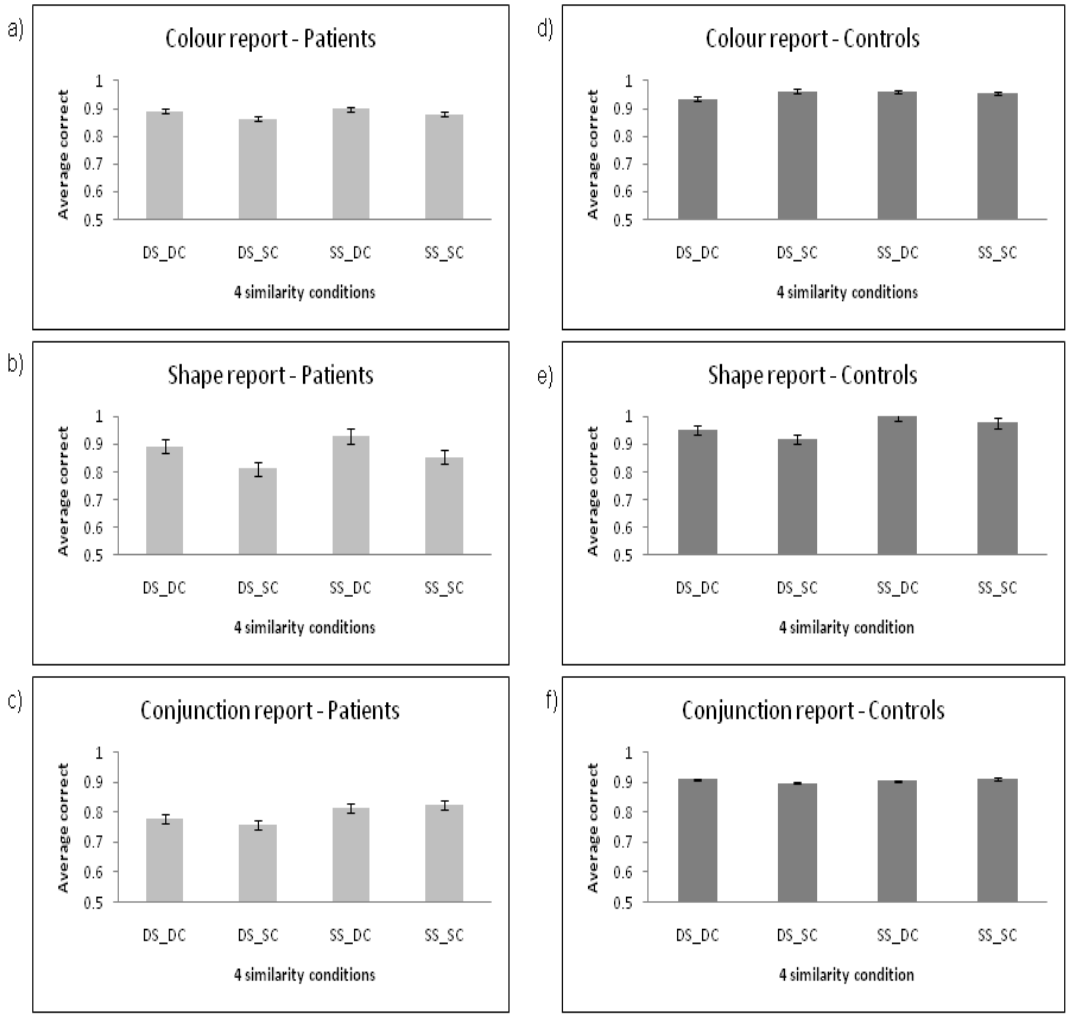


Figure 2.6. Performance of the pooled parietal and frontal groups and the control group are shown. The effect of feature similarity between T1 and T2 with performance average across duration and the feature and conjunction report conditions is presented. DS_DC (colour and shape of T1 and T2 are different); DS_SC (T1 and T2 share the same colour but have different shape); SS_DC (T1 and T2 share the same shape but have different colour); SS_SC (T1 and T2 have same colour and shape).

Controls only. Finally to test whether the detrimental effect of shape (dis)similarity was specific to the patient group but not to controls, a separate analysis was run on the control data only. As above a 3 x 2 ANOVA was run with the within-subject effect being: feature target report (colour, shape and conjunction) and shape similarity (different shape vs. same shape). Reliable main effects of feature target report, *F* (2,

18) = 11.15, $p = 0.001$, and shape similarity, F (1, 9) = 8.64, $p < 0.05$, were found. An interaction between feature target report and shape similarity also occurred, F (2, 18) = 3.73, $p < 0.05$. As with the patients, the control group too showed a detrimental effect of shape similarity in reporting the two targets, different shape mean = .929, SDE = .018; same shape mean = .952, SDE = .012. This was the case especially in the shape report condition whereas in the colour and conjunction report conditions the detrimental effect of having dissimilar shapes was not reliable (different vs. same shape: colour report, t (9) =-.987, $p = .350$; shape report, t (9) = -3.044, $p < 0.05$, conjunction report, t (9) = -.316, $p = .759$.

(4) *Error analysis*

An error analysis was performed in order to investigate temporal binding by examining the occurrence of illusory conjunction errors (ICs) and temporal swap errors. IC errors were recorded as mistakes in which the perceptual properties of the stimuli were misattributed: i.e. T1 = red triangle, T2 = blue circle; IC = red circle or blue square (only 1 of these had to be reported for the trial to be classed as an IC trial). The data were calculated for each group in the conjunction target report condition where the two targets differed in both perceptual attributes [DS_DC][1]. Parietal patients were first compared with frontal patients on the rate of their IC errors relative to the total error produced. No significant difference was found between the groups; parietal patients IC error percentage = 14.63%, frontal patients IC errors percentage = 14.73%, Fisher exact = .342 (2-tailed). The patients were then compared as a single group against the controls. A significant difference was found in the rate of IC errors, patients IC error percentage = 14.68%, controls IC errors percentage = 2.08%; Fisher exact = .025 (2-tailed).

[1] The other conditions were not included for this analysis because assignment of reported features to either T1 or T2 was then ambiguous, when at least one of the features was shared across the stimuli.

Temporal swap errors (errors in which the two attributes of each target were correctly matched but the temporal order of T1 and T2 were swapped) were also classified in which T1 and T2 were reported in reverse order. Again this analysis was confined to trials where T1 and T2 were completely different and conjunction report was required. Parietal patients were first compared with frontal patients on the rate of their swap errors relative to the total error rate. No significant difference was found between the two patient groups: parietal patients swaps errors percentage = 5.93%, frontal patients swap errors percentage = 5.04%, Fisher exact = .223 (2-tailed). The patients were then compared as a group with the control group on the rate of swap errors produced relative to the total number of errors. A significant difference was found between the two groups; patients swap errors percentage = 5.53%, controls swap errors percentage = 0%, Fisher exact = .043 (2-tailed).

(5) *Correlation analysis with cognitive impairment measures*

A final analysis was performed in order to establish the relations between the overall AB measure and different cognitive impairments shown by the patient groups across a number of neuropsychological tests of attention and working memory. Cancellation, sustained attention, selective attention and working memory measures were taken from the Birmingham University Cognitive Screen (BUCS; see www.bucs.bham.ac.uk). The extinction scores are taken from a computer-based experimental measure of extinction. In this extinction task, the letters A-D were randomly presented (as white letters on a black background) either on the left, the right or bilaterally 3deg to the left or right of fixation, for 200ms (letter sizes 0.5deg). Patients were asked to identify the letters present. The extinction score reflects: (the

difference between the report of single items on the contralesional side vs. ipsilesional side) – (the differences in the report of contra- and ipsilesional items under bilateral presentation conditions). Controls performed at ceiling (i.e., with an extinction score of 0) under these conditions. The key cancellation task provides a measure of visual neglect (the asymmetry between the numbers of target keys cancelled on the left or right of an A4 page). The sustained attention measure reflects the maintenance of performance across blocks of trials in the selective attention task (performance on block 1 – that on block 3). The selective attention measure indexes the ability to respond only to a small set of target words while ignoring related distractors (respond to 'yes', hello' and 'please' as targets but do not respond to 'no', goodbye' or thanks', which are distractors, all words are presented auditorily at random time intervals) and working memory reflects the ability to maintain the target words for the selective attention task (tested prior to the experimental trials and also immediately afterwards). Clinical disorders such as unilateral neglect are known to be associated with impairments in sustained attention (Manly and Robertson, 1998) and working memory (Malhotra et al., 2005), in addition to the spatial bias characteristic of neglect. As shown in Table 2 (above), both the frontal and parietal groups were impaired relative to controls on most of the tests of attention with the exception being the measure of spatial attention provided by the cancellation task, where only the parietal group was impaired (note that the patient groups differed in their performance on this task, with the parietal patients performing worse; $t(9)=2.11$, $p<0.05$, 1-tailed, while they did not differ on the other tasks; all $t<1.0$. The extinction and neglect scores were correlated across patients, $r(11) = .554$, $p = 0.039$, 1-tailed, but none of the other measures correlated, largest $r(11) = -.254$ for cancellation vs. selective attention, $p=.226$. Each neuropsychological score was correlated with a measure of the AB - the difference in performance between the single target report task (T2 alone) and the dual target report

(T1-T2), in the condition where patients were asked to report both features (colour and shape) of both targets. As shown in Table 2.2, no significant correlation was found between the AB measure and measures of visual neglect (Key Cancellation test), visual extinction, sustained attention or working memory. However a significant correlation was found between selective attention and the magnitude of the AB, r = .866, p = .001, (see Fig. 2.7. for the scatter plot). A high score on the selective attention task means that patients were impaired at only selecting the target and selected the distractors too, while a high AB score indicates that the patients showed a large drop in performance between reporting T2 alone and reporting T2 after identifying T1. The maximum extinction score was 48 (never reporting the contra-item on bilateral trials and always reporting the contralesional item on unilateral trials). For the key cancellation the mean control performance was 49.2 (hits), SD = 1.5; for the sustained attention the mean control score was 10.96, SD = 3.5; for the selective attention the mean control performance was 52.67, SD = 1.59; for the working memory score the mean control performance was 3.05, SD = .33. A star indicates a score outside of the control range.

Table 2.2. *Correlation of the magnitude of the AB against different cognitive tests for the patient group*

Patients	AB measure	Extinction	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	0.04368	30*	12*	3.5*	1*	4*
P.F.	0.19565	11*	0	6*	5.5*	3
M.H.	0.01977	7*	2*	0	0	5*
J.B.	0.12256	7*	3*	1*	11*	4*
T.M.	0.10677	22*	8*	2*	4*	3
Frontals						
D.S.	0.3194	1	1*	3*	11.5*	4*
P.W.	0.03143	17*	0	1*	1*	4*
P.H	0.26922	30*	0	2.5*	10.5*	5*
G.A.	0.17084	2	0	7*	6.5*	5*
J.Q.	0.01668	0	0	2.5*	0	5*
A.S.	0.09264	7*	3*	1*	1*	4*
Pearson Correlation		-0.017	-0.095	0.421	0.866	-0.102
Sig. (2-tailed)		0.961	0.757	0.198	0.001	0.766

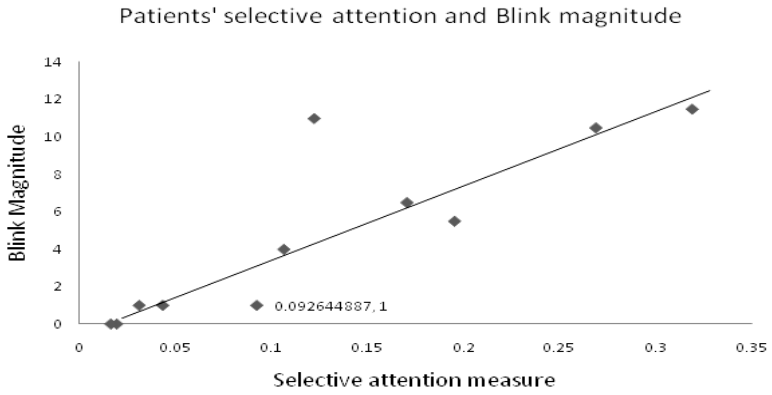


Figure 2.7. Distribution of patient scores in the selective attention task in relation to the 'blink' measure. The blink measure was calculated as the difference between the single target report (T2 only) minus the dual target report (T1-T2) in the conjunction report condition

Discussion

Using a minimal two-target sequence (cf. Duncan et al., 1994), a reliable attentional blink was generated, with responses to T2 in the two-item report condition (T1-T2) being worse than in the one-item baseline (T2 only). Despite the attempt to match performance overall across the groups the patient groups tended to perform worse than controls. More importantly, the differences between the patients and the controls were exaggerated under the AB conditions. The patients showed a deeper AB than the controls and this was maintained across the durations examined. Indeed the patients did not reach the baseline (T2 only) level of report even at the largest duration

examined in the conjunction report condition. Strikingly, though, there were no differences between the frontal and parietal patient groups in their overall AB across time. The parietal patients presented with a greater degree of neglect than the frontal patients on the cancellation task and more of the parietal patients showed visual extinction, but there was also no evidence for any relation between the AB and clinical measures of biased spatial attention (extinction and neglect).

Previous studies have reported differences in the AB between patients with inferior and more superior parietal damage (Shapiro et.al. 2002) and between patients with and without neglect (Hussain et. al., 1997). The PPC group here did include two patients with relatively more superior lesions than the others (MH and PF, with lesions involving the IPS and the superior parietal lobule) but omitting these patients made little difference to the results, F (1, 9) = 2.56, p = .144. Hussain et al. compared a group of neglect patients with heterogeneous lesions (damage could fall in the PPC, in frontal cortex and/or in the basal ganglia) with non-neglect patients presenting lesions which included the temporal and medial frontal lobes or subcortical regions. The AB was increased for the neglect group leading Husain et al. to argue that this temporal processing deficit contributed to the syndrome. Critical to the current study may be that it included patients with dorsolateral pre-frontal lesions along with PPC patients and both sets of lesions may compromise the attentional selection network (cf. Corbetta and Shulman, 2002). Consistent with this, both patient groups manifested clinical deficits in a range of tests of attention (Table 2.2), though only the parietal group showed a reliable spatial bias. The failure to find differences in the AB across the patient groups however poses difficulties for the specific argument that poor temporal selection is necessary linked to biases in spatial selection. This is also supported by the failure to find any correlation between the overall magnitude of the

AB and the clinical measures of spatial attention (visual extinction and visual neglect). It is possible that the earlier results demonstrating a link between the AB and neglect arose in part because of baseline differences between the neglect patients and the non-neglect patients and controls – these baseline differences were reduced here by the two-item presentation procedure and by our attempt to equate overall performance levels. One possibility is that parietal patients and patients with neglect have to commit more resources than other patients and controls to resolving briefly presented, masked letters (and note that we tended to need longer durations overall to approximately match overall performance for the parietal patients to the other groups). There are sufficient resources to report a single letter but not two (under AB conditions). However, once this problem is counter-acted (by using longer duration stimuli), the time taken to consolidate stimuli in memory (to avoid the AB) is not longer for these patients than for other patient groups. On this account, posterior parietal damage, and biases in spatial attention do not necessarily generate poor temporal consolidation but they may produce a more basic problem in coding letters in the first place.

Although there was no evidence for a linkage between neglect and the AB, there was a strong correlation between the magnitude of the AB and a measure of selective attention across all the patients. This measure (from the BUCS) reflects the ability of patients to select only targets and to refrain from responding to distractors. In the present circumstance, a lack of selective attention may lead to patients selecting the masks as well as the target letters, disrupting the report of the second target. Prior studies of the AB in control participants demonstrate that the AB is most pronounced when targets are followed by masks and other distractors, which participants have to refrain from selecting (Raymond et al. 1992; Chun and Potter 1995). Indeed, when

participants are asked to perform a simple short-term memory task in addition to the report of T1 and T2, so that selective attention is temporarily engaged in another task, the problem of selecting targets from masks and distractors is not present, then the AB is greatly reduced (Olivers and Nieuwenhuis 2006). According to Olivers and Nieuwenhuis, the AB arises due to the demands on rejecting targets, which can in turn inhibit the processing of subsequent items. On this view, patients with poor selective attention may either suffer a larger AB because they encode masks into short-term memory and this disrupts their report of the second target, or because the increased competition for selection for these patients leads to increased inhibition of subsequent items.

In addition to the patients showing an overall increase in the AB, there was also evidence of poor temporal selection and binding. In particular, relative to controls, the patients generated increased numbers of illusory feature-swaps between T1 and T2, and they also generated proportionately greater numbers of temporal swaps (reporting T2 as T1 and vice versa). This may reflect a deficit (in temporal binding) separate to the problem we observed linked to poor selective attention; alternatively, poor selective attention, an increased AB and greater illusory conjunction and swap errors may all be caused by poor binding of stimuli in working memory. In the selective attention tests (from BUCS) responses to distractors may occur when target representations are not well-bound in memory (so that participants make false positive errors to them). In the AB procedure, poor binding in working memory will both increase the AB and lead to illusory conjunction and swap errors.

As well as having a greater AB than the controls, the patients also showed greater differences in two-item report in the conjunction condition compared with the single feature baselines. This again fits with the idea that the patients encounter more

problems in binding visual features than controls, and hence their deficit is most apparent when feature binding is required (with conjunction report compared with reporting single feature targets). The problems in the conjunction condition also suggests that temporal binding and temporal swaps errors may be functionally related and reflect some common process such as synchronized neural firing. Interestingly in other studies with similar patients groups to those used here, Humphreys et al. (2009) found evidence for spatially impaired binding in PPC patients but not in the pre-frontal patients. Thus there is evidence that temporal binding may dissociate from spatial binding, and while PPC damage may generate problems in both forms of binding, pre-frontal damage leads to temporal deficits without concomitant spatial problems. This goes against the idea that binding is a unitary process, and different mechanism may bind features to space and temporal intervals.

Although there was evidence for an increased AB for the patients (as a whole group) compared with the controls, and also for impaired temporal binding in the patients, the qualitative pattern of the error data did not vary across the groups as a function of the similarity of the shapes and colours of the items. Both PPC patients, frontal patients and controls showed detrimental effects of shape dissimilarity which tended to occur across all the report tasks; performance was worse when the T1 and T2 shapes differed relative to when they were the same. The effect of shape (dis)similarity may reflect difficulty in switching selection of the more difficult attribute (shape rather than colour) across the stimuli on one trial. There was no evidence however for repetition blindness (cf. Baylis et al., 1993). It should be noted that, even in cases of spatial selection, the neuropsychological evidence for repetition blindness effects is not universal and there are reports of null effects of stimulus similarity (Kitadono and Humphreys, 2007) or even reverse effects (better report with more similar items;

Humphreys et al., 2000). The factors that generate positive or negative effects of stimulus similarity still need to be clarified (see Riddoch et al., 2010). The evidenced from the current study is that similarity across separate temporal events is not detrimental to report. The similar effects of (dis)similarity on the patients and controls, though, suggests that all participants implemented similar report processes, although the patients seemed worse than the controls at the rapid assimilation of the information present (the AB) and at temporal binding. These data highlight that temporal encoding and binding can be separated from the control processes that 'weight' different features for report (Bundesen et al., 2005).

Chapter 3

TASK SWITCHING AND THE ATTENTIONAL BLINK: NEUROPSYCHOLOGICAL EVIDENCE

Abstract

Data are reported on the effects of task switching on a minimal (two-target) version of the Attentional Blink (AB) in patients with lesions centered on either posterior parietal or pre-frontal cortex. Unlike prior neuropsychological studies of the AB, an attempt was made to match overall performance across the groups by varying the stimulus exposure durations. Despite this attempt at matching, the patients showed a larger AB than the controls and this effect was exacerbated under conditions in which a switch was required between the stimulus properties reported for the first and second targets. This deficit in the AB under switching conditions was unrelated to the presence of spatial deficits in the patients (visual extinction, neglect), but it did correlate with whether the patients had an impairment in selecting between targets and distractors in a test of auditory attention. The data point to poor target selection being an important factor in the AB in neuropsychological patients, a problem which is exacerbated under task switching conditions.

Introduction

In Chapter 2 of this thesis, the Attentional Blink paradigm was used to assess visuo-temporal selection in brain damaged patients and to examine possible differences in performance between individuals with frontal lobe compared to inferior parietal damage. Under the particular experimental conditions examined (e.g., with performance overall equated across the patient groups), there were few differences between patients with parietal and with frontal lesions, though both were relatively impaired compared with control (non brain-lesioned) participants. However, in the version of the AB procedure assessed, participants had to carry out the same task on the two target events on a trial. In contrast to this, many previous studies of the AB on normal subjects have used conditions in which the task switched from the first to the second target event (e.g. Raymond et al., 1992). For example, participants might be asked to report the identity of a white letter (T1) and then to detect whether an X is present or absent. Work with normal participants indicates that the AB is increased when the task must be switched between T1 and T2 (e.g. Potter and Chun, 1998; Arnell and Jolicoeur, 1999, Kawahara et al. 2003), suggesting that task switching can be at least one contributing factor to AB effects. Failures to separate out effects of task switching from other factors contributing to the AB are problematic when the AB is applied as a diagnostic test to assess the effects of a given brain lesion/neuropsychological symptoms on temporal aspects of information processing. For example, in their study on the relations between the AB and visual neglect, Hussain et al. (1997) presented in a RSVP (rapid serial visual presentation) a sequence of black letters and one white letter which represented the first target to be detected (T1). On half of the trials T1 was followed at different time intervals by a black X

which represented the second target (T2). Thus participants had to switch from the task set required for the T1 event (select a letter defined by its colour, white) to a different task set for the T2 event (select a letter defined by its shape, X). The neglect patients were shown to be significantly impaired compared with controls. It is possible, however, that at least part of the increased AB found in neglect patients may relate to a problem in switching task set, compounded by any problem in consolidating a representation of T1 in memory (the account offered by Husain et al., 1997).

Problems in task switching have been found in a number of different neuropsychological syndromes and after a variety of brain lesions. For example, Aron et al. (2004) investigated task switching with Stroop stimuli. Compared with controls there were significantly greater switch costs in patients with both left and right frontal lesions. The specific nature of the problems differed across the two lesion types, though. The right frontal group appeared to have particular difficulty in inhibiting a response to the initial stimulus, and so showed a greater impairment when there was a short inter-stimulus interval. In contrast, the left frontal group showed a more generalized difficulty in suppressing the initial task set, and so presented with a deficit at both long and short response-stimulus intervals. Shallice et al. (2008) extended this argument, proposing that even finer-grained distinctions can be made between different task-switching deficits in contrasting patient groups. They suggested that there could be an impairment to what they call the 'energizing' process, localized in dorso-lateral prefrontal cortex, which is recruited when tasks become more difficult (see Hampshire et al., 2009; for a similar argument). Through this process, extra resources are recruited to enable task switching to take place. Second, there may be disrupted to a specific process of error monitoring, associated with the anterior

cingulate – this error monitoring process would enable patients to register when response conflicts arise and to adjust processing to optimize processing (e.g. Botvinck et al. 1999). A third possibility is that superior regions of medial frontal cortex are responsible for holding a task set for a later execution (e.g., after switching takes place). Finally, the left lateral frontal region may be involved in setting-up complex action–schemas required for any tasks performed under dual-task conditions. Later on during the task, these procedures may become more automated and hence the errors for the LL group reduce. Recently, Funes, Lupianez and Humphreys (2010) have further argued that frontal patients can be relatively normal at task switching provided switching is cued by the stimulus; their impairment is primarily in switching across tasks in a top-down manner, when there is no cue to switch in the stimulus itself. Whichever factors are critical, we can expect that patients with damage to pre-frontal regions will have some difficulty in task switching, and hence they will show an exaggerated AB under those conditions. Since neglect can be associated with damage to (right) pre-frontal cortex (Husain and Kennard, 1996; Mort et al., 2003) task switching deficits in patients with frontal lesion may lead to a poor AB as typically tested. This need not only be confined to patients with frontal lesions, though. An increasing body of neuroimaging research has investigated other cortical areas thought to be crucial in task set reconfiguration and task conflict (Barber and Carter, 2005; Liston et al., 2006) - including posterior parietal as well as prefrontal cortex (see Sohn et al., 2000; Serences et al. 2005; Serences and Yantis, 2007). Sohn et al. argue that, while the prefrontal cortex mediates endogenous preparation to switch tasks, the posterior parietal cortex may be more involved when task switches are driven exogenously. Under AB conditions, switches of attention may be contingent on both the endogenous ‘set’ to switch the response to the second target stimulus, and by an

exogenous response to the properties of the second target stimulus, Problems in both posterior parietal as well as frontal patients may result.

Given evidence on effects of parietal and frontal lesions on task switching, it may be possible to tease apart difficulties in attentional processing in parietal and frontal lobe patients under conditions in which the task set must be switched between the T1 and the T2 events. To test these possibilities, this study examined the effects of task switching on AB in contrasting groups of neuropsychological patients and controls. Participants either took part in an AB procedure where no task switch was required (blocks one and two of the current study), or they had to switch their task set between the T1 and T2 events (blocks three and four). For example, in the first two blocks of trials participants were asked to report the same feature for both T1 and T2, whereas in the second two blocks of trials participants were asked to switch from reporting (for example) the colour of T1 and the shape for T2. The switch and no-switch trials were run in separate blocks and before each block participants were reminded the task response requirements. This means that participants had to hold in WM the task-set configuration for a number of consecutive trials. In the switch block, performance could decrease for various reasons: (i) the requirement to switch task set, (ii) the requirement to carry out two rather than one task (report colour then shape, or vice versa), and (iii) the need to hold the 'report different attributes' instruction in working memory. However, effects of two rather than one task, and the increase in the working memory load, were present in the conjunction report task of Chapter 2 (Correani & Humphreys, submitted), when contrasted with the single feature report trials (since the conjunction report task required that two attributes had to be coded from T1 and T2, and the working memory load was higher). If these factors alone were crucial, then the contrast between the switch and no-switch conditions here

should resemble the contrast between the conjunction and single feature trials found earlier, and the common deficit across frontal and parietal patients should again be found. On the other hand, if there is an additional contribution from task switching between T1 and T2, then the contrast between the switch and no switch trials should be greater than that between the conjunction and single feature trials, and it is possible that a selective effect of lesion site could emerge.

Method

Participants

Seventeen patients were tested, ten with their main lesion focused on the posterior parietal cortex (M.P., J.B., M.H., P.F., R.H., D.B., J.F., F.L., T.M., M.C.) and seven with their primary lesion involving frontal cortex (P.W., G.A., A.S., F.K., J.W., D.S., P.H.). The patients' clinical characteristics, gender, ages and lesion descriptions are presented in Table 2. Eight age and sex matched healthy participants (mean age 68.37; SD 7.72) were also tested. All participants were naïve in respect to the experiment and they received a basic color vision assessment in which they were required to name the colour of each stimulus presented one at a time on the computer screen. If this preliminary test was failed (which could reflect a naming problem) the Ishihara's Test for Colour Deficiency (1981) was used to assess colour perception. All patients passed either the first or the second task.

Table 3.1. *List of the patients tested, lesion site and clinical details. IPL, inferior parietal lobe; SPL, superior parietal lobe; SMg, supramarginal gyrus; ANg, angular gyrus; ITg, inferior temporal gyrus; MTg, middle temporal gyrus; STg, superior temporal gyrus; IFg, inferior frontal gyrus; MFg, middle frontal gyrus; SFg, superior frontal gyrus.*

Patients	Sex/age/ handedness	Main lesion site	Major clinical symptoms	Aetiology	Years post-onset
Parietal patients					
DB	M/71/R	Left inferior parietal and superior temporal cortex	Right extinction	Stroke	12
JB	F/71/L	Left inferior occipital, lingual and parahippocampal gyrus. Right parietal (ANg,SMg, IPL), temporal (ITg,mtG,STg) and frontal (IFg,MFg)cortex	Left extinction, Left neglect (in reading and writing)	Stroke	10
MC	M/68/R	Right occipito-parietal-temporal extending to inferior frontal gyrus	Left neglect	Stroke	4
JF	M/65/R	Enlarged sulci in posterior parietal cortex, especially on the left	Apraxia, Dysgraphia, word finding difficulties	Posterior atrophy	6
PF	F/58/R	Left parietal (IPL,SPL,ANg) and right parietal cortex (ANg,IPL,SPL	Right extinction, Dysgraphia	Stroke	8
MH	M/53/R	Lentiform nucleus, left parietal (SMg, ANg, IPL, SPL),cortex	Right extinction, Dysgraphia	Stroke	10
FL	M/72/R	Left IPS plus lenticular nuclei	Right extinction, some visual naming problems, amnesia, attentional dyslexia	Carbon monoxide	15
TM	M/70/R	Right inferior parietal cortex (ANg, IPL), superior temporal cortex and inferior frontal	Left neglect Left extinction	Stroke	12

RH	M/74/R	Left angular and supramarginal gyri, superior temporal gyrus	Right extinction Neglect in reading Impaired verbal STM	Stroke	8
MP	M/59/L	Right parietal (SMg,IPL), temporal (MTg,STg) and frontal (IFg,MFg) cortex	Left neglect, Right hemiplegia	Aneurism	15
<u>Frontal patients</u>					
GA	M/52/R	Bilateral medial anterior temporal lobes, extending into left medial frontal region	Aphasia Amnesia Dysexecutive syndrome	Herpes simplex encephalitis	13
PH	M/34/R	Left medial and superior temporal lobe, Left inferior and middle frontal gyri	Right hemiplegia Aphasia Extinction under brief exposures	Stroke	10
PW	M/73/R	Right inferior and middle frontal gyri, right superior temporal gyri	Left hemiplegia Dysexecutive syndrome	Stroke	8
DS	M/71/R	Left inferior, middle and superior frontal gyri	Right hemiplegia Aphasia	Stroke	14
FK	M/39/R	Bilateral inferior and middle temporal lobes, medial frontal	Dysexecutive syndrome, some recognition problems	Carbon monoxide poisoning	14
AS	M/71/R	Right middle frontal and temporal cortices	Left extinction	Stroke	6
JW	M/70/R	Right middle frontal gyrus	Left extinction, aspects of dysexecutive syndrome	Stroke	4

Stimuli

This experiment was programmed using E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002). Similarly to Chapter 2, (Correani and Humphreys, submitted), the stimuli comprised three different geometrical shapes (triangle, circle and square) in either of three different colours (red, blue and green). Each shape measured 25x25 mm at its widest point and was viewed by each participant from a distance of approximately 65 cm, subtending a 2.2° x 2.2°of visual angle. In contrast with Experiment 1 (Correani and Humphreys, submitted), target 1 and target 2 (T1 and T2) always differed in shape and colour.

Design and Procedure

The experiment had a 4 x 2 x 4 design factors: four task switch conditions (colour-colour; shape-colour; colour-shape; shape-shape); two target load conditions (T1-T2 and T2 alone); four time intervals. Participants carried out 4 blocks of trials, 1 for each task switch condition: in the first two blocks (the no-switch condition), participants were asked to detect the same feature both for the first and the second target (e.g. report either the colour or the shape of both T1 and T2), with T1 and T2 colour being critical in the first block and shape in the second block. In the other two blocks (the task switch condition), the patients were asked to report two different features for T1 and T2.(in one block, report the colour of T1 and report the shape of T2; in a second, report the shape of T1 and the colour of T2). In the dual target task participants were asked to report both T1 and T2, in the single target task they were asked to ignore T1 and report only T2. There were 4 time intervals between these stimuli (inter-stimulus

intervals of 50, 150, 450 and 1350ms; see Figure 3.1). For each time interval there were 36 possible target combinations (144 trials in total, per block), and each permutation was presented once in a block. There were also no repeats of a particular T1-T2 combination within a time interval. In order to gain sufficient data for each participant, the dual-target task experiment was performed twice with a week time interval in between.

All participants viewed each stimulus on a Gateway Pentium PC from a distance of 65 cm at the centre of the screen on a grey background (RGB: 190-190-190) on a 17-inch monitor with a 1024 x 768 pixel resolution. All the patients carried out 288 trials divided into two sessions, 144 for the dual-target task (report T1 and T2) and 144 for the single-target task (report T2 alone). Controls performed 144 trials in both report conditions (T2 alone and T1-T2). The exposure time for T1 and T2 was varied across patients in order to match performance on average (see below). Each target was presented for an average duration of 60.2 ms (with a duration range between 12-90 ms) for the patient group and for an average of 28.6 ms (with a duration range between 12-35 ms) for the control group. The fixation cross appeared at the start of the experiment and stayed on the screen for 2000 ms. During the interval between the T1-mask pair and the T2-mask pair a blank screen was presented, with the masks and the blanks being presented for 50 ms duration (see Figure 3.1).

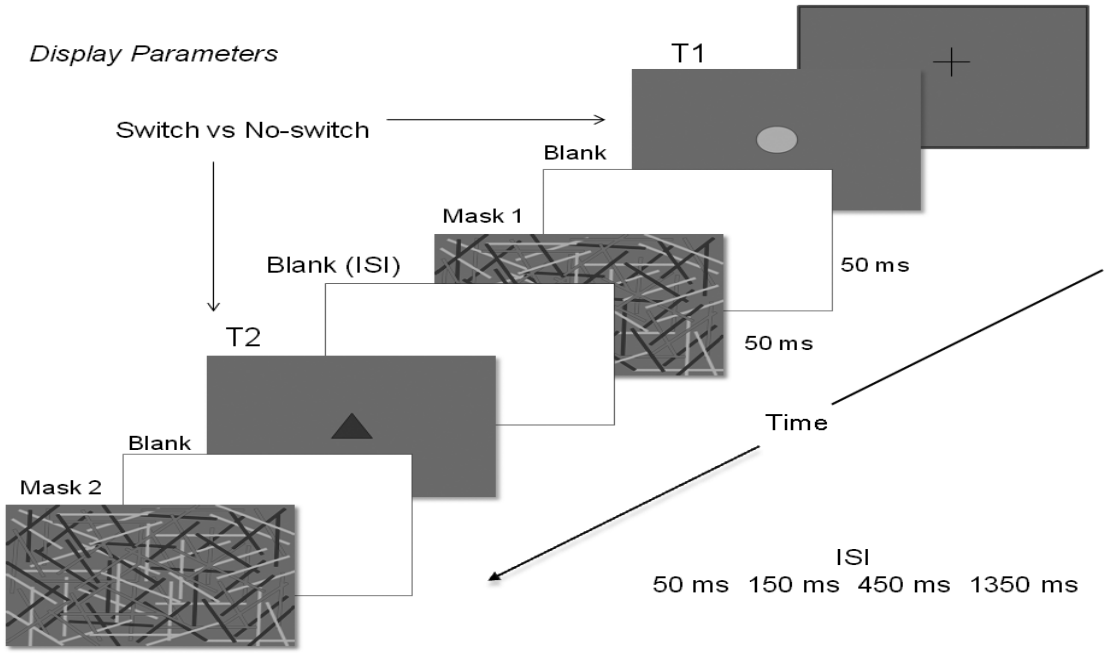


Figure 3.1. Illustration of the sequence of events on a trial. The same display parameters were used for the dual task when participants had to report both T1 and T2 and for the control task when participants had to ignore T1 and report only T2. Task switch occurred within the trial sequence and applied to the report of T1 and T2 features.

The order of the different ISIs was counterbalanced across all four report conditions but presented in a fixed order for each participant. Subjects received an initial 20 practice trials or until they reported feeling confident with the task. Answers were always recorded manually by the experimenter for all participants. Trials that patients did not fixate (judged by the experimenter) and trials in which the first target was missed (T2 report not consistent on T1 report) were discarded.

Similarly to Chapter 2 (Correani and Humphreys, submitted), target exposure time was individually set during the preliminary training session for all participants in order to reach a minimum of 70% correct responses across the different report tasks. Sample blocks of 20 trials were run in which all the four time intervals were equally

represented. In the first ten trials participants were asked to perform the same task for the report of T1 and T2; in the second ten trials they were asked to switch task between the two targets. This procedure was carried out to try and ensure that overall performance was roughly equated across the groups, averaging across all the conditions of interest. Starting from an exposure time of 50 ms, this was increased by 5 ms a time until participants did not score 2/3 of the trials correctly. This in turn means that the main interest focuses on differential effects of a given variable (e.g., the time interval, the report task, the similarity of T1 and T2) on report across the groups. Such differential effects would indicate a qualitative difference between the groups over and above general effects of task difficulty.

Results

The analyses were divided into three sections.

(1) A first analysis assessed whether there were overall differences in stimulus time exposure across the groups and whether there were overall differences in performance.

(2) A second analysis assessed whether there was a differential AB across the parietal and frontal groups. Subsequently the patients as a single group were compared with the controls.

(3) A third analysis examined whether the type of task to be performed on each target (T1 or T2 reported as a colour or as a shape) affected performance. Again parietal patients were compared with frontal patients and then all the patients were compared as a single group with controls.

(4) Finally a correlation analysis was performed between: (i) switch-cost measures relative to the magnitude of the AB (see below), and (ii) the performance of all patients on different neuropsychological tests (from the BUCS – www.bucs.bham.ac.uk) assessing impairments in visual selection and visual attention.

(1) *Overall differences in durations and performance level*

A first analysis assessed differences in stimulus durations (the target time exposition was varied across participants, please see the *Stimuli and procedure*) across groups in order to assess whether the patients required longer exposures in order to set the average level of performance close to that of the controls. A one-way-ANOVA showed a significant difference in target duration between the groups, F (2, 22) = 12.73, $p < 0.001$ (parietals mean duration: 58.20 ms, frontals mean duration: 48.42 ms, controls mean duration: 21.5 ms). The two patient groups differed significantly from the non-lesioned controls, but they did not differ from one another: parietals vs. frontals: t (15) = 1.07, $p = .301$; controls vs. parietals: t (16) = 5.90, $p < 0.001$; controls vs. frontals: t (13) = 3.52, $p < 0.005$.

Moreover a one-way-ANOVA applied on a measure of overall performance across groups (performance averaged across the different conditions) showed a significant difference in the overall performance level between the three different groups (averaged across all conditions: task type, target load and time interval). A significant difference in overall level of performance was found between the groups, F (2, 22) = 3.60, $p < 0.05$ (parietal mean overall performance = 0.83, SDE = 0.13; frontal mean overall performance = 0.82, SDE = 0.11, control mean overall performance = 0.95, SDE = 0.34). The overall performance of the two patient groups differed significantly

compared to the control performance but they did not differ from one another: parietals vs. frontals, t (15) = .16, $p > 0.05$; parietals vs controls, t (16) = - 2.37, $p < 0.05$; frontals vs. controls, t (13) = -3.12, $p < 0.01$.

2) The overall AB effect

Patients only. A general AB effect was observed in all groups (see Figure 3.2.). Data from the patients only were firstly analysed in a 4 x 2 x 4 factor ANOVA with 3 within-subjects factors - Task type (with four levels: colour report for both T1 and T2 (CC), shape report for both T1 and T2 (SS), colour report for T1 and shape report for T2 (CS), shape report for T1 and colour report for T2 (SC)); Target Load [dual target report (T1 and T2) and single target report (T2 alone)]; Time Interval (50, 150, 450, 1350 ms). The between-subject factor was patient group (frontal vs parietal).

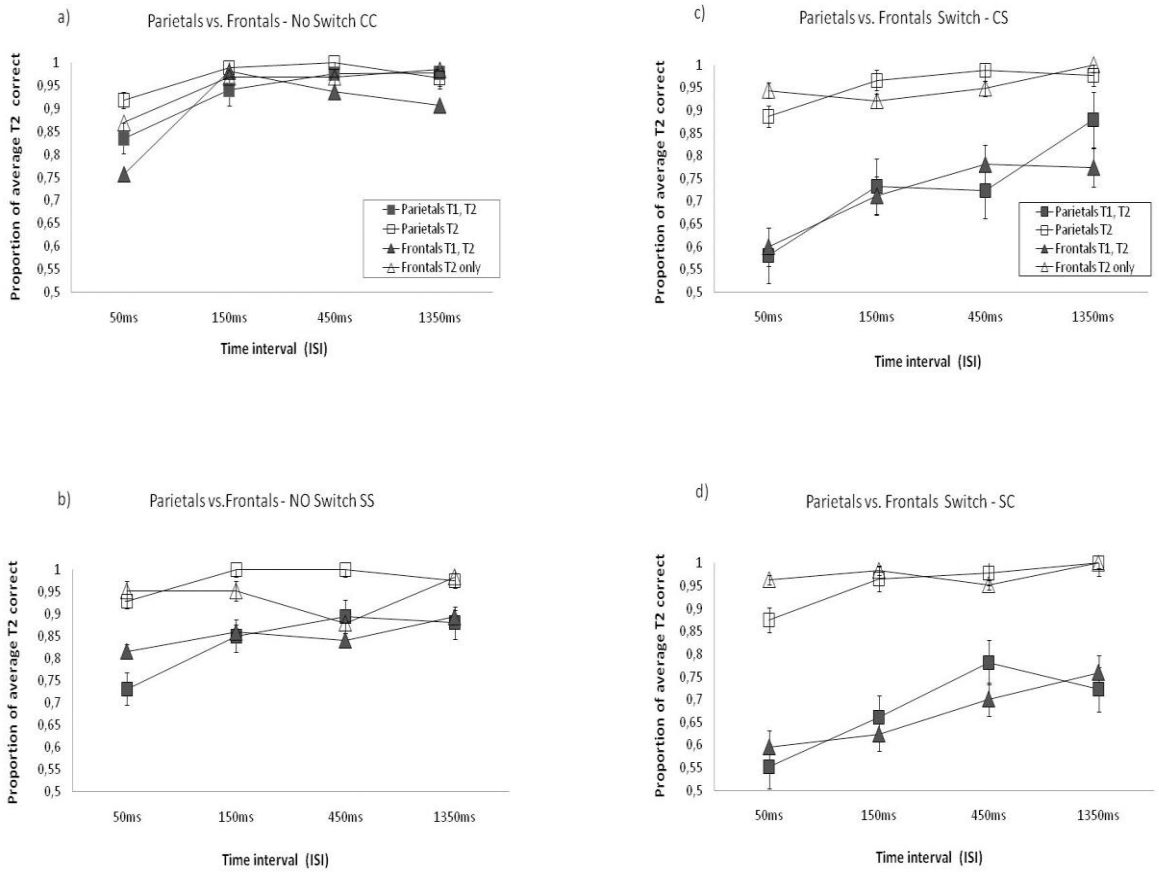


Figure 3.2. Performance of parietal and frontal patients in the overall AB in the four task type conditions; the first two conditions did not require any switch from one task-set to another, in the second two conditions, a task switch was required: a) CC, report colour for both T1 and T2; b) SS, report shape for both T1 and T2; c) CS, report colour for T1 and shape for T2; d) SC, report shape for T1 and colour for T2

There were reliable main effects of task type [F (3, 45) = 13.75, $p < 0.001$], target load [F (1, 15) = 31.24, $p < 0.001$] and time interval (ISI) [F (3, 45) = 10.64, $p < 0.001$]. Interactions were also found between task type and target load [F (3, 45) = 18.52, $p < 0.001$] and target load and time interval [F (3, 45) = 5.45, $p < 0.005$]. The first interaction between task type and target load occurred because there was a substantial drop in the performance of the patients when T2 was reported after T1 and

the task switched rather than stayed the same [Colour report for T1 and T2 target mean= .936, SDE= .013; Shape report for T1 and T2 target mean= .903, SDE=.019; Colour report for T1 and shape report for T2 mean= .838, SDE= .031; Shape report for T1 and colour report for T2 mean= .819, SDE =.034]. The interaction between target load and duration shows an AB effect, where the disadvantage in reporting T2 followed by T1 was greater at early lags compared to later lags. There was no overall difference in performance between the two groups of patients [F (1, 15) = 0.051; p = 0.824], and no interactions of group with any other factors [all F<1.0]. T1 accuracy was above 90% for both patient groups.

Patients vs. controls. Given that no significant difference in performance was found between the parietal and the frontal patients, their data were combined as a single group and compared with the control group using the same design ANOVA as above (see Figure 3.3.). An overall significant difference between the patient group and the control group was found [F (1, 23) = 7.340, p <0.05]. Reliable main effects were also found for task type [F (3, 69) = 11.909, p <0.001], target load [F (1, 23) = 23.84, p <0.001] and duration [F (3, 69) = 8.51, p <0.001]. There were interactions between task type and target load [F (3, 69) = 15.49, p <0.001] and between task type, target load and group [F (3, 69) = 11.909, p <0.001], along with an interaction between target load and duration [F (3, 69) = 11.909, p <0.001]. The interaction between task type and target load arose because the AB (the difference between reporting T2 after T1 vs. reporting T2 alone) was greater in the two switch task conditions compared with the conditions where there was no switch. The interaction between target load and duration arose because the AB effect was larger with a short ISI than with a longer ISI. The interaction between task type, target load and group arose because the

patients showed larger effects of switching, particularly when T1 was reported along with T2, compared with the controls (see Fig. 3). However for the controls alone there remained an interaction between task type and target load [F (3, 21) = 4.74, $p < 0.05$]. The control group showed worse performance in the task switch conditions (SC, CS) compared to the no-switch task condition (CC, SS), especially in the dual target condition (T1-T2) compared to the single target condition (T2 only). T1 accuracy was above 90% for the patient group and above 95% for the control group.

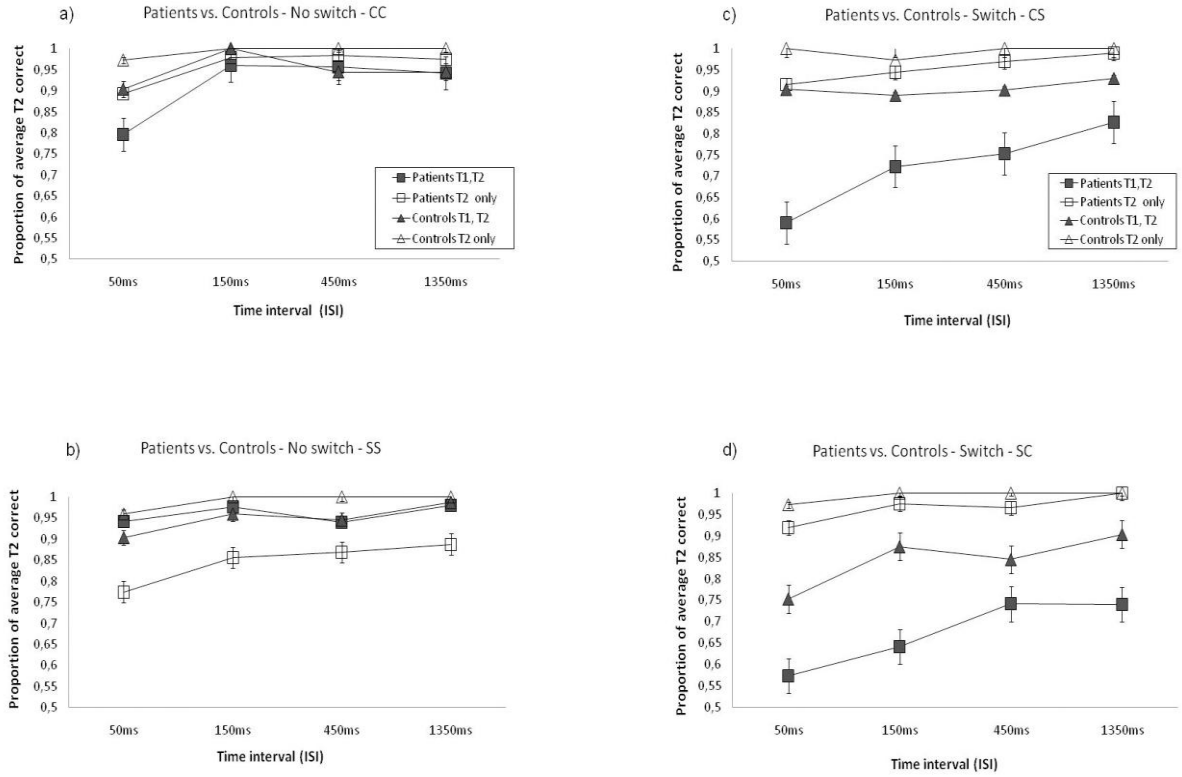


Figure 3.3. Performance of the patient group compared as a whole to the control group. The conditions were the same as those presented in Figure 3.2.

3) Effect of task on target report

A further analysis was performed to investigate the relationship between the task performed on T1 (colour or shape reported for T1) and the task performed on T2 (colour or shape reported for T2) on switching tasks. Only performance in the dual target report condition (T1-T2) was considered. The parietal and frontal patients were first analysed as one group alone and then they were compared with the control group.

Effect of T2, patients only. The effect of the task performed on T2 was tested by averaging all data across the different durations and considering results from the dual target condition (T1-T2) only. A 2 x 2 ANOVA was conducted where the within-subject factors were: the relationship between T1 and T2 (switch vs no-switch) and the feature reported for T2 (colour or shape). Group was analysed between-subjects. A main effect of task switch (the effect of switching in reporting T1 and T2) was found [F (1, 15) = 19.47, p = 0.001] along with an interaction of task switch and feature reported for T2 [F (1, 15) = 11.52, p < 0.005]. There was no main effect of feature reported for T2 [F (1, 15) = .539, p = .474] (see Figure 3.4a). In the dual target condition participants performed particularly poorly when the task switched from shape to colour report for T2 [SC mean= .676, SDE=.059; CS mean= .723, SDE= .052], however the advantage for the same task (no-switch) over the different task (switch) condition held for both T2 colour report and T2 shape report [CC-SC, t= 5.14, p< 0.001; CC-CS, t= 4.56, p <0.001; SS-CS, t= 3.37, p< 0.005; SS-SC, t= 4.36, p<0.001].

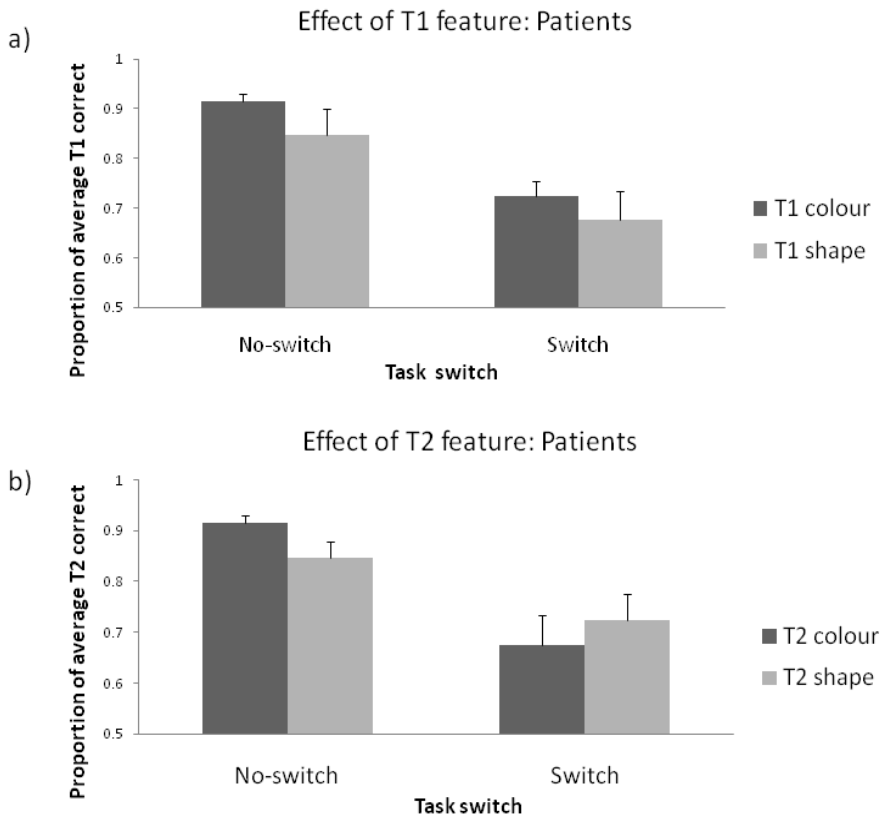


Fig. 3.4. Effect of the to-be reported feature for T2 (a) and for T1 (b) in both the no-switch condition and the switch condition. All patients found more difficult to perform in the switch condition compared to the no-switch condition.

Effect of T1, patients only. One other way to assess performance is to consider whether the switching task difficulty for patients could be determined by the task performed on T1 (report T1 as a colour or shape) rather than the task performed on T2. To assess this, the data were analysed again with an ANOVA where the within-subject factors were: 1) task type with two levels: switch vs no-switch and 2) feature to be reported for T1: colour and shape. The between-subject factor was patient group. No significant difference between the parietal and the frontal groups was found [F (1, 15) = .019, p = .892]. There were reliable main effects of task type [F (1, 15) = 19.47, p = 0.001] and T1 feature report [F (1, 15) = 11.52, p < 0.005]. Patients performed

worse under switch conditions [no-switch mean = .880, SDE = .022; switch mean = .700, SDE = .055]. They also found it harder to report T2 when they had to report the shape of T1 [T1 as a colour mean = .819, SDE = .032; T1 as a shape mean = .762, SDE = .042] (see Figure 3.4b). These results corroborate the hypothesis that the task performed on T1 may be a critical factor contributing to the decrement in performance in the dual target condition. However, there was no interaction between task switch and the difficulty of the T1 task [F (1, 23) = .564, p = .460].

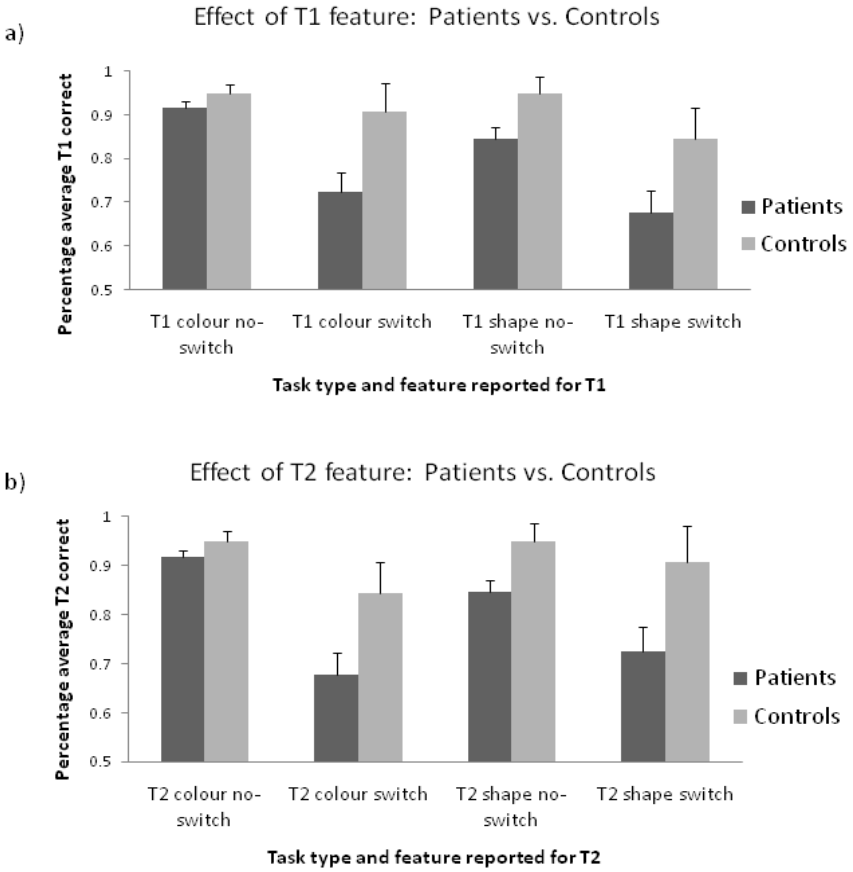


Figure 3.5. Effect of the to-be reported feature for T2 (a) and T1 (b). Here parietal and frontal patients were compared as one group with the control group.

Effect of T2, patients vs. controls. Given that no significant difference in performance was found between the parietal and the frontal patients, their data were combined as a single group and compared with the control group using the same ANOVA design as above (see Fig 3.5a., above). An overall significant difference between the patient group and the control group was found [F (1, 23) = 5.05, p <0.05]. Patients performed significantly worse compared to controls [patients mean = .791, SDE = .030; controls mean = .912, SDE = .044]. There was also a reliable main effect of task switch [F (1, 23) = 17.829, p <0.001], (Fig.3.4.a). Both groups found more difficult reporting T2 in the switch condition compared to the no-switch condition [no-switch condition mean = .915, SDE = .016; switch condition mean = .788, SDE = .040]. No main effect of task on T2 was found [F (1, 23) = .564, p = .460]. There was an interaction between task switch and task on T2 [F (1, 23) = 10.48, p <0.005] (Figure 3.5a). There was a drop in performance from task switching particular when colour had to be reported for T2.

Task performed on T1, patients vs. controls. The data where analysed in a 2x2 ANOVA with the within-subject factors being: task switch (switch vs. no-switch) and task on T1 (report colour vs. report shape). The between-subject factor was group. A significant difference was found between the groups [F (1, 23) = 5.05, p < 0.05]. Reliable main effects of task switch [F (1, 23) = 17.829, p < 0.001] and task on T1 [F (1, 23) = 10.48, p <0.005] were found. Both patients and controls found more difficult reporting T2 when they had to switch task from T1 and T2 [no-switch mean = .915, SDE = .016; switch mean = .788, SDE = .040]. Moreover performance dropped particularly when the initial task was to report the shape rather than colour of T1 [T1 as a colour mean = .874, SDE = .024, T1 as a shape mean = .829, SDE = .031] (see Figure 3.5b). The results again showed a predominant effect of feature reported for T1

on the accuracy in reporting T2, but this did not interact with task switching [$F(1, 23) = .564$, $p = .46$ for the interaction].

4) Correlation analysis with cognitive impairment measures

In order to establish the relations between the overall AB under switch and no-switch conditions and different cognitive impairments shown by the patient groups, correlations were conducted between the AB measures and the neuropsychological test data. The neuropsychological assessments were based on measures of cancellation, sustained attention, selective attention and working memory (for full description of the single tasks score criteria and normative data, please see Chapter 2), taken from the Birmingham University Cognitive Screen (BUCS; see www.bucs.bham.ac.uk). Each neuropsychological score was correlated with three different measures of the AB. The first two measures consisted in the difference in performance between the single target report task (T2 only) and the two target report task (T1-T2) for both the no-switch and switch conditions. These measures were obtained by averaging across time interval and colour and shape report for each task type condition. A third measure of the switch cost under AB conditions was obtained using data from the two target report only. This consisted of the difference in the no-switch and switch conditions, averaged over time interval and colour and shape report. As shown in Table 3.2 (below), no significant correlation was found between the overall AB for the no-switch condition and measures of visual neglect (key cancellation), extinction, sustained attention, selective attention and working memory.

Table 3.2. *Correlation of the BUCS neuropsychological tests and a measure of the overall AB in the no-switch condition. Note that the Key cancellation task provides a measures of spatial neglect*

Patients	no-switch overall	Extintion	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	0.03	30	12	3.5	1	4
P.F.	0.05	11	0	6	5.5	3
M.H.	0.04	7	2	0	0	5
J.B.	0.18	7	3	1	11	4
T.M.	0.02	22	8	2	4	3
Frontals						
D.S.	0.15	1	1	3	11.5	4
P.W.	0.16	17	0	1	1	4
P.H	0.04	30	0	2.5	10.5	5
G.A.	0.04	2	0	7	6.5	5
A.S.	0.01	7	3	1	1	4
Pearson Correlation		-0.304	-0.331	-0.247	0.447	-0.331
Sig. (2-tailed)		0.394	0.35	0.492	0.195	0.35

Similar analyses on the overall AB switch measure and the neuropsychological measures showed a significant correlation between the selective attention measure and the magnitude of the AB in the switch condition, $r = .708$, $p = .022$. As mentioned in Chapter 2, a high score in the selective attention task reflects impairment in selecting between target and distractor words under conditions of auditory presentation. Under the present AB conditions this may translate into patients having difficulty in screening out the irrelevant mask following the target stimuli. The correlation indicates that patients who had difficulty in segmenting the targets and masks were impaired in the task switching condition.

Table 3.3. *Correlation of BUCS neuropsychological tests and a measure of the overall AB in the switch condition. The Key cancellation task provides a measure of spatial neglect.*

Patients	switch overall	Extintion	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	0.02	30	12	3.5	1	4
P.F.	0.49	11	0	6	5.5	3
M.H.	0.15	7	2	0	0	5
J.B.	0.62	7	3	1	11	4
T.M.	0.01	22	8	2	4	3
Frontals						
D.S.	0.33	1	1	3	11.5	4
P.W.	0.2	17	0	1	1	4
P.H	0.31	30	0	2.5	10.5	5
G.A.	0.41	2	0	7	6.5	5
A.S.	0.06	7	3	1	1	4
Pearson Correlation		-0.561	-0.605	0.36	0.708	0.078
Sig. (2-tailed)		0.092	0.064	0.306	0.022*	0.831

Finally as shown in Table 3.4. (below), a correlation analysis was also performed on a measure of the switch cost in the AB and the neuropsychological tests. A significant correlation was found between the switch cost measure in the AB and the selective attention index, r = .663, p = .037. A poor ability to select targets from masks (poor selective attention) is associated with larger drops in performance under conditions where tasks switch relative to when the tasks stay the same.

Table 3.4. *Correlation of neuropsychological tests from the BUCS and a measure of switch costs in the AB. The Key cancellation task provides a measure of spatial neglect.*

Patients	switch cost	Extintion	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	-0.01	30	12	3.5	1	4
P.F.	0.43	11	0	6	5.5	3
M.H.	0.12	7	2	0	0	5
J.B.	0.43	7	3	1	11	4
T.M.	-0.01	22	8	2	4	3
Frontals						
D.S.	0.19	1	1	3	11.5	4
P.W.	0.04	17	0	1	1	4
P.H	0.25	30	0	2.5	10.5	5
G.A.	0.35	2	0	7	6.5	5
A.S.	0.04	7	3	1	1	4
Pearson Correlation		-0.55	-0.576	0.479	0.663	0.106
Sig. (2-tailed)		0.099	0.081	0.161	0.037*	0.771

Discussion

Evidence for an AB effect was found in control and both parietal and frontal patients using a 2-item report task with a fixed alternative-run paradigm. This effect was greater under conditions of task switching compared to when the task performed on T1 and T2 remained the same. The effect of task switching on the AB matches results reported in studies with normal participants by Chun and Potter (1998), Arnell and Jolicoeur (1999) and Kawahara et al. (2003). Consistent with previous neuropsychological analyses of the AB (e.g. Husain et al., 1998), the patients showed

a larger AB compared to the controls. However as in Chapter 2 of this thesis (Correani and Humphreys, submitted), there was no evidence for a differential AB effect for the parietal compared to the frontal group. Across both patient groups, however, the AB was particularly pronounced under switch conditions, and the differences relative to the control group were largest in this case. There is thus evidence for both frontal and posterior parietal lesions disrupting task switching here, and this particularly exacerbates the problems that patients have in reporting T2 after T1.

These data suggest that parietal and frontal patients did not perform significantly differently from each other, consistent with previous evidence for an involvement a fronto-parietal network in task switching and task-set reconfiguration (e.g. Sohn et al.2000; Liston et a; 2006). In Chapter 2 (Correani and Humphreys, submitted) a detrimental effect of reporting two rather than one attribute was found (conjunction report: report both colour and shape for both targets). This could reflect a problem in switching from one reporting dimension to another. To test for the possibility that task switching produced an additional drop in performance here we contrasted the case in which the report task on T1 and T2 switched compared with when the task remained identical for T1 and T2 (repeat trials). The greater difficulty for switching in the patients compared with the controls was not greater on frontal than parietal patients. This is consistent with components of both endogenous and exogenous switching being involved in the present case (e.g. Roger and Monsell, 1995; Goschke, 2000; Rubinstein et al. 2001).

The switch and no-switch trials were run in separate blocks and before each block participants were reminded of the task response requirements. This means that participants had to hold in WM the task-set configuration for a number of consecutive trials. These extra demands on WM could be a cause of the drop in performance on

switch relative to repeat trial, particularly in the patients tested here. Shallice et al. (2008) suggest that frontal patients can show greater difficulty at the beginning of a block of switch trials, due to problems in setting-up an initial action-schema. Shallice et al. also suggest that these difficulties may recede across a trial block. If this was the case then the patients here should have found it easier to perform the fourth relative to the third switch block. Surprisingly this was not the case. Patients, and to a lesser extent controls as well, found it more difficult to carry out the last switch block of trials where they were asked to report the shape of T1 and the colour of T2. This detrimental effect in reporting T2 after T1 was shown to be due to the type of task performed on T1 rather than the task performed on T2. This suggests perhaps a prioritization in the colour selection (Anderson et al., 2010) for T1 which slows down the assimilation of its shape and increases the AB. It could be argued that colour processing is carried out by a more ventral route (which is spared in our patients) while the processing of shapes is carried out by a more dorsal route (Konen and Kastner, 2008), which is possibly impaired the current group of patients.

Finally there was no evidence of any correlation between the AB effect (in both the no-switch and the switch conditions), or the switch cost, and measures of visuo-spatial impairments (neglect, extinction) in patients. The only significant correlations to emerge, relative to the neuropsychological tests, were between performance in the switch trials (and a measures of the drop in performance under switch conditions) and a measure of selective attention. For both frontal and parietal patients, poor selection in a test of auditory attention (from the BUCS) was associated with poor performance under task switching conditions. From this single correlation, it is difficult to know the relations between the measures. Poor switching between targets and distractors, in the auditory attention measure, could lead to patients responding (incorrectly) to

distractors as well as targets, and it could generate the problems the patients have when they have to switch report attributes between T1 and T2 in the AB procedure. Alternatively, a poor ability to select a target from distracting information (e.g., selecting the mask as well as the target in the AB procedure) could generate the AB as well as poor performance in the auditory selective attention task. It will be interesting for future work to separate out the cause-and-effect relations here, perhaps by manipulating the ease of target selection (e.g., making targets and distractors more discriminable) or the ease of task switching (giving cue to switch on each trial). The important point, however, is that the deficits in the AB and the drop in performance under switch conditions are not necessarily related to spatial neglect; rather the effects are associated with a non-spatial deficit in selection.

Chapter 4

TEMPORAL SELECTION AND CROSS-MODAL INTEGRATION IN PARIETAL AND FRONTAL PATIENTS: AN ATTENTIONAL BLINK STUDY

Abstract

Data are reported on the effects of an irrelevant auditory tone on the report of targets in a reduced form of an attentional blink (AB) procedure. The results indicated that tones that were coincident with targets tended to disrupt identification of those targets, both for patients with brain lesion (centred on either frontal or parietal cortex) and for age-matched controls. In the patients, both an increased AB and the detrimental effect of the coincident tone tended to increase in individuals who had poor selective attention. The detrimental effects of the tones are linked either to the tones distracting/reducing resources from targets or to the tones enhancing target-mask integration.

Introduction

In Chapters 2 and 3 of this thesis, I have presented data indicating that, while the attentional blink (AB) tend to increase in brain-lesioned patients compared with controls, this increase was present in patients with frontal as well as parietal lobe lesions. In addition, these deficits were associated with a clinical impairment in selective attention in the patients, rather than (e.g.) a deficit in visuo-spatial attention. This runs counter to previous studies which have associated a deficit in temporal selection to damage to the parietal cortex (Shapiro et al. 2002) and to the presence of visuo-spatial neglect **(**Husain et al. 1997). The present data, however, suggest that an increased AB is not tied to a closely localized lesion but rather to more global changes within a fronto-parietal attentional network (cf. Corbetta and Shulman, 2002), and to generally selection processes rather than being confined to spatial attention.

In the present Chapter, I report an attempt to take further this notion that an increased AB relates to poor selection in general. To do this, I manipulated a variable that can increase stimulus selection – the presence of a non-spatial auditory cue. As noted below, there is emerging evidence that visual selection can be improved by auditory cueing. Here I assessed whether this could modulate the selection deficit found in patients with posterior parietal and frontal lobe lesions, and whether any changes reflected impaired selection rather than other characteristics of the patients (e.g., spatial biases in attention).

Auditory cueing could improve visual processing in various ways – for instance, because such cues activate a general alerting function (Posner et al., 1976) or because of enhancement of auditory and visual processing channels (perhaps modulated by the superior culliculus; Stein et al., 1984, 1996). Robertson and Manly, 1999 (see also Robertson et al., 1997; Manly et al., 2005) have noted that deficits in neuropsychological patients can be associated with poor arousal. Posner and Petersen (1990) have argued that arousal levels are modulated by variation in norepinephrine in the right hemisphere, and that patients with right parietal lesions are more affected by omitting a pre-target auditory cue compared to left parietal lesioned patients (Posner et al. 1987). After right hemisphere lesions, arousal levels can drop and this is associated with impairments in non-spatial as well as spatial selection (Manly and Robertson, 1998). In the present case, reduced arousal may mean that there is inefficient selection of stimuli presented for brief exposures, and consequent increases in the AB. Giving patients an auditory cue could temporarily raise arousal levels, and thus prompt better performance. Work investigating the influence of auditory stimulation on visual attention in brain damaged patients (e.g. Robertson et al., 1998; Frassinetti et al., 2002; Van Vleet et al., 2006) has shown that an auditory tone can temporarily ameliorate deficits in visuospatial attention in patients with unilateral neglect. For example Robertson et al. (1998) presented to eight right-damaged neglect patients after a random delay, a visual horizontal bar which appeared on one side of fixation followed by a bar on the other side at a variable SOA. Patients were required to judge which bar appeared first with no time limit in responding. A 300 ms tone was presented centrally on 25% of all trials before the first target. Participants were instructed to ignore the tone when it was presented. Patients became aware of left events half a second later then right events on average, due to a "strong 'priority entry' advantage for right visual events (pp.170)". This effect was corrected when a warning

sound occurred phasically before the appearance of the target. Although the central sound occurred unpredictably and lasted only few seconds the authors suggested that the enhanced performance on warning trials was due to temporary increases in arousal, which facilitated processing of stimuli in the impaired field. These effects were not modulated by varying the perceived location where the auditory appeared to originate from. Other researchers (e.g., Frassinetti et al., 2002; Van Vleet and Robertson, 2006), however, have found that the location from which the auditory cue is presented is crucial for it to enhance performance. Evidence that auditory cues are most effective when they come from the neglected field suggests that cross-modal spatial cueing may also play a role (Driver and Spence, 1998; Schmitt et al., 2000; McDonald et al., 2000). .

In addition to any effects on arousal, temporal synchronization between visual and auditory stimuli may modulate information processing. This last possibility is raised by a study by, Van de Burg et al. (2008), who demonstrated that a simple nonspatial auditory signal drastically reduced reaction times in a highly demanding visual search task. In this experiment the authors asked normal participants to search and judge the orientation of either a horizontal or vertical line among up to 48 oblique line distractors. At random intervals during search the colour of distractors as well as the targets changed randomly. The change in the target colour could be accompanied by a warning beep which did not provide information about the colour, position or orientation of the to-be detected target. Search was greatly speeded by the auditory beep. In a second experiment, Van de Burg et al. replaced the auditory stimulation with a visual warning signal consisting either of the fixation dot briefly disappearing prior to the target change or a peripheral halo of light (to control for the possible narrowing of attention in the first manipulation). There was no benefit to search from

nonspatial visual cuing. A third experiment manipulated the time interval between the auditory stimulus and the visual target. If the tone simply acted as a warning signal indicating when the change in the target took place, no benefit should be found in the condition where the beep appeared after the target presentation. In contrast, Van de Burg et al. found that performance improved even when the tone was presented after the visual signal. A fourth experiment additionally showed that search benefitted even when the tone synchronized with the change in distractors rather than targets. This last result suggests that the auditory cueing effect does not reflect some top-down strategy based on search for a change coincident with the beep, since synchronization with distractors was also beneficial. Van de Burg et al. proposed instead that the improvement was due to the temporal synchronization of the sound with a visual event, which makes the event either easier to attend to (when it coincides with the change in the target) or to reject (when it coincides with the change in the distractor). It may also be, however, that the auditory cue increases non-spatial arousal facilitating search more general even when it is not coincident with a visual change (Experiment 3).

In a study examining temporal selection, Vroomer and de Gelder (2000) provided evidence of increased accuracy in detecting a target embedded in a rapid visual presentation (RSVP) when the target was paired with a non-specific auditory stimulus (though the cue did not contain any information about the nature or location of the target). More recently Olivers and Van de Burg (2008) introduced the use of an auditory cue to a classical AB task. In four experiments these authors manipulated the occurrence of a non-specific beep sound in relation to target and distractor stimuli. The auditory cue could be presented before the targets, together with the presentation of either T1 or T2, or together with a distractor. Performance was improved when both

T1 and T2 were accompanied by a beep (the blink on T2 was abolished), with little evidence of a trade-off the beep and report of the other (non-cued) target. This would fit with the idea of enhanced perceptual processing of the visual stimuli coincident with the auditory cue. On the other hand, performance was also improved when the auditory cue was presented together with distractors, which could occur because perceptual enhancement through temporal synchronization aids the rejection as well as the selection of stimuli. Performance was not enhanced when the auditory cue preceded the targets, suggesting in this case that increased arousal may not be critical.

To test effects of arousal and/or temporal synchronization in Chapter 4 I conducted an AB study where an auditory cue was either absent or synchronized with either the first target (T1) or the second target (T2). This experimental design allowed me to control for possible alerting or cueing effect which could occur by a pre-target sound presentation (e.g. Van Vleet and Robertson, 2006). For example, increases in arousal may be associated with better report of both T1 and T2, even when the tone is coincident with only T1, though T2 might benefit most if this target suffers most from low arousal in patients. On the other hand, visuo-auditory synchronization may lead to enhanced report of the targets that are coincident with the auditory cue.

Method

Participants

Fifteen patients were tested, seven with their main lesion in the frontal cortex (F.K., D.S., P.W., G.A., J.W., P.H., A.S.) and eight with their main lesion focused on the posterior parietal cortex (P.F., D.B., T.M., J.B., M.H., M.P., R.H., J.F.[2]). The primary clinical characteristics of the patients are listed in Table 1. Nine, age and sex matched healthy controls were also tested (Mean Age = 68.22, SDE = 7.36). All participants were naïve with respect to the experiment and they received a basic color vision assessment in which they were required to name the colour of each stimulus presented one at a time on the computer screen. If this preliminary test was failed (which could reflect a naming problem) the Ishihara Test for Colour Deficiency was used to assess colour perception more formally [19]. All patients passed either the first or the second task. Moreover auditory processing was assessed in all patients and controls by presenting an auditory stimulus (beep sound) identical to that used in the experiment, which participants were asked to detect. Following the detection of the auditory stimulus, all participants were asked to judge whether the tone was sufficiently loud for their hearing and if not its intensity was adjusted as required.

[2] Note that patients R.H. and J.F. were excluded for the first analysis which assessed and overall AB effect (please see results below).

Table 4.1. *List of the patients tested, lesion site and clinical details. IPL, inferior parietal lobe; SPL, superior parietal lobe; SMg, supramarginal gyrus; ANg, angular gyrus; ITg, inferior temporal gyrus; MTg, middle temporal gyrus; STg, superior temporal gyrus; IFg, inferior frontal gyrus; MTg, middle temporal gyrus; SFg, superior frontal gyrus.*

Patients	Sex/age/ handedness	Main lesion site	Major clinical symptoms	Aetiology	Years post-onset
Parietal patients					
DB	M/72/R	Left inferior parietal and superior temporal cortex	Right extinction	Stroke	12
JB	F/72/L	Left inferior occipital, lingual and parahippocampal gyrus. Right parietal (ANg,SMg, IPL), temporal (ITg,mtG,STg) and frontal (IFg,MFg)cortex	Left extinction, Left neglect (in reading and writing)	Stroke	10
JF	M/66/R	Enlarged sulci in posterior parietal cortex, especially on the left	Apraxia, Dysgraphia, word finding difficulties	Posterior atrophy	6
PF	F/59/R	Left parietal (IPL,SPL,ANg) and right parietal cortex (ANg,IPL,SPL	Right extinction, Dysgraphia	Stroke	8
MH	M/54/R	Lentiform nucleus, left parietal (SMg, ANg, IPL, SPL),cortex	Right extinction, Dysgraphia	Stroke	10
RH	M/75/R	Left angular and supramarginal gyri, superior temporal gyrus	Right extinction Neglect in reading Impaired verbal STM	Stroke	8
MP	M/60/L	Right parietal (SMg,IPL), temporal (MTg,STg) and frontal (IFg,MFg) cortex	Left neglect, Right hemiplegia	Aneurism	15

Frontal patients					
GA	M/53/R	Bilateral medial anterior temporal lobes, extending into left medial frontal region	Aphasia Amnesia Dysexecutive syndrome	Herpes simplex encephalitis	13
PH	M/35/R	Left medial and superior temporal lobe, Left inferior and middle frontal gyri	Right hemiplegia Aphasia Extinction under brief exposures	Stroke	10
PW	M/73/R	Right inferior and middle frontal gyri, right superior temporal gyri	Left hemiplegia Dysexecutive syndrome	Stroke	8
DS	M/72/R	Left inferior, middle and superior frontal gyri	Right hemiplegia Aphasia	Stroke	14
FK	M/39/R	Bilateral inferior and middle temporal lobes, medial frontal	Dysexecutive syndrome, some recognition problems	Carbon monoxide poisoning	14
AS	M/72/R	Right middle frontal and temporal cortices	Left extinction	Stroke	6
JW	M/71/R	Right middle frontal gyrus	Left extinction, aspects of dysexecutive syndrome	Stroke	4

Stimuli

Consistent with Experiments 1 and 2 reported in Chapters 2 and 3 of the thesis, the stimuli used in the present experiment comprised three different geometrical shapes (triangle, circle and square) in either of three different colours (red, blue and green). Each shape measured 25x25 mm and was viewed at the centre of the screen by each participant from a distance of approximately 65 cm, (subtending 2.2° x 2.2°of visual angle). Similarly to Chapter 3, targets 1 and 2 (T1 and T2) never matched in colour or shape.

Design and procedure

The experiment had a 3 x 2 x 3 factorial design where there were three sound conditions (sound on T1; sound on T2 and no-sound condition); two target load conditions (dual target report- report T1 and T2; single target report- report T2 only) and three time intervals. The new factor manipulated here consisted in the presentation of a non-specific auditory cue (a beep, not providing any information on the nature of the target) which appeared during the AB sequence. The tone (705 kbps) was presented for 50 ms and was either absent or it occurred simultaneously with the onset of either T1 or T2.

The experiment was programmed using E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002). Each target stimulus was followed by a short blank interval (50ms) and then a mask (for 50ms) (see Fig. 4.1.). There were three inter-stimulus intervals (ISIs) between the offset of the mask after T1 and the onset of T2 (50, 150, 450 ms). Participants performed two blocks of trials for the two target report conditions (reporting T1 and T2; reporting T2 only). There were 24 colour-shape combinations

for T1 and T2, with the pairing drawn at random from combinations of three colours and three shapes with the only proviso being that no features were repeated on a trial. Within each block of trials, the time intervals were presented on equal numbers of trials for each permutation of each target feature (24) leading to 72 possible combinations for each sound condition. The order of the different ISIs was counterbalanced across the different sound conditions but presented randomized in a fixed order for all participants. Participants viewed the stimuli presented on a Gateway Pentium PC from a distance of 65 cm while they were wearing headphones. There were 216 trials for the dual target report task (T1-T2) and 216 trials for the single target report task (T2 alone). Unlike the earlier experiments presented in the thesis, the target exposure time here was set to 50ms for all participants. This means that performance levels cannot be equated, but it also means that effects of the auditory cue were not confounded by differences in the exposure of the visual stimuli – it is possible that auditory-visual integration could differ when the coloured shapes appeared for difference exposures. This change also means that the data are, in some respects, more comparable to prior studies of neuropsychological deficits in the AB (Husain et al., 1997). The fixation cross appeared before each trial and stayed on the screen for 2000 ms.

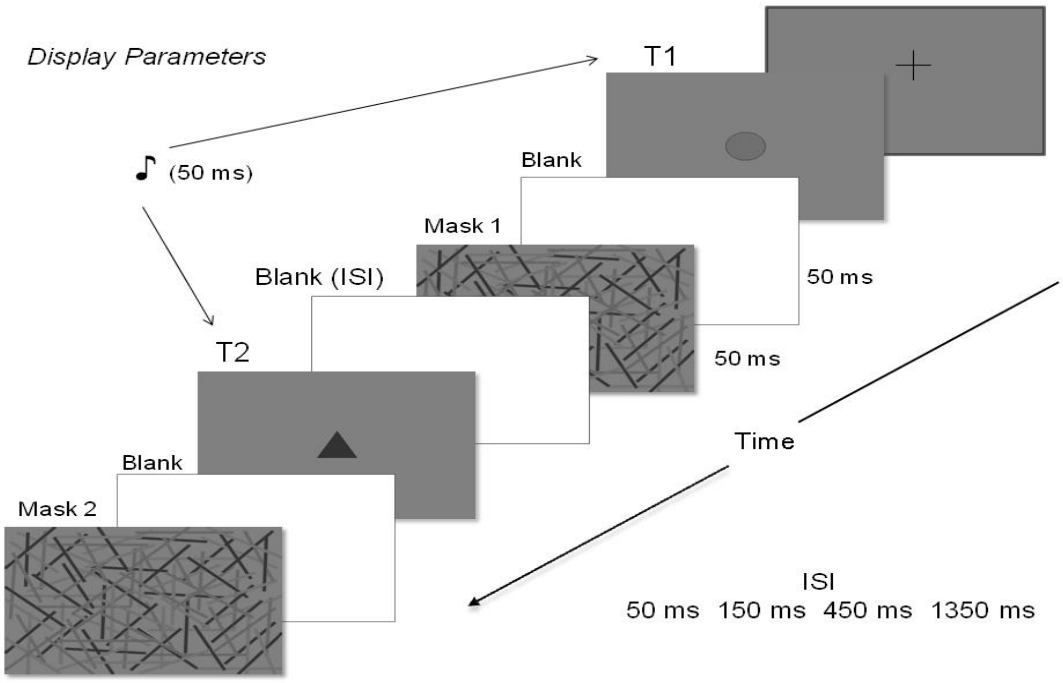


Figure 4.1.. Illustration of the sequence of events on a trial. Participants received an RSVP stream of stimuli, consisting in coloured shapes and were instructed to report both colour and shape of both T1 and T2 in the dual target report condition but only the colour and shape of T2 in the single target report. The tone was presented for 50 ms simultaneously with T1 onset or T2 onset or was absent.

Participants received 20 trials practice or until they reported feeling confident with the task and they were able to hear the tone clearly. The practice comprised a sample of trials representing most of the possible combinations between the three sound conditions and the three time intervals. Answers were recorded manually by the experimenter and trials in which the first target was missed were discarded for the analysis of the overall AB effect, but not for the second part of the analysis (see below).

Results

Three different type of analysis were performed on the data.

(1) A first analysis assessed the overall AB effect. Here only those trials where T1 was reported correctly were considered. Two patients were excluded from this analysis (R.H., J.F.) because their performance on T1 was very poor. Firstly the parietal patient group was compared with the frontal patient group. Secondly the group of patients as a whole was compared with a group of nine controls.

(2) In a second analysis all trials were considered irrespective of whether T1 was reported correctly prior to the report of T2 (T2 report contingent on T1) and, in addition, the accuracy of each target was scored separately. This last step was carried out in order to test for possible effects of sound on the correct report of each individual target (see below for more details). Correct report of either the first target (T1) or the second target (T2) was recorded regardless the order of report and the relationship between the two targets on a trial (T2 not contingent on T1). Patients R.H. and J.F. were included in this analysis. Again a first analysis assessed a possible difference between parietal patients and frontal patients and then the patients group as a whole was compared with the control group.

(3) Finally a correlation analysis was performed between a measure of (i) the attentional blink magnitude in the no sound condition as well as (ii) a measure of the effect of the auditory stimulation on reporting T1 and T2 in relation to the performance of all patients in neuropsychological tests (from the BUCS – www.bucs.bham.ac.uk) assessing impairment in visual selective attention, sustained attention and working memory.

The overall AB effect

Patients only: Data[3] for the parietal and frontal patients were first analysed in a 3 x 2 x 3 ANOVA with the within-subject factors being: 1) sound type (with three levels: no sound, sound on T1onset and sound on T2 onset); 2) target load (with two levels: dual target report (T1-T2) and single target report (T2 alone)); and 3) time interval (with three levels: 50, 150, 450 ms). The between-subject factor was patient group (parietal vs frontal). No overall significant difference was observed between the parietal patients and the frontal patients [the trend was for the frontal patients to perform worse; F (1, 11) = 3.83, p = .076]. The only main effect was for target load [F (1, 11) = 26.09, $p < 0.001$] where patients found it more difficult to report T2 when following T1 compared to when they had to report T2 alone [dual target report mean = .738, SDE = .052, single target report mean = .938, SDE = .023] (Figure 4.2.). No sound type effect was found [F (2, 22) = .305, p = .740]. There was also no overall effect of time interval [F (2, 22) = 1.35, p = .279]. No interactions were reliable. Thus identification of T2 following T1 was not ameliorated when accompanied by a simple tone. T1 accuracy was above 95% for both patient groups.

[3] Note that trials where T1 is reported incorrectly and T2 is reported correctly were discarded from the present analysis (as in the classic AB measure) but will be considered in the second analysis applied to the data in this Chapter (see below).

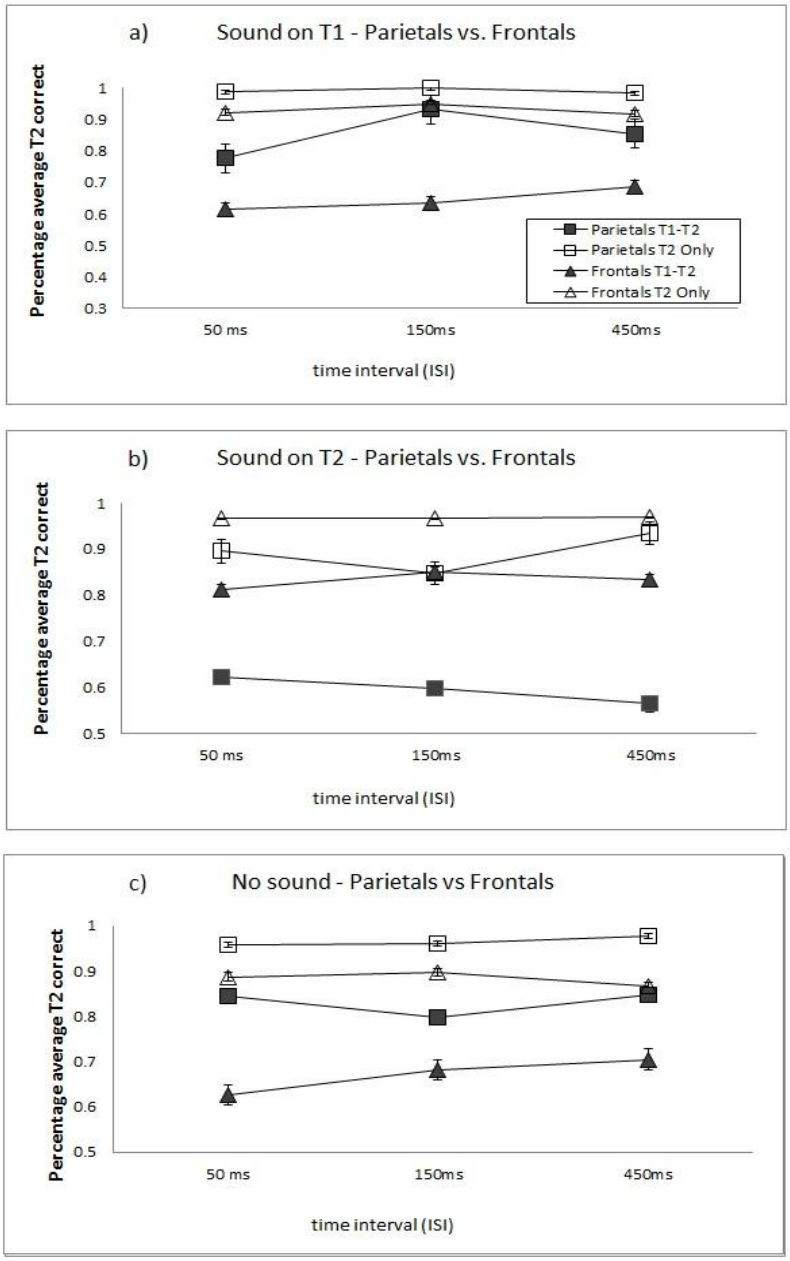


Figure 4.2. Overall performance of parietal and frontal patients in the two target report condition (T1-T2) and the single target report condition (T2 only) along the three sound conditions: a) No-sound; b) Sound on T1; c) Sound on T2. As shown in the figures, the only significant difference in performance found for the two groups of patients was between the dual target report condition and the single target report condition. No significant effect of time interval or sound type occurred.

Patients vs Controls: Given that no difference in performance was found between the parietal patients and the frontal patients, the patients' data were taken as a single group and compared against the control group, using the same 3 x 2 x 3 ANOVA as above (Figure 4.3.). A significant difference between the groups was found [F (1, 20) = 6.881, $p < 0.05$]; patients performed worse than the controls [patients mean = .833, SDE = .030; controls mean = .956, SDE = .036]. A main effect of target load was found [F (1, 20) = 29.42, $p < 0.001$], where the dual target report condition (T1-T2) lead to a lower performance compared to the single target report condition (T2 alone) (T1-T2 report mean = .824, SDE = .030; T2 alone mean = .965, SDE = .015). Moreover a main effect of time interval was also found [F (2, 40) = 6.89, $p < 0.05$], due to a drop of performance at the earliest lag [50ms mean = .881, SDE = .026; 150ms mean = .903, SDE = .023; 450ms mean = .900, SDE = .023] relative to the second and third lags [Lag1-Lag 2, t (21) = -.2.19, $p < 0.05$; Lag 1-Lag 3, t (21) = -2.24, $p < 0.05$; Lag 2- Lag 3, t(21) = .232, $p = .819$]. Also an interaction between target load and group was found [F (1, 20) = 6.371, $p < 0.05$]. This interaction occurred because there was a significant difference in performance between the patient group and the controls in the dual target report condition [t (12.6) = -3.24, $p < 0.05$] but there was no significant difference in performance between the two groups in the single target report condition [t (13.1) = -2.351, $p = .70$]. Patients performed worse compared to controls in the dual target report condition [patients T1-T2 report mean = .730, SDE = .209; controls T1-T2 report mean = .919, SDE = .027]. T1 accuracy was above 95% for both the patient group and the control group.

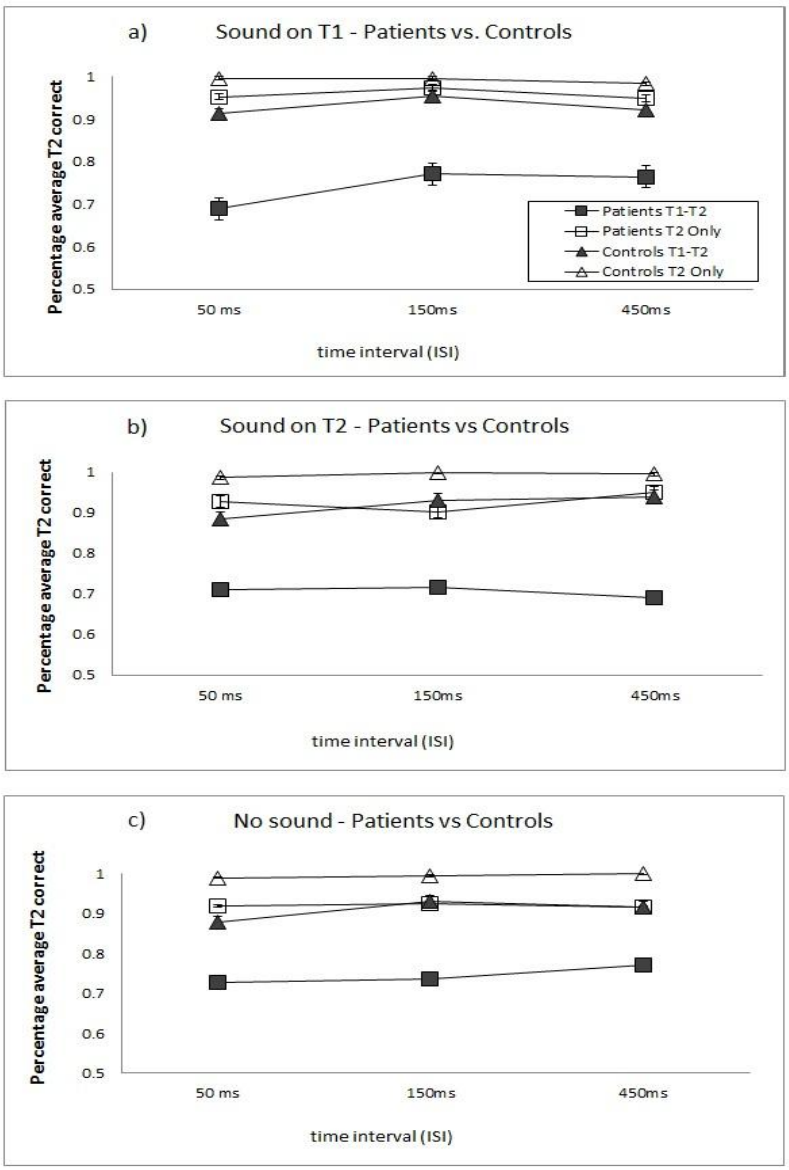


Figure 4.3. Overall performance of the patients group and the control group in the two target report condition (T1-T2) and the single target report condition (T2 only) along the three sound conditions: a) No-sound; b) Sound on T1; c) Sound on T2. As shown in the figures, a significant difference in performance was found between the two groups. Differently from the previous analysis which compared the two groups of patients, here a significant effect of time interval was found at the earliest Lag. No sound effect was found.

Single target accuracy and the effect of sound

In the previous analysis of the overall AB, sound did not influence performance. However, this analysis failed to look directly at whether there was an overall effect of sound influencing the report of each single target considered individually. In scoring the classic AB (Raymond et al. 1992), a trial would be considered as correct if both T1 and T2 are reported correctly; conversely a trial where T1 was reported correctly and T2 incorrectly, was scored as an error (the AB effect). Finally, all those trials where T1 was reported incorrectly and T2 correctly were discarded from the analysis (T2 not contingent on T1).

Here those trials in which T1 was reported incorrectly and T2 correctly were included in the analysis and scored as T2 correct regardless of whether T1 was correct.

Again a first part of the analysis evaluated whether there was a difference in performance between the parietal and frontal patients; subsequently the patient group as a whole was compared with controls. Here patients R.H. and J.F. were included in the parietal group.

Patients: A 2 x 3 x 3 ANOVA was performed on the data obtained from all the patients, with the within-subject factors being: 1) target correct (with two levels: correct report of the T1 target and correct report of the T2 target); 2) sound type (with three levels: no-sound, sound on T1 onset and sound on T2 onset); and 3) time interval (with three levels: 50, 150, 450 ms). The between-subject factor was patient group. No overall difference was observed between parietal and frontal patients [F (1, 13) = .085, p = .775]. Only a main effect of target correct was observed [F (1, 13) = 11.45, p = 0.005,]. There was no significant effect of sound type [F (2, 26) = .092, p = .913] or time interval [F (2, 26) = 1.41, p = .261]. Interactions were found between target

correct and sound [F (2, 26) = 4.19, $p < 0.05$], target correct and group [F (1, 13) = 5.37, $p < 0.05$] and target load, sound and group [F (2, 26) = 3.16, $p = 0.05$]. In order to explain these latter interactions two further analysis were performed: 1) first considering data where no sound was applied and then 2) data where a sound was applied on either T1 onset or T2 onset.

No-sound only: a 2 x3 ANOVA was performed on the data when no sound was applied to the targets (Figure 4.4.), with the within-subject factors being: 1) target correct (correct report of T1 targets and correct report of T2 targets); and 2) time interval (with three levels: 50, 150, 450 ms). The between-subject factor was case. No significant difference was found between the two groups of patients [F (1, 13) = .167, p =.690]. Only a main effect of target was observed [F (1, 13) = 13.50, $p < 0.005$], where worse performance was shown in reporting T2 (see Figure 4.4) [absolute corrects on T1 mean = .729, SDE = .063; absolute correct on T2 mean = .597, SDE = .077]. There were no interactions.

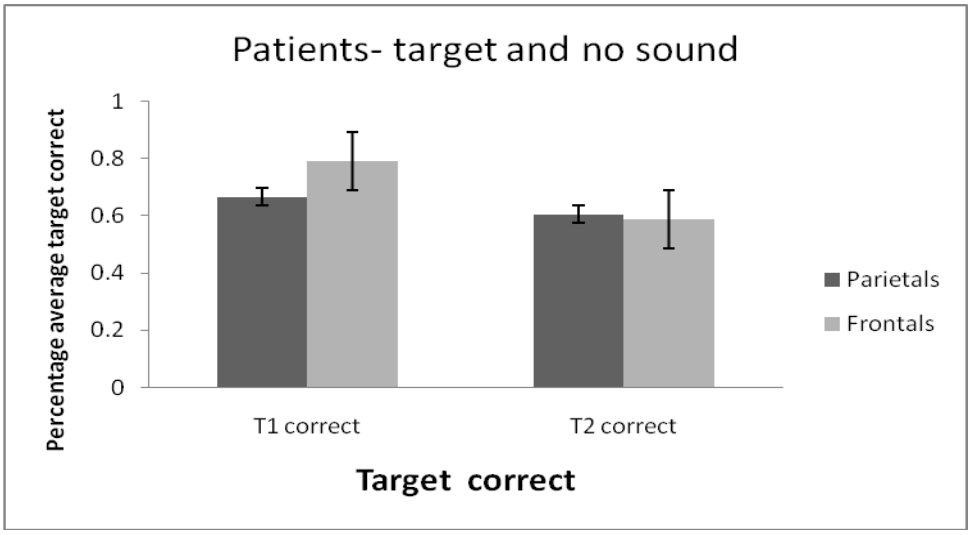


Figure 4.4. Data on the correct report of both T1 and T2 in the no sound condition only are presented for both the parietal and the frontal patients. As shown the report of T2 was significantly worse compared to the report of T1. Note that data for each patient were averaged across time intervals because no difference in performance was found between the different ISIs.

Sound on targets only: a 2 x 2 x 3 was performed on data where a tone was applied on T1 and T2 (Figure 4.5.). The within-subject factors were: 1) sound type (sound on T1 vs. sound on T2); 2) target correct (correct report of T1 targets and correct report of T2 targets); and 3) time interval (with three levels, 50, 150, 450 ms). The between-subject factor was group. No significant difference was found between parietal and frontal patients [F (1, 13) = .054, p = .820]. A main effect of target correct was found [F (1, 13) = 10.01, $p < 0.05$] reflecting the worse performance in reporting T2 [absolute correct on T1 mean = .781, SDE = .067; absolute corrects on T2 mean = .589, SDE = .079]. Interactions between target correct and group [F (1, 13) = 5.76, $p < 0.05$], and target correct and sound type [F (1, 13) = 7.99, $p < 0.05$] were found. The interaction between target correct, sound type and group was not reliable [F (1, 13) = 3.77, p = .074].

The interaction between target correct (T1 vs T2) and group was due to the frontal patients finding it relatively more difficult to report T2 relative to T1, when compared to the parietal patients [Frontal patients T1 target correct report mean = .783, SDE = .098; frontal patients T1 target correct report mean = .557, SDE = .115; Parietal patients T1 target correct report mean = .653, SDE = .092; parietal patients T2 target correct report mean = .622, SDE = .108]. An independent t-test performed on the difference in T1 and T2 correct report showed a reliable contrast between the two groups [t (13) = - 2.401, $p < 0.05$]. The second interaction between target correct and sound type was due to a cross over between the effects of the sounds on T1 and T2 and the report of the T1 and T2 items. However in this case individual t-tests were not significant [T1 correct report with sound on T1 vs T1 correct report with sound on T2, t (14) = -.690, p = .502; T2 correct report with sound on T1 vs T2 correct report

with sound on T2, t (14) = 1.181, p = .257] the interaction were due to the cross-over pattern, with T1 report lower with a sound on T1, and T2 report lower with a sound on T2.

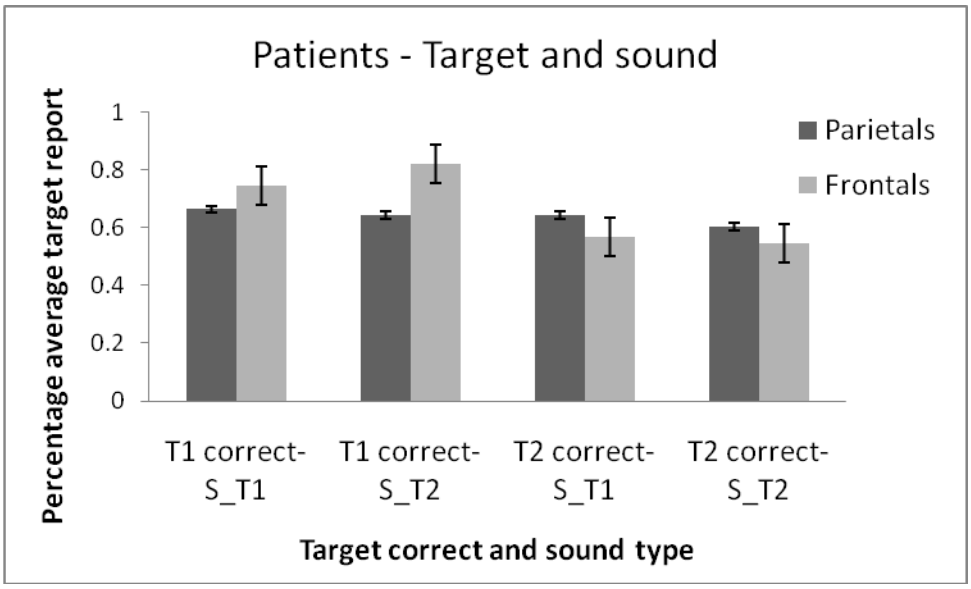


Figure 4.5. The correct report of T1 when the sound was applied on T1 (T1 correct-S_T1), the correct report of T1 when the sound was applied on T2 (T1 correct-S_T2), the correct report of T2 when the sound was applied on T1 (T2 correct-S_T1) and the T2 correct when the sound was applied on T2 (T2 correct-S_T2) for both the parietal and frontal patients. Note that data for each patient was averaged across time intervals because no significant effect on performance was found across different ISIs. The graph shows a cross over between the report of T1 and T2 and the sound applied on T1 and T2.

Patients vs Controls: Because no significant difference was found between the parietal and frontal patients, the two groups were amalgamated for comparisons with controls, using the same 2 x 2 x 3 ANOVA design as above. The between–subject factor here was group. A main effect of target correct report was found [F (1, 22) = 7.534, p = 0.01]. A significant difference was found between the patient group and the control group [F (1, 22) = 10. 73, p < 0.005], where the patient group performed worse compared to controls [patient mean = .655, SDE = 053; control mean = .940, SDE = .069]. No effects of sound type [F (2, 44) = .010, p = .99] or time interval [F (2, 44) =

.315, p = .732] were found. An interaction between target absolute correct and sound type was found [F (2, 44) = 3.55, p < 0.05]. This interaction was decomposed below by assessing performance with no sound and then with sound on either T1 or T2.

No sound only: a 2 x 3 ANOVA with the same design as above was applied on the data from the patient group and the controls (see Figure 4.6. below). A significant overall difference was found between the patients and the controls [F (1, 22) = 10.01, p < 0.005]. There was main effect of target [F (1, 22) = 10.62, p < 0.005], where performance in reporting correctly T2 was worse compared to the report of T1 [T1 correct mean = .840, SDE = .041; T2 correct mean = .754, SDE = .049]. No interactions were found.

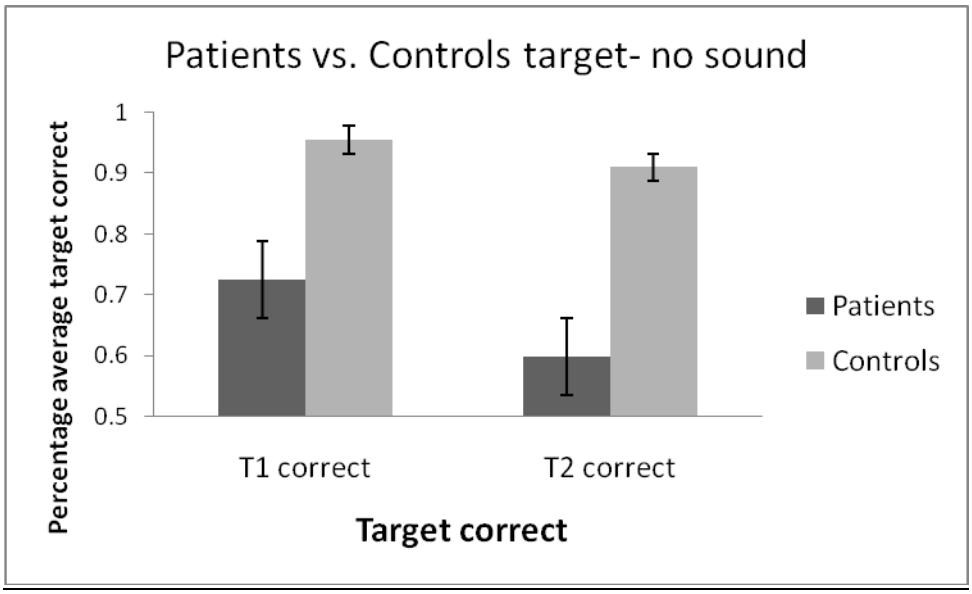


Figure 4.6. The correct report of T1 and T2 in the no sound condition, for patients (as a whole) and controls. Note that the data were averaged for both groups across the time interval because no main effect of the ISIs was found and there were no interactions.

Sound on targets only: a 2 x 2 x 3 ANOVA was applied on the patients and controls data with the same design as above. (Figure 4.7.). A significant difference was found between the controls and the patients [F (1, 22) = 10.79, $p < 0.005$], with the patients performing worse compared to the controls [patient mean = .625, SDE = .054; control mean = .944, SDE = .070]. A main effect of target correct report was found [F (1, 22) = 6.039, $p < 0.05$], where participants performed worse in reporting T2 compared to when they reported T1 [T1 target correct report mean = .836, SED = .044; T2 target correct report mean = .760, SDE = .080]. No effect of sound type [F (1, 22) = .009, p = .924] and time interval [F (2, 44) = .067, p = .935] were found. An interaction between target report and sound type was found [F (1, 22) = 5.78, $p < 0.05$]. This last interaction was due again to a cross over between the report of T1 and T2 and the sound applied on T1 and T2. As before, though, t-tests between the critical conditions were not reliable [T1 target correct report with sound on T1 vs. T1 target correct report with sound on T2, t (23) = -1.033, p = .313; T2 target correct report with sound on T1 vs. T2 target correct report with sound on T2, t (23) = 1.183, p = .249].

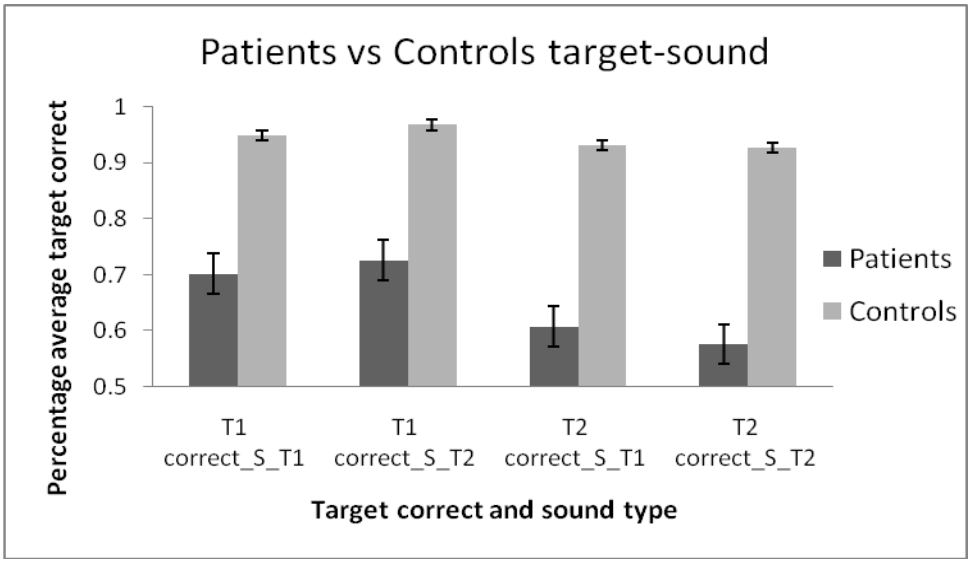


Figure 4.7. Performance of the patient and control groups in the correct report of T1 when the sound was applied on T1 (T1 correct_S_T1), the correct report of T1 when the sound was applied on T2 (T1 correct_S_T2), the correct report of T2 when the sound was applied on T1 (T2 correct_S_T1) and the correct report of T2 when the sound was applied on T2. Note that data were averaged across time interval because no main effect of ISI was found.

Correlation analysis with cognitive measures

Similarly to Chapters 2 and 3 of this thesis, a correlation analysis was finally performed in order to establish whether there was a relationship between a sound effect influencing the AB and other cognitive processes. Cancellation, sustained attention, selective attention and working memory measures were taken from the BUCS. For a full description of the single task scores and the normative data please see Chapter 2. First a measure of the overall AB in the no-sound condition was scored for all the patients[4]. It consisted in the difference between the single target report condition (T2 only) and the two target report condition (T1-T2) for the no-sound condition only, where data were averaged across time intervals. There was one

[4] Note that that patients J.F and R.H. have been excluded from this first analysis consistently with their exclusion in the AB overall analysis (please see the *Participants* section of the Methods).

reliable correlation, between the magnitude of the AB and the measure of selective attention from the BUCS (see Table 4.2).

Table 4.2. *Correlation of the AB magnitude in the no-sound condition only against different cognitive tests for the patients group.*

Patients	AB no sound	Extintion	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	0.1	30	12*	3.5	1	4
P.F.	0.35	11	0*	6	5.5	3
M.H.	0.18	7	2*	0	0	5
J.B.	0.03	7	3*	1	11	4
T.M.	-0.01	22	8*	2	4	3
Frontals						
D.S.	0.28	1	1*	3*	11.5*	4*
P.W.	0	17*	0*	1*	1*	4*
P.H	0.58	30*	0*	2.5*	10.5*	5*
G.A.	0.34	2	0*	7*	6.5*	5*
A.S.	-0.02	7*	3*	1*	1*	4*
F.K.	0.11	8*	0*	0*	0	4*
J.W.	0.18	2	0*	0*	16*	4*
Pearson Correlation		-0.017	-0.095	0.421	0.866	-0.102
Sig. (2-tailed)		0.961	0.757	0.198	0.001	0.766

A second measure of the effect of the auditory stimulation on the AB magnitude consisted in the sum of (a) the drop of performance in reporting T1 in the coincident sound condition, and (b) the drop in performance in reporting T2 in the coincident sound condition. The first measure (a) was obtained by subtracting the data for correct report of T1 when the sound was applied on T2 and the data for correct report of T1 when the sound was applied on T1. The second measure (b) was obtained by the subtraction of data of the absolute correct report of T2 when the sound was on T1 and the correct report of T2 when the sound was applied on T2. The two resulting measures were then summed together to give a general measure of the effect of the sound. As shown in Table 4.3. a significant correlation was found between the sound

effect in the AB and the selective attention measure, $r = .622$, $p = .018$. Similarly to Chapter 2 and 3, a high score in the BUCS selective attention task reflects an impairment, shown by the patients, at only selecting a target rather than the distractors in an auditory selection task, while a high sound effect in the AB score indicates the sum of the drop in performance when a tone was applied singularly on each target.

Table 4.3. *Correlation of the Sound effect in the AB only against different cognitive tests for the patients group.*

Patients	Sound Effect	Extintion	Key Cancellation	Sustained Attention	Selective Attention	Working Memory
Parietals						
M.P.	-0.01011433	30*	12*	3.5*	1*	4*
P.F.	0.094925075	11*	0*	6*	5.5*	3*
M.H.	-0.010974581	7*	2*	0*	0	5*
J.B.	0.077667888	7*	3*	1*	11*	4*
T.M.	0.163493753	22*	8*	2*	4*	3*
J.F.	0.070339145	1	0*	3.5*	2*	5*
R.H.	-0.063369963	16*	0*	2*	1*	4*
Frontals						
D.S.	0.217742885	1	1*	3*	11.5*	4*
P.W.	0.162406482	17*	0*	1*	1*	4*
P.H	0.058412698	30*	0*	2.5*	10.5*	5*
G.A.	0.019224511	2	0*	7*	6.5*	5*
A.S.	0.043478261	7*	3*	1*	1*	4*
F.K.	-0.02965035	8*	0*	0*	0	4*
J.W.	0.202590743	2	0*	0*	16*	4*
Pearson Correlation		-0.218	-0.079	-0.046	0.622	-0.257
Sig. (2-tailed)		0.455	0.795	0.875	0.018	0.375

Discussion

In the present Chapter I asked whether the synchronisation of an auditory stimulus with either the first target (T1) or a second target (T2) affected the report of T2 in an AB task, compared to a no sound condition. Previous studies have shown a beneficial effect from a synchronized auditory beep on the report of visual targets (Vroomer and de Gelder, 2000; Olivers and Van de Burg, 2008). However, there was no evidence for a synchronization effect here. Across the different groups of participants there was an interaction between the report of T1 and T2 and whether the beep appeared with T1 or T2, but this was not an effect of synchronization. Report of T1 tended to improve when the beep appeared on T2 whilst the report of T2 tended to decrease. This result suggests that the effect of the tone tended to be detrimental to reporting the visual stimulus it was coincident with. Indeed, in analysing the data from the patients alone there was a correlation between report of a target when the tone was coincident with it, rather than with the other target, and a measure of selective attention. This suggests that poor selection generally was linked to the detrimental effect of the tone on reporting the coincident target. Several accounts can be offered to explain the detrimental effect of the coincident tone. One possibility is that the tone momentarily distracted or took resources away from the processing of the target. A second is that, perhaps due to the nature of the paired target-mask presentations used here, the tone tended to increase integration of the target and mask pair that it occurred with – especially if the effect of the tone tended to lag its actual occurrence (see below). Such an effect here could explain why the data (even for controls) differ from prior results of the effects of tones on the full AB procedure (Olivers and Van der Burg., 2008). In the full AB procedure, the linkage of each target to a mask will be less apparent and may be a less critical factor in target report. Note also that the earlier results have been

reported with young participants, whilst all the current data were collected on older participants (both patients and controls). Distracting effects of the tones may overwhelm any benefits from auditory-visual integration in older participants. Whether target-mask integration or more general distraction is critical, identification of the visual target will decrease. This detrimental tone effect was larger in individuals with poor target-distractor selection more generally.

On top of the detrimental effects of having a coincident tone, we found that the patients generally showed a larger AB than the controls and, if anything, the AB was larger for patients whose primary lesion was in frontal cortex, compared to patients with a primary parietal lesion. This contradicts the idea that an increased AB is specifically linked to damage to posterior parietal cortex (Shapiro, Hillstrom and Husain, 2001). Moreover, there was no evidence for a correlation between either the AB or the detrimental effect of sound and measures of spatial bias in visual attention (measures of extinction and neglect), but there was a correlation of both measures and an index of how well patients could selectively attend to auditory targets and reject auditory distractors (the selective attention measure from the BUCS). The result with the basic AB effect replicates the data reported in Chapters 2 and 3 here, and it highlights a major constrain on performance which is the ability to select the target and reject ongoing distraction – from the masks (for the basic AB effect) and from a coincident tone. The effect of poor selection here was more pervasive than any effects of spatial bias.

Although a tone coincident with a target appeared to disrupt performance, there was some evidence for report of T1 tending to improve when a tone was presented at the onset of T2. This could reflect increased arousal, which could help consolidate a representation of T1 in memory (given that the benefit came from a following tone, an

effect on memory consolidation seems more plausible than an effect on the encoding of T1). The benefit when the tone followed T1 may be because the effect of the tone on arousal was rather sluggish, with the increase in arousal lagging behind onset of the tone. There was no evidence, however, for this effect to be larger in the patients than the controls, which might be expected if the patients more generally had lower arousal (Manly and Robertson, 1998) – any effect of arousal was additive across the different groups.

In sum, the current results provide confirmatory evidence that the AB is related to poor selective attention in patients, and it is inflated following damage to a fronto-parietal network, rather than being linked more specifically to damage in the posterior parietal cortex. On top of this, auditory tones coincident with visual targets tended to disrupt report of those targets, a problem that was again associated with poor selective attention. The detrimental effect of the coincident tone may reflect the tone consuming resources or it enhancing target-mask integration, so that target report is disrupted.

Chapter 5

EFFECT OF A TASK-IRRELEVANT COGNITIVE LOAD ON TEMPORAL ATTENTION IN NORMAL PARTICIPANTS

Abstract

The effect of a task-irrelevant memory load on stimulus consolidation and feature binding was tested in normal participants using a simplified version of the Attentional Blink (AB) paradigm (the attentional dwell time procedure; Duncan et al., 1994). Target feature similarity and memory load were manipulated as well as the time interval between the two targets (ISIs). Participants were presented first with either one (low memory load) or three (high memory load) digits which they had to hold in memory followed by two targets (T1 and T2) presented within a simplified RSVP stream (with only masks and no distractors). At the end of each trial participants were required to report the colour or shape or the conjunction of the two for either both targets (dual target presentation) or just the second target (T2 only report). Subsequently participants had to report the digits shown at the beginning of each trial. The results showed a drop in performance under high relative to low load conditions, with the effects being strongest in the conjunction report condition. These results are consistent with the memory load disrupting performance when more features had to be bound for target report. In addition, the load disrupted performance when only T2 had to be reported. This last result suggests that participants may have had to suppress the identification of T1 in the simplified blink procedure, and this was particularly difficult under load conditions. The results are discussed in terms of feature consolidation and T1 suppression.

Introduction

In Chapters 2-4 of this thesis I have presented data on the temporal limits of information processing in patients with brain lesions. The limited ability to report multiple stimuli, notable in the patients, is not confined to neurological cases however, as it can be found too in normal participants. Over the past fifteen years the 'Attentional Blink' (AB) paradigm has been extensively used as a tool to measure the temporal properties of attention in normal subjects, as stimuli are processed in rapid succession, (Broadbent and Broadbent, 1987; Raymond et al. 1992; Chun and Potter, 1995).

In Chapter 1, a distinction was made between theories of temporal attention and the AB. On one side, various accounts have proposed that the AB reflects the consumption of processing resources by the processing of the first to-be-identified stimulus (T1) – either due to (i) the interference produced by the competition between T1 and the post-T1 items for retrieval and consolidation into visual short-term memory (VSTM) (Raymond et al.,1992; Shapiro and Raymond, 1994, Shapiro et al., 1994), (ii) the time to resolve the interference produced by target-distractor similarity which slows down the consolidation of T1 in WM (so taking up resources from the processing of T2; Chun and Potter, 1995; Jolicoeur, 1999; Jolicoeur and Dell'Acqua, 2000), (iii) the temporary loss of control over an input filter by WM (Di Lollo et al., 2005; Kawahara et al., 2006) and (iv) the time/resources taken to bind type-token representations for T1 (Bowman and Wyble, 2007). On the other side, the overinvestment account ('boost and bounce' theory, Olivers and Meeter, 2008) suggests that the AB is caused by an attentional filter being set to enhance target

properties for selection and to suppress distractors. The application of an attentional filter leads to a temporary closure of an 'attentional gate', preventing T2 from being processed. All of these accounts stress mechanisms of 'executive control' over visual processing – where executive control refers to a number of different higher functions such as monitoring the incoming visual information, filtering and inhibiting the irrelevant information and processing it in WM for a later consolidation in long term memory (LTM) (e.g. Baddeley and Della Sala, 1996; Miyake and Shah, 1999; Cowan, 2005). It follows that processes that disrupt executive control should impact on the AB. For example, if fewer resources are available for consolidating stimuli in executive working memory, then the AB should increase. Attempts to disrupt executive processes in the context of the AB have been carried out by Akyürek and colleagues (2005, 2006, 2007). On the basis of bottle-neck theories these authors hypothesized that presenting a memory load task prior to T1 presentation would increase the time of consolidation of T1 and consequently the magnitude of the AB. While in their first studies these authors failed to prove a direct effect of a memory load (either if it was target-related or distractor-related) on the magnitude of the AB, their latest study (2007) showed that the magnitude of the AB is dependent on the processing capacity of WM. In a first study (2005) Akyürek introduced a short term memory (STM) task prior to target presentation. Participants were first presented with a set of two, four or six items to be memorized followed by an RSVP stream containing both targets (digits) and distractors (letters). The memory task was designed to be (i) distractor-related, target-related or neutral (Experiment 1); (ii) contain meaningless visual symbols in the (Experiment 2) or (iii) accompanied by a verbal suppression task in which subjects were asked to repeat a word out loud during each trial (Experiment 3). At the end of each trial participants were first presented with a single visual item to assess if it was part of the STM set and subsequently they

were asked to judge whether T1 and T2 were even or odd numbers. Akyürek et al. found that the STM task impaired the report of both T1 and T2 for both alphanumeric and abstract symbols - particularly if the items to be memorized were distractors and target related, compared to the case where they were neutral. Moreover, giving participants a memory load of symbols and introducing a verbal suppression task affected performance in the RSVP without altering the magnitude of the AB. Akyürek et al. claimed that the results support both the hypothesis that there is a limited capacity *within* WM (with interference produced by competition between similar items) as well there being limited resources to transfer information *to* WM for consolidation. However, as the AB itself was not affected, the results do not indicate that the limited WM-based processes are fundamental to the AB effect. In a later study (2007) Akyürek et al. had participants give a speeded response to T1 based upon whether it matched with the WM set; in contrast, T2 report was not time limited. Akyürek et al. found a detrimental effect of memory load on performance which increased at larger memory set sizes. However this effect of load was independent of the AB (the relation between target report and the time interval between the stimuli). These data again suggest that the factors determining the AB may be independent of the processes tapped by the load tasks.

Recently Visser (2010) manipulated memory load using an experimental design very similar to one employed by Akyürek et al. (2007). Like Akyürek et al., Visser failed to find that load modulated the size of the AB – with the exception being when T1 was subject to strong masking (in Experiments 4 and 5). The presence of strong masking of T1 presumably puts additional strain on the consolidation of that item. The effect of the memory load then suggests that this consolidation process is resource limited, so that slowing the process (under load conditions) increases the AB.

In contrast with thesis results, Olivers and Nieuwenhuis (2005, 2006) found a reduced AB when participants performed a memory task, when presented with positive affecting pictures or when they were asked to think about their holiday and when presented with music tunes. Olivers and Nieuwenhuis account for these data in terms of the overinvestment hypothesis (Olivers and Meters, 2008). According to this account, the report of T2 can suffer from an over- investment of attentional resources on T1 which produces temporary closure of an attentional gate to prevent interference from post T1 distractors. However, if attentional resources are temporary engaged in something different (e.g. a memory task), then control over the attentional filter should be less strict; if the gate is not closed than there may be better processing of T2 even at short lags. This was what Olivers and Nieuwenhuis found. Given the somewhat different results and interpretations in the literature, the present chapter set out to assess the effects of a concurrent memory load task on a simplified version of the AB procedure. The simplified version of the classical AB procedure (Duncan et al., 1994) uses two targets (T1 and T2) plus post-target masks, but no distractors. With this simplified procedure, the AB cannot be attributed to distractor interference and, perhaps more directly than the standard AB procedure, effects can be attributed to temporal limits on processing. In addition it is not clear that the over-investment account predicts that there should be an AB with this procedure, since the need to cut-out distractors should be reduced. This simplified version of the AB procedure was carried under two load conditions – with a memory load of 1 or 3 items help while the T1 and T2 stimuli were presented. Under these conditions, any effect of the memory load may be more easily attributed to effects on memory consolidation rather than (e.g.) disrupting the over-investment of attention. On top of this, I manipulated the complexity of target report (in separate blocks participants were required to report sometimes only the colour of both T1 and T2, sometimes only the shape and finally,

in the more cognitively demanding condition; both the colour and the shape - conjunction report). If the more complex report task demands the binding of features in memory, then the AB should be larger for conjunction than feature report, and effects of memory load might arise most strongly for conjunction report (requiring longer memory consolidation). Finally target similarity was also manipulated. Problems in binding might increase when T1 and T2 have the same features, since it has been argued that the process of establishing a token identity for T2 might be more difficult under these conditions (e.g., see Kanwisher, 1987, 1990, 1991; work on repetition blindness).

Method

Participants

Twenty healthy subjects (7 male and 13 females; mean age = .25.6, SDE = 6.21) with normal or corrected-to-normal vision took part. All but one were graduates or postgraduates at the University of Birmingham. All participants were naïve in respect to the experiment and all received a basic color vision assessment consisting in naming the colour of each stimulus presented singularly on the computer screen. If this preliminary test was failed the Ishihara's Test for Colour Deficiency was used to assess colour perception [19]. All participants were right handed.

Stimuli

The stimuli were presented on a gray background (RGB: 190-190-190) on a 17-inch monitor with a 1024 x 768 pixel resolution. Each participant viewed the stimuli from a distance of approximately 65 cm. Similarly to Chapter 2, the stimuli comprised three different geometrical shapes (triangle, circle and square) in either of three different

colours (red, blue and green). Each shape measured (25x25 mm) at its widest points and subtended 2.2° x 2.2° of visual angle. Moreover digits sampled from a range going from 0 to 9 were presented prior the presentation of the colored shapes (memory load). The digits measured 15x15 mm at their widest point.

Design and Procedure

The experiment had a 3 x 2 x 2 x 3 x 3 factorial design where the factors were: 1) target feature report with three levels (report of colour, shape or both shape and color); 2) target load with two levels (dual target report (T1-T2) and single target report (T2 only)); 3) memory load with two levels (low memory load (one digit report) and high memory load (three digit report)); 4) time interval (ISIs) with three levels (50ms, 450ms, 150 ms); and 5) target similarity with three levels (T1 and T2 with different shapes and colours, same colours but different shapes, or same shapes but different colours).

These three levels of target similarity were generated by the random permutation of the different colours and shapes representing each target. The different colour and shape combinations led to three different target similarity conditions, which were as follows:

(1) T1 and T2 differed in both perceptual characteristics: shape and colour (DS_DC).

(2) T1 and T2 were different in shape but had the same colour (DS_SC).

(3) T1 and T2 had the same shape but were different in colour (SS_DC).

Hence there were 72 possible target similarity combinations for each time interval and 36 for each memory load condition, represented in a single trial in a block.

The experiment was programmed using E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002). Participants received a compensation of £7 at the end of the experiment. The experiment started with 10 practice trials followed by two sessions including, respectively, a dual target task condition (T1 and T2) and a single target task condition (T2 alone). The order in which these two sessions were performed was counterbalanced across participants. The experiment lasted about 1 hour 20 minutes and participants were encouraged to have a break in between sessions. Both the dual target report session and the single target report session consisted of three blocks. On each trial, the participant's task was to report different features of T1 and T2 (accordingly to which block they were performing) and subsequently to report either one or three digits which they were instructed to memories before the target presentation. Block order was counterbalanced across all participants; however each participant performed the dual target task and single target task in the same block order. In one block participants were asked to report only the colour of the two targets T1 and T2 (colour report). In the other block they had to report only the shape of T1 and T2 (shape report). Finally in a third block participants were asked to report both colour and shape of the two items (conjunction report). Each time interval was represented by an equal combination of the two memory loads (combination of either 1 or 3 digits to be memorises) which were randomly drawn by E-prime while running the experiment. Moreover T1 and T2 were represented by equal numbers of each permutation of colour and shape for each time interval (see below). No combination of features was repeated within the same time interval within the same trial block. However because the possible permutations of features (number of trials) for each time interval were greater when T1 and T2 were dissimilar

compared to when either the colour was the same but the shape was different or vice-versa, all feature report conditions had the same number of trials at each time interval but not the same number of trials representing the three different target similarity conditions. In each block there were 40 trials in which T1 and T2 were both different in shape and colour [DS_DC]; 16 trials in which T1 and T2 had different shapes but the same colour [DS_SC] ; and 16 trials in which T1 and T2 had the same shape but different colour [SS_DC]. The inter stimulus interval (ISI) between the two targets could be 50 ms, 150 ms or 450. Differently from Experiment 1 in Chapter 2, the condition in which T1 and T2 had the same shape and the same colour (SS_SC) here was excluded from the design as well as the longest ISI (1350ms). For each of the three ISIs there were 24 data points for each report condition (blocks) for both the single target report and the control task. All participants performed 216 trials for the dual-target task (T1-T2) and 216 trials for the single-target task (T2 alone). Before the start of the experiment all participants received automated instructions on the screen.

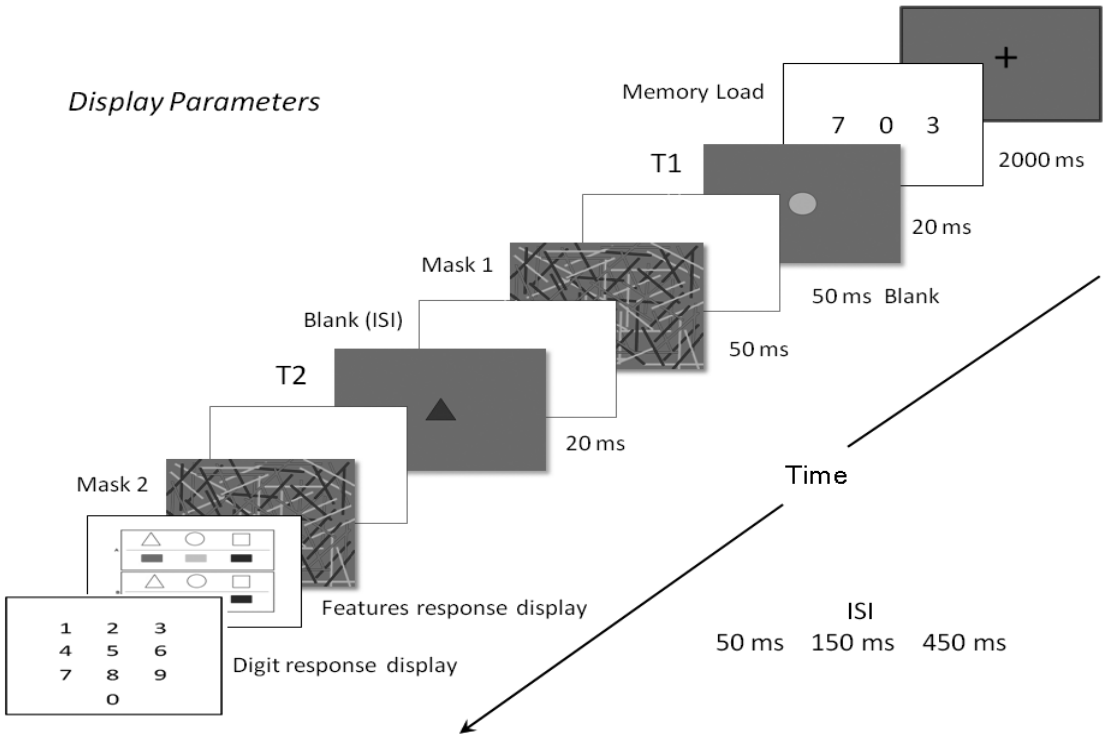


Figure 5.1. Illustration of the sequence of events on a trial. The same display parameters were used for the dual target task when participants had to report both T1 and T2 and for the control task when participants had to ignore T1 and report only T2 (note that the T2 only feature response display was different from the one illustrated here, see Figure 5.2., b). The memory load (here, the example of a high memory load with three digits to be memorised) was presented immediately after fixation.

Each block was initiated by the subject by a mouse click which triggered a further onscreen set of instructions reminding the subject to memorise the digit they were about to be presented with and stating which task to perform (e.g. in the case of the shape report condition: "please report the shape of the first and the second target"). Each block of trials was only initiated when the participant reported being fixated on a central cross presented for 1000 ms. After a mouse click, either one digit appeared centrally on the screen or three digits, one in the centre of the screen and the other two at equal distance from the centre, were presented for 2000 ms. Subjects were asked to memorise the digit(s) and report them later when asked. Immediately after the digit(s)

presentation a sequence of two targets (T1 and T2) was shown at the centre of the screen for 70 ms (with a 5 ms pre-release rate), on a grey background followed by two masks. During the interval between the T1-mask pairing and the T2-mask pairing, a blank screen was presented which lasted alternatively 50, 150 and 450 ms (ISI), with the masks and a blank screen following each target, respectively being presented for 50 ms duration (see Fig.5.1). At the end of each trial participants produced an unspeeded response with a mouse by clicking an onscreen representation of both target features and the digits (see below).

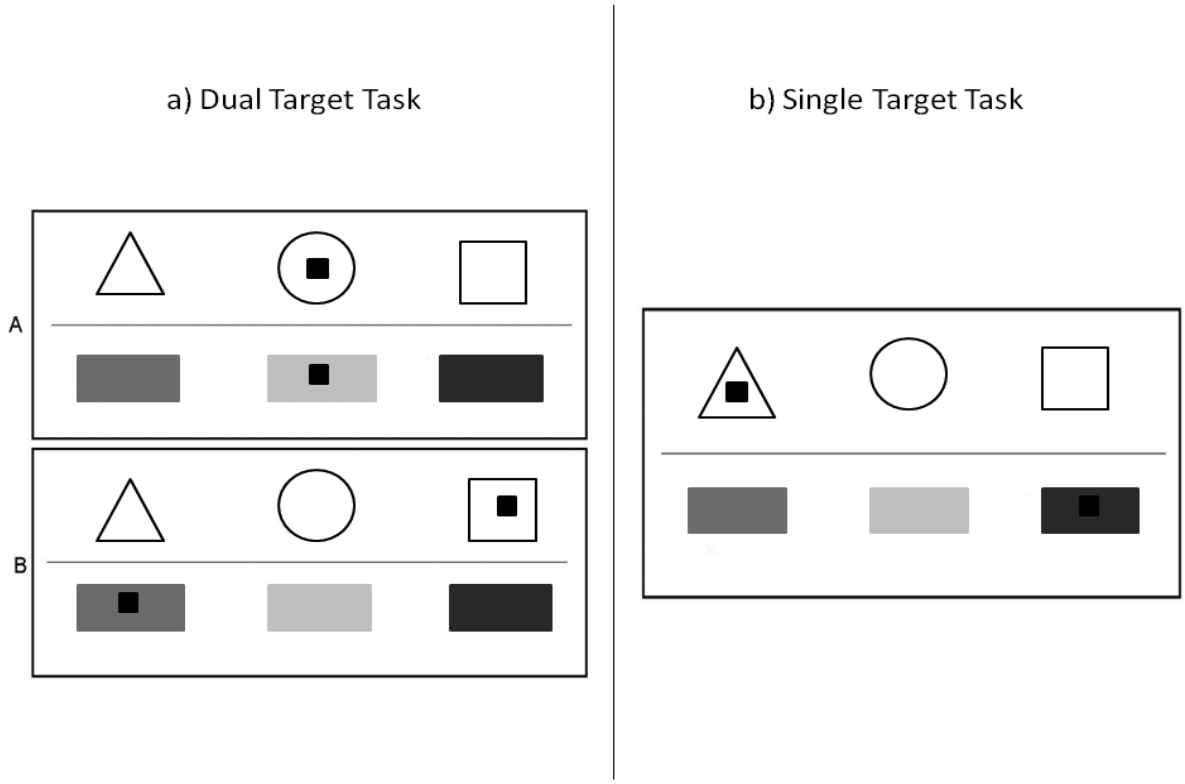


Figure 5.2. Illustration of the two response feature display. On the left hand side (a) the dual target response display is shown where the upper rectangle represented T1 (A), and the lower rectangle represented T2 (B). Here the example shows a case where participants had to report both the colour and shape of T1 and T2 (conjunction condition). Once participants selected their responses the features selected were marked with a black solid square. On the right hand side (b) the single target response display is shown, where participants had to report the colour and the shape of T2 only.

In the case of the dual target report (T1-T2), the display used by participants to report the identity of T1 and T2 was divided into two rectangles each made up of two sections: the upper part of the display was designed to report the target shapes which were represented by three basic shapes silhouettes (a square a triangle and a circle), the lower part was designed to report the target colours which were represented by three solid blocks of colour (red, green and blue), (see Figure 5.2., a). If only the colour (colour report) or the shape (shape report) had to be identified only the solid blocks of colours or the shape silhouettes were presented within the same onscreen display. In the case of the single target task (T2 only) (see Figure 5.2., b), the display used was the same as for the dual target report with the only difference consisting in the presentation of only one rectangle placed at the centre of the screen (see Figure 5.2., b). After each of the to-be reported items was selected by a mouse click a small solid black squared appeared which overlapped the feature selected to show the participants their selection. In order to report the memorised digit(s) participants had to click on a solid black square button placed in the left lower part of the screen, which led to a second visual display with a basic representation of a phone keypad (see Figure 5). Again subjects had to click with the mouse on the numbers they wanted to report. After the digit(s) was clicked participants had to click on a solid black square to pass onto the next trial. The order in which both the digits (in the case of the high memory load condition with 3 digits) as well as the target's colours and the shapes were reported did not compromise the accuracy of the response.

The form of the AB procedure used here mirrors that employed by Duncan et al. (1994) with the addition of a memory load. It represents a reduced RSVP procedure, where effects due to masking between similar items (typically encountered with RSVPs of letters and shapes) are minimized because of the absence of

distractors. The measure of the AB here may provide a relatively pure index of temporal constraints on visual selection without additional masking components.

Results

The analyses were divided into three sections.

1) Similarly to Chapter 2 (Correani & Humphreys, submitted), a first analysis assessed whether participants shown an AB effect and whether it differed across target report condition (colour, shape and conjunction) and memory loads. Data here were summed across stimulus similarity.

2) A second analysis examined whether stimulus similarity between T1 and T2 had an effect on performance. To maximise the data, performance was summed across the different time intervals and only data of the dual target report condition were used.

3) A third analysis assessed the effect of the memory load on performance regardless of whether T1 and T2 were reported correctly. Accuracy in reporting digits only was examined in relation to the target tasks (dual vs. single) and feature report task (colour, shape and conjunction) across the three different time intervals and the two memory loads.

1) The overall AB effect and memory load

The aim of this first analysis was to test for an overall AB effect in normal subjects and a possible beneficial effect of an unrelated memory task performed during the experiment. The data were analysed using a 3 x 2 x 3 x 2 ANOVA with the within-subject factors being: 1) target feature report (colour vs. shape vs. conjunction of colour and shape); 2) target load [dual target task (T1 and T2) vs. single target task (T2 alone)]; 3) time interval (50ms, 150ms, 450ms) and 4) memory load [1 digit (low memory load) vs. 3 digits (high memory load)]. Reliable main effects were found for target feature report [F (2, 38) = 66.39, $p < 0.001$], time interval [F (2, 38) = 46. 41, $p < 0.001$] and memory load [F (1, 19) = 13.19, $p < 0.005$]. No main effect of target load was found [F (1, 19) = .747, $p = .398$]. There were 2-way interactions between target feature report and time interval [F (4, 76) = 14.37, $p < 0.001$], target load and time interval [F (2, 38) = 14.92, $p < 0.001$], target feature report and memory load [F (2, 38) = 4.69, $p < 0.05$]. There were also 2 3-way interactions between (a) target feature report, target load and time interval [F (4, 76) = 4.08, $p = .005$and (b) target load, time interval and memory load [F (2, 38) = 3.75, $p < 0.05$]. T1 accuracy was above 95% for all participants.

In order to understand the two-way interaction between target feature report and memory load (which was not qualified by further higher-order interactions), data from the conjunction report only were considered, averaged across time interval and target load. Performance was significantly worse when participants had to hold in memory three digits (high memory load) and report both the colour and shape of both targets, compared to when they had to hold in memory only one digit (low memory load), [t (1, 19) = 3.46, $p < 0.005$]. In contrast to this, there was no effect of memory load for the feature conditions [t<1.0].

The 3-way interaction between target feature report, target load and time arose because the drop in the conjunction relative to the feature conditions arose most strongly at the short ISI and for condition T2 only, relative to condition T1-T2. To test for this, the data were averaged across the two memory loads at the shortest ISI (50 ms) for each target report condition (T1-T2; T2 only). In addition data from the two feature conditions were averaged together and taken from the results for the conjunction condition. The resulting measure (the cost of conjunction coding) was then contrasted across the two target report conditions (T1-T2 vs. T2 only), to test for possible differences in performance as the demands on target report varied. No significant difference was found between the report of T1 and T2 and T2 only [t (19) = -1.206, p = .243]. There was a trend for the drop in the conjunction relative to the feature conditions to increase for condition T2 relative to T1-T2, at the short ISI, but this was not reliable.

The 3-way interaction between target load, time interval and memory load was assessed by averaging the data across the target feature report conditions and calculating the difference between measures of the low memory load condition and the high memory load conditions at the short ISI. The cost of increasing the memory load was greater in the T2 only condition relative to the T1-T2 condition at the shortest time interval [t (19) = 2. 77, $p < 0.05$].

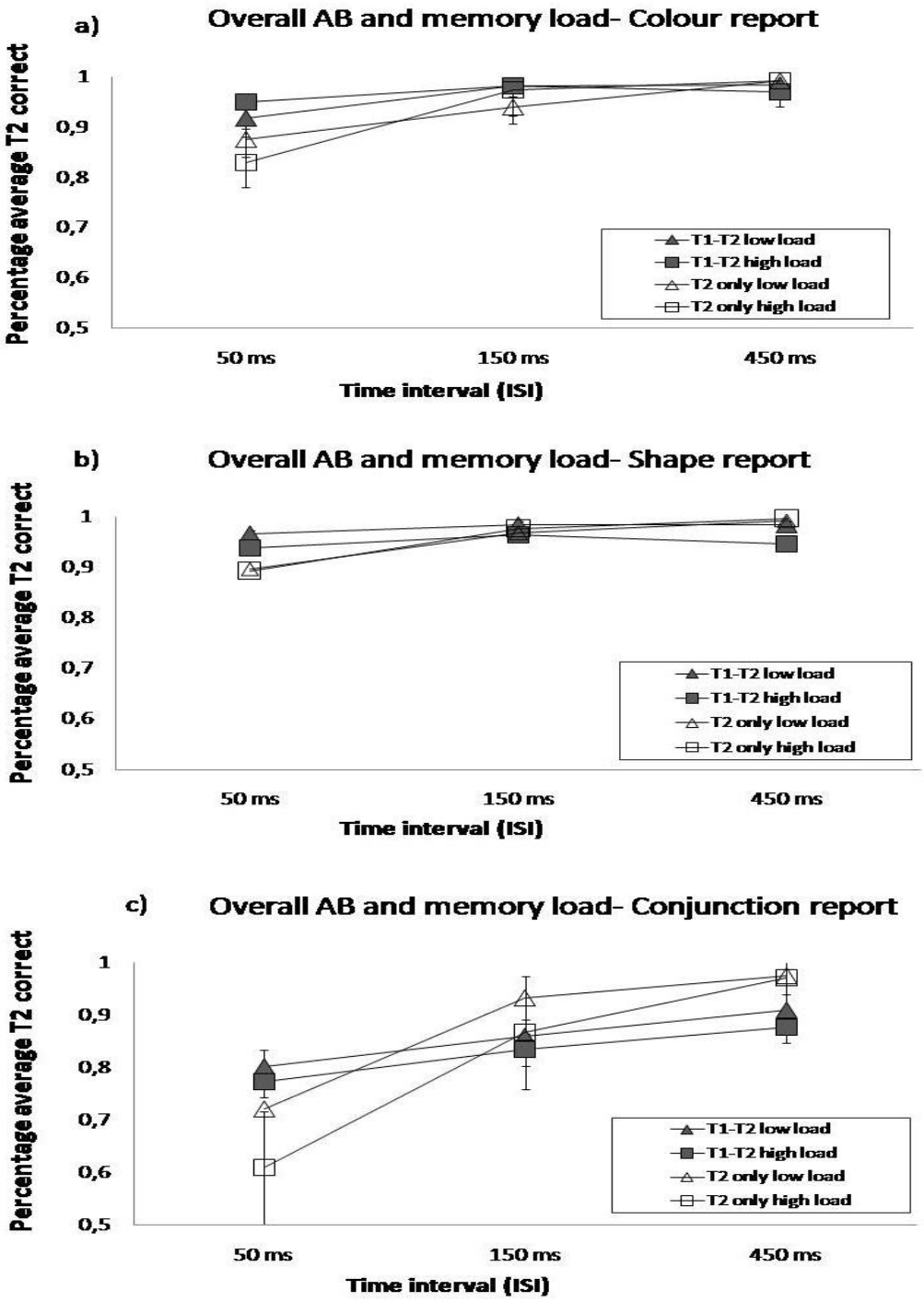


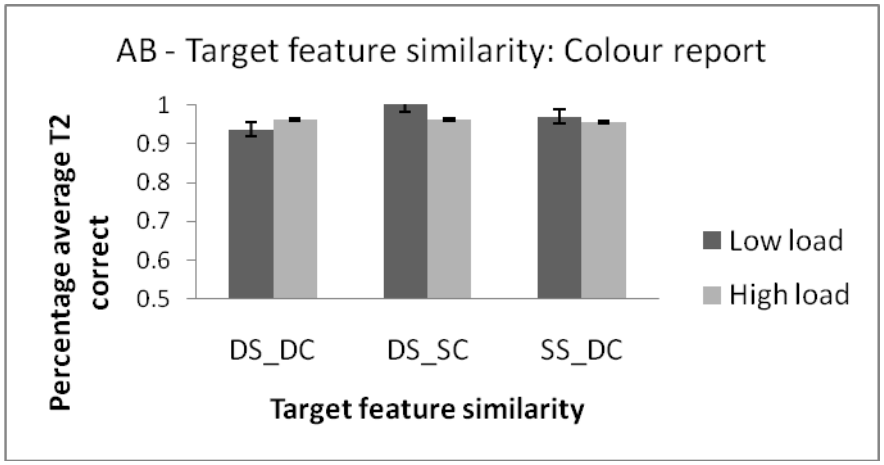
Figure 5.3. The accuracy of T2 identification as a function of the memory and target load conditions at each ISI in each of the three target feature report conditions: a) participants had to report the colour of both targets; b) participants had to report the shape of both targets; c) participants had to report both the colour and the shape (conjunction) of T1 and T2.

2) Target Similarity Effect and Memory Load

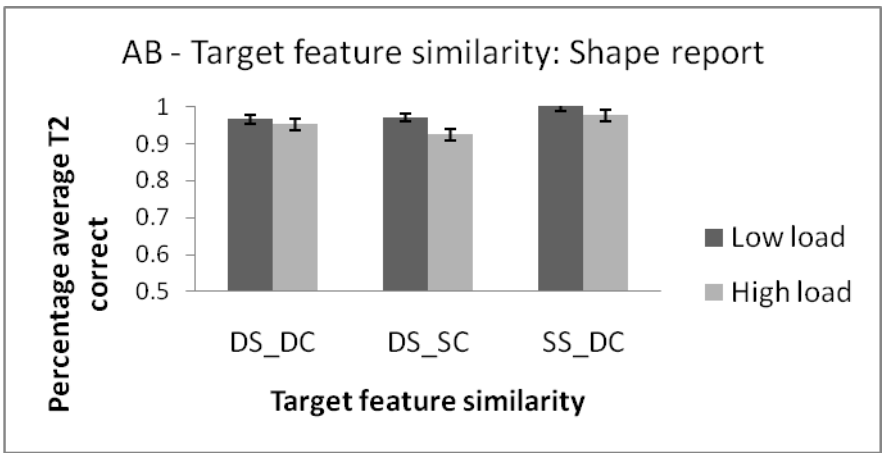
The aim of this analysis was to test for possible effects of feature similarity between targets under the different memory load conditions. Data were analyzed only for the dual target report only (T1-T2) where T2 was contingent on T1.

The data were averaged across time interval. A 3 x 3 x 2 ANOVA was performed with the within-subjects factors being: 1) target feature report (colour, shape and conjunction), 2) target feature similarity (T1 and T2 having different colour and shape - DS_DC; T1 and T2 having same colour but different shape – SC_DS; T1 and T2 having different colour but same shape – DC_SS), and 3) memory load (high load vs. low load). Reliable main effects were found for target feature report [F (2, 38) = 59.46, $p < 0.001$], target feature similarity [F (2, 38) = 11.30, $p < 0.001$] and memory load [F (1, 19) = 10.59, $p < 0.005$]. There were 2-way interactions between target feature report and target feature similarity [F (4, 76) = 7.82, $p < 0.001$], and target feature report and memory load [F (2, 38) = 3.80, $p < 0.05$], and these were subsumed in a 3-way interaction between target feature report, target feature similarity and memory load [F (4, 76) = 5.084, $p = 0.001$].

a)



b)



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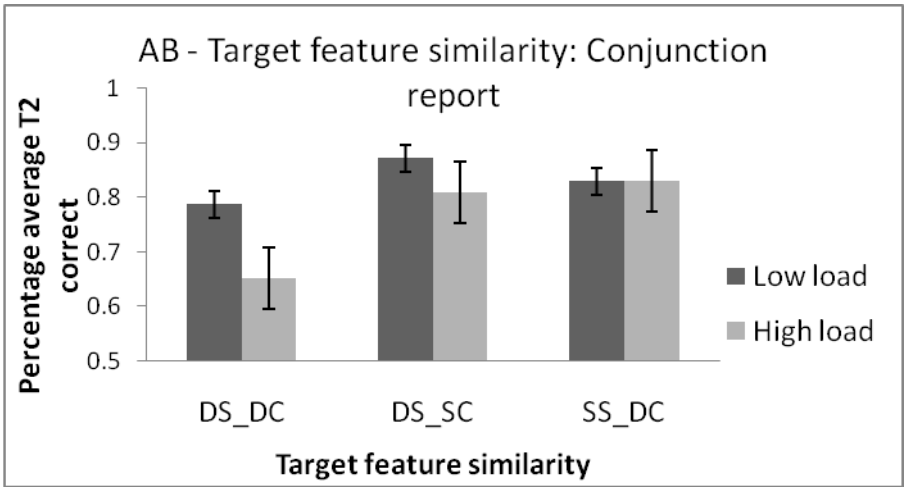


Figure 5.4. Participants performance in the dual target task condition only (T1-T2) averaged across time interval (ISI) showing the effect of the three target feature similarity conditions (DS_DC: T1 and T2 had different shape and different colour; DS_SC: T1 and T2 had different shape but the same colour; SS_DC: T1 and T2 had the same shape but different colour) across the three target feature report conditions: a) colour report; b) shape report; c) conjunction of colour and shape report.

The 3-way interaction occurred because the effects of high memory load and conjunction report were most pronounced when targets had different colours and shapes. Taking the feature conditions together, there were no effects of for memory load [F (1, 19) = 2.96, p = .101] or target feature similarity [F (2, 38) = 3.11, p = .056]. Moreover there was no interaction between target feature similarity and memory load [F (2, 38) = 2.758, p = .076]. In contrast to the results for the feature conditions, conjunction report was affected by memory load and target feature similarity (Figure 5.4.c). In the low load condition, there was no effect of target feature similarity (F<1.0). In the high load condition there was an effect of target feature similarity [F (2, 38) = 13.17, p < 0.001]. Report was worse when the targets had dissimilar features (condition DS_DC) relative to when the colour was the same (DS_SC, t (19) =-3.66, p < 0.005) and relative to when the shape was the same (SS_DC, t (19) = -5.93, p < 0.001).

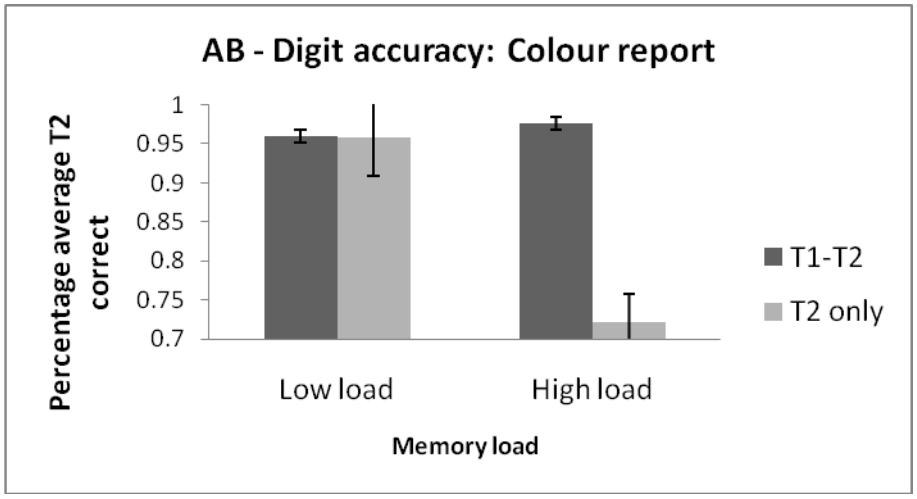
3) Digit Accuracy and Memory Load

Accuracy on reporting digits was analysed to test for a specific effect of memory load. A 3 x 2 x 3 x 2 ANOVA was performed on the data with the within-subject factors being: feature target report (colour, shape and conjunction); target load [dual target task (T1-T2); single target task (T2 only)], time interval (50 ms, 150ms, 450ms) and memory load (high load and low load). Only a reliable main effect of feature report was found [F (2, 38) = 11.08, p < 0.001]. Interactions were present though, between feature target report and target load [F (2, 38) = 14.50, p < 0.001], feature target report and memory load [F (2, 38) = 6.54, p < 0.005], and feature target report, target load and memory load [F (2, 38) = 6.06, p = 0.005]. To explain the latter interaction a separate analysis was run first for the conjunction report condition alone. There was

only a reliable main effect of target load [F (1, 18) = 5.97, p < 0.05]. No interactions were found.

A 2 x 2 x 3 ANOVA was performed for just the low memory load (1 digit) condition with the within-subjects factors being: feature report (colour vs. shape); target load (dual target task vs. single target task) and time interval (50 ms, 150 ms, and 450 ms). No reliable main effects were found for target feature report [F (1, 19) = .029, p = .868], target load [F (1, 19) = 2.19, p = .155] or time interval [F (2, 38) = .713, p = .496]. Another ANOVA for the high memory load (3 digits) with the same design as above revealed reliable main effects of target feature report [F (1, 19) = 13. 96, p = 0.001] and target load [F (1, 19) = 12. 028, p < 0.005], which interacted [F (1, 19) = 14. 84, p = 0.001]. There was a drop in digit report when colours had to be reported under high load conditions, particularly in the T2 only condition

a)



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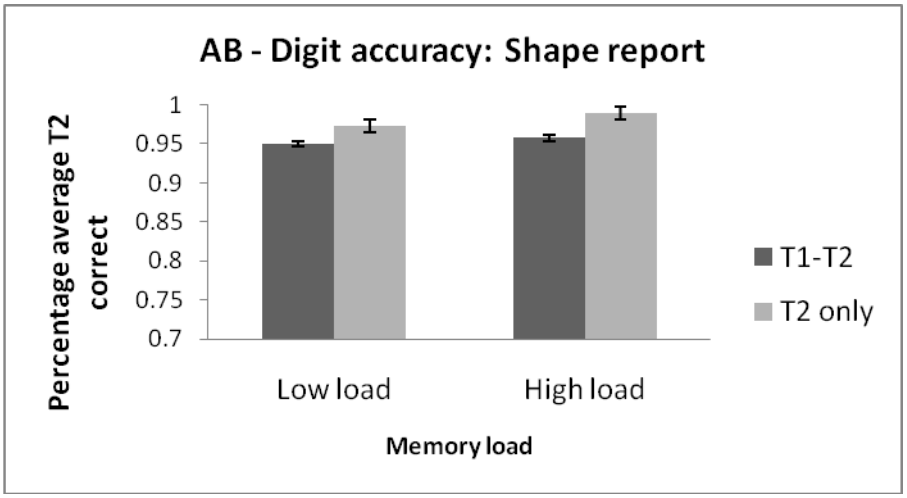

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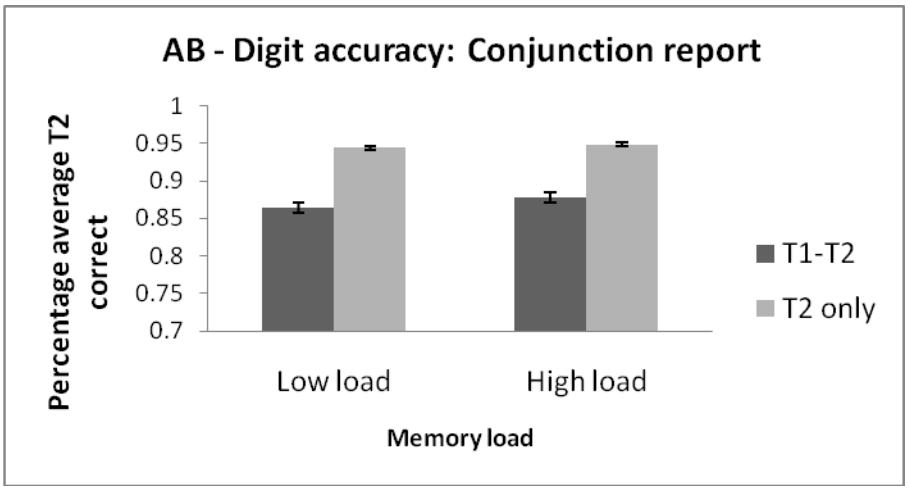

Figure 5.5. Participants accuracy for the digit report in the dual target task (T1-T2) and the single target task (T2 only) for the two memory load conditions (high load and low load) in the three target feature reports: a) colour report; b) shape report; conjunction of colour and shape report.

Discussion

In the present experiment reliable effects of lag on performance were found. Performance was worse at a short lag (50 ms) but this result occurred both when T2 was reported alone as well as when it was reported following T1. The effects in the T2 only condition are considered in more detail below. There were also effects of what type of feature participants were required to report for both T1 and T2, and load – report was worse in the conjunction condition and when the memory load was higher. The effect of conjunction report increased in the higher load condition. This is consistent with interpretations of the AB which attribute its effect to the time and cognitive resources taken to bind type/token representation of T1 (Bowman and Wyble, 2007) - following the general assumption that feature conjunctions requiring more time to be bound in memory than single features (e.g. Treisman and Gelade, 1980). Here it can be assumed that the increased time to consolidate feature conjunctions is exacerbated under load conditions, reducing task performance.

As well as increasing the difference between the feature and conjunction report conditions, the memory load also had a strong effect on the report of T2 when T1 had to be ignored (single target report). Given that the T2 only condition is normally easier than the T1-T2 report condition, this result is intriguing. One account of it is that, under the minimal AB conditions employed here, participants must suppress the tendency to automatically identify T1 as well as T2[5]. The difficulty in effecting this task set may increase under the high memory load, due to combined demands of load and top-down suppression on executive processes. The net result would be that participants often miss T2. According to this argument, the minimal blink procedure is

[5] This tendency would be reduced under the more standard RSVP conditions using to elicit the AB, given that multiple target-like stimuli are then presented.

not simply a ‘slimmed down’ version of the standard RSVP task, but it actually introduces an additional process (T1 suppression) in the ‘control’ condition (report T2 only).

Although performance was influenced by the number of features to be identified, the effects of feature similarity did not fit with accounts that have previously been made about the binding process. Kanwisher (1987, 1991), for example, has argued that one of the constraints on target report under RSVP conditions is the binding of type-token representations – the features of a stimulus and its position in a visual stream (e.g.). When the features of consecutive stimuli are the same, then the demands on type-token binding might increase due to the difficulty in establishing that a new token representation must be formed. Results consistent with this have been reported in the literature on repetition blindness (Kanwisher, 1987; Kanwisher, Driver and Machado, 1995; Chialant and Caramazza, 1997; Chun, 1997). In contrast to repetition blindness effects, however, the data here indicated that performance was worse when the features of T1 and T2 differed. This was particularly the case when the conjunction of features had to be reported and when the memory load increased. These data suggest that binding may be eased by repeating the features of targets, perhaps because the feature representations are already activated. When multiple items occur in an RSVP stream, binding between the specific features of stimuli would need to be complemented by binding the stimulus to the correct temporal slot, to form an independent token representation. This token formation may be more difficult when features repeat, even if the feature binding process itself is eased. If these arguments hold, then feature repetition might be detrimental in the full RSVP procedure but beneficial when the demands on token representation are reduced (in the minimal version of the AB procedure, as here).

One other result to note is that feature similarity also had an impact on the recall of items in working memory. The results showed a drop in performance in recalling the digits when the colour of T1 and T2 were the same. It is possible that this might reflect a form of trade-off in attention between the target stimulus and the memory stimulus. For example, repetition of the features of target might allow targets to be encoded more easily (see above) and selected for report. The loading into memory of items for report may disrupt the memory stimuli, worsening memory performance. This cost was particularly evident when the task was only to report T2. This fits with the idea that this condition introduced extra demands on processing – the cost of discounting T1.

In terms of accounts of the AB, the current data indicate that there are load-related effects even when the influence of distractor interference is largely removed (using the minimal AB procedure). Hence the load effects cannot be attributed solely to attempts to minimise distractor interference – contrary to the arguments of Visser (2010). In addition the data go against the 'overinvestment' account of AB effects (Olivers and Meters, 2008), where we might expect the load to reduce the attentional 'overinvestment' and so improve the report of T2 as well as T1. Rather than these accounts, the results fit with the idea that the AB reflects the time to consolidate features in memory, a process that is exaggerated when conjunctions of features have to be reported and when memory is already loaded (Raymond et al. 1992; Shapiro and Raymond, 1994). However, the results also indicate that extra processes might be needed to prevent the automatic identification of T1 under some conditions (with a minimal presentation procedure). These extra processes may be confined to particular conditions – e.g., when only two targets are presented or (perhaps) when T1 is highly salient (e.g. Folk et al., 2002, 2008) but not present in all AB experiments.

Chapter 6

EFFECTS OF SPATIAL LOCATION ON SPATIOTEMPORAL SELECTION IN A PATIENT WITH UNILATERAL NEGLECT

Abstract

The ability of a patient with unilateral neglect (MP) to select visual stimuli over time was assessed using a simplified version of the Attentional Blink (AB) paradigm (Duncan, Ward and Shapiro, 1994). The location of an initial stimulus was varied prior to report being required to a central item at fixation. Data showed an AB effect which was particularly worse when the first target (T1) was presented contralesionally (left) compared to when it was presented on the ipsilesional side or at fixation. Moreover MP showed a somewhat worse report of T2 also when T1 was presented in the ipsilesional field, particularly at medium time interval between targets. The data go against the two main accounts which explain spatial biases in neglect patients in terms of either (i) an hyperattentional investment towards the ipsilesional field (right) or (ii) a problem in disengaging attention from the ipsilesional side. Finally an effect of colour similarity was found in the report of T2: when T1 and T2 had a different colour performance was worse. This finding is difficult to be attributed to a repetition blindness effect when targets share the same attributes (Baylis et al., 1993) but may be the result of an effect of colour priming between T1 and T2 when the two targets share the same colour attribute (Gilchrist et al., 1996; Humphreys et al., 1998).

Introduction

Unilateral visual neglect is a neurological syndrome typically caused by infarction of the right parietal and temporo-parietal cortical regions (Vallar and Perani, 1986; Vallar 1993) although it has been shown it can occur also after fronto-parietal damage (e.g. Husain and Kennard, 1996) and to regions of the superior parietal and temporal cortex (Chechlacz et al., 2010; Karnath et al., 2001). Patients with visuo spatial neglect are typically unaware of events occurring in the contralesional field and are impaired in reporting object or events occurring in this side of space (i.e., the left side of space in a patient with right hemisphere damage). This syndrome is heterogeneous and patients have been reported with a variety of overlapping symptoms including: neglect of personal vs. extra-personal space (Bisiach et al., 1986), neglect in 'representational space' as well as in perception (Bisiach and Luzzati, 1978, Guariglia et al., 1993), neglect of the contralateral parts of objects rather than space (Chechlacz et al., 2010). Most of the literature on visuospatial neglect proposes that an abnormal deployment of spatial attention is critical to the disorder (e.g. Bisiach and Vallar, 2000). Kinsbourne (1987, 1993) for example argued that neglect reflects an impaired ability to orient attention to the contralesional side of space. The disorder is more prevalent after right than left hemisphere damage because the right hemisphere normally controls attention to both sides of space while the left hemisphere only controls orienting to right space. After damage to the left hemisphere, the bilateral orienting abilities of the right hemisphere can compensate by orienting to the right as well as the left; however, after right hemisphere damage, there remains only an orienting response to the right field, so generating left neglect. A similar view has been put forward by Ladavas and colleagues (e.g. Ladavas et al., 1990; Gainotti et al.,

1991; Smania et al. 1998). These investigators have proposed that neglect is associated with an over-investment of attentional resources on the ipsilesional side (the 'hyperattention' account). For instance Smania et al. tested four groups of patients divided on the basis of whether the patients had a right or left lesion with or without neglect and or extinction. The investigators used a visual detection task in which a 10 ms light was flashed at four different locations away from the centre along a horizontal line either to the right or the left hemifield. Right hemisphere damaged patients showed a strong asymmetry effect consisting of an "eccentricity-dependent" drop of performance in the contralesional visual field compared to the ipsilesional side, which did not show such a dramatic deterioration of performance. The maximum 'hyperattention' was found at a central ipsilesional position, which might reflect the coupling of a hyperattentional bias to the right plus also the drop in visual performance for more peripheral targets.

A somewhat different account, though, was put forward by Posner and colleagues (e.g. Posner, Cohen and Rafal, 1982; Posner, Walker, Friedrich and Rafal, 1984; for a general review see Losier and Klein, 2001). Posner et al. suggested that neglect was caused by a specific problem in disengaging attention from the ipsilesional side of space. These authors found that neglect patients could respond to a positive cue to attend to the contralesional side (see also Riddoch and Humphreys, 1983), but they were impaired at responding to the contralesional side when first cued to attend to the ipsilesional field. These authors proposed that once a visual stimulus is presented on the ipsilesional side of space it stops patients from reorienting their attention on the contralesional side. In a review of the disengagement phenomenon, Losier and Klein (2001) noted evidence for poor ipsilesional disengagement across 16 different peer-

reviewed publications, with the effects being larger at shorter cue-target stimulus onset asynchronies (SOAs) and following peripheral rather than central cues.

Evidence for non-spatial components in visual neglect has also been shown by Husain et al. (1997). These authors used the 'attentional blink' (AB) paradigm to test for temporal dynamics in the deployment of attention over time. They tested a heterogeneous group of patients with different lesions sites. There was a prolonged AB effect in neglect patients when the stimuli were always presented at one central location, so eliminating contributions from spatial biases on target report. The data presented by Husain et al., (see also Hillstrom et al., 2004) highlight temporal rather than spatial contributions to the neglect syndrome[6]. Effects of the temporal dynamics of processing have also been noted in the phenomenon of visual extinction – which also reflects a spatial bias in selection (e.g., see Duncan, Humphreys and Ward, 1997). Di Pellegrino et al. (1997) found that visual extinction occurred not only for targets appearing simultaneously at bilateral spatial locations but also for targets presented in a temporal succession (see also Mavritsaki et al., 2009). Most notably, there could be extinction even when the contralesional item led the ipsilesional stimulus in time, a result that does not fit with the idea of poor disengagement from the ipsilesional side – but which is consistent with an over-anchoring attentional bias to the ipsilesional side. Di Pellegrino and colleagues proposed a competition model to account for their findings. They suggest that although a contralesional target would have a temporal advantage when presented first, the appearance of a second target in the ipsilesional field may still be sufficient to overwhelm processing of the contralesional item, especially if there is a persistent attentional bias to the ipsilesional side.

[6] In Chapters 2 and 3 of this thesis, I have presented evidence against a strict linkage between the spatial and temporal components of neglect as I found that a prolonged AB was more strongly affected by poor non-spatial selection in patients, rather than a specific spatial bias.

The consequences of any spatial bias on temporal processing in neglect were examined by Hillstrom et al. (2004). They tested a neglect patient with lesions to the right inferior parietal, temporal and frontal lobe in a simplified AB procedure. The patient performed two blocks of trials. In one block T1 and T2 were presented at fixation with a variable SOA between the two targets; in a second block T1 was still presented at fixation but the position of T2 was varied unpredictably either on the right or on the left of fixation. Hillstrom et al. found that there was a prolonged AB on the identification of T2 when it was presented in the contralesional space, while there was a 'normal' AB effect when T2 was presented at fixation. No blink was found when T2 was presented ipsilesionally. These data can be accommodated if there is rapid consolidation into visual short-term memory (VSTM) of items appearing on the ipsilesional side, which enables these items to survive the AB. On the other hand, prolonged consolidation of contralesional stimuli will lead to poor perceptual report and a pronounced AB.

This interpretation of the relations between spatial and temporal processing deficits in neglect makes clear predictions for performance under AB conditions when, in contrast to Hillstrom et al. (2004), the spatial location of T1 is varied while the location of T2 is held constant. If there is slow consolidation into VSTM for contralesional items, then, for a target at fixation there should be a pronounced AB following T1 on the contralesional side, due to the extra time spent consolidating this item relative to when T1 appears on the ipsilesional side. Likewise, when T1 appears on the contralesional side, fast consolidation should release the attentional system to identify a target at fixation; a small AB (at best) should result. The opposite predictions are made by a spatial disengagement accounts. This account states that

attention tends to remain on the ipsilesional side, once a stimulus is processed there. It follows that there should be poor report of T2 at fixation when T1 falls on the ipsilesional side (and note that attention would need to be shifted contralesionally to identify the central target following an initial ipsilesional item). These different predictions were tested here.

In this study, I tested a patient with hemispatial visual neglect following damage that affected parietal, frontal and superior temporal regions (Figure 6.1.). A simplified AB paradigm was used, with two letters (T1 and T2) and masks. Opposite to Hillstrom et al. (2004), the location of T1 rather than T2 was varied. Does the location of T1 modulate identification of T2 in such a patient? Is presenting T1 in the ipsi/contralesional field beneficial or disruptive to the identification of T2?

Case Report

MP suffered an aneurysm of the right middle cerebral artery in 1992, resulting in a right middle cerebral artery occlusion and infarct which damaged regions centred on the right frontoparietaltemporal junction (see Figure 6.1.). The affected regions included the inferior frontal gyrus, the superior temporal gyrus, the supramarginal and angular gyri and the post-central gyrus (see Edwards and Humphreys, 1999: Humphreys and Riddoch, 2001). M.P. was sixty three years old when the present study was conducted.

MP showed a mild left hemiparesis for his upper limb. Verbal intelligence, assessed by the National Adult Reading Test (NART), predicted a full scale IQ of 90 (more recently he scored the equivalent of an IQ of 105). MP exhibited a variety of cognitive deficits. He presented with unilateral neglect, extinction, poor spatial

orientation, reduced arithmetic abilities (dyscalculia) and impaired counting, decreased short term memory, and some problems in face processing. Clinical neglect was shown in the standardised Behavioural Inattention Test (BIT; Wilson, Cockburn, and Halligan, 1987) where MP scored 94/146, exhibiting neglect in a variety of tasks. On line bisection, MP scored 28/36, missing items in the final left column; in the star cancellation task, he omitted all of the target stars on the far left and cancelled 9/19 stars; in the next left column, he cancelled all the remaining stimuli. In a separate line bisection task, with lines placed randomly on a page, MP omitted all items on the left and showed an average shift of 3% toward the right in the stimuli bisected. However, his copying skills were relatively good, showing only few omissions.

MP also exhibited problems in face processing (he scored 25/50 in the Warrington test of face memory (he performed better for words rather than faces (45/50), and 7/14 in the immediate recognition of famous faces (control level 13 or more)). MP showed evidence of extinction to the facial identity and gender of the left side of chimeric faces (scoring 0/20 at identifying left-sided face and 10/22 chance, at discriminating its gender). Object recognition was relatively good.

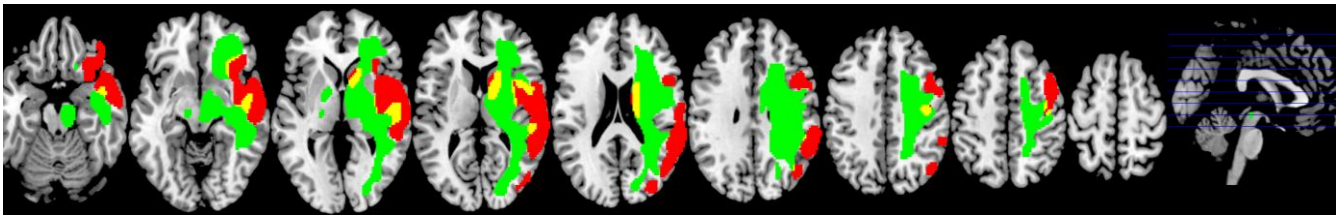

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Figure 6.1. Transcription of a T1 MRI scan (3T recorded at 1mm isotropic). The red areas are locations where there was a change in voxel density for MP relative to 200 control scans. The green regions indicate areas where there was reduced white matter density for MP. . The changes were detected using voxel-based morphological analysis in SPM5(http://www.fil.ion.ucl.ac.uk/spm/software/SPM5), and they are overlaid here on a standard multi-slice template in MRIcron. The images were first segmented into grey matter, white matter, and cerebro-spinal fluid (CSF), and the resulting tissue classes images were normalized without modulation (i.e., to compensate for the effect of spatial normalization). Images were smoothed with a Gaussian kernel of 2 x 2 x 2 mm. The analyses are based on one sample t- tests with 3 covariates: healthy grey/white matter vs patient grey/white matter, age and gender. All areas are FWE corrected with p=0.05 and an extent threshold specifying that only significant blobs containing ≥100 voxels be included in the lesion

Experimental Investigation

General method

Stimuli

The stimuli were similar to those used in Chapter 2 of the present thesis, with the only difference consisting in the position in which the first stimulus (T1) was presented on the screen. The stimuli comprised three geometrical shapes (circle, triangle and square) presented in three different colours (red, green and blue). Each shape measured 35 x 35 mm at its widest point and was presented on a gray background (RBG: 190-190-190) on a 17-inch monitor (1024 x 768 pixels) from a viewing

distance of approximately 65 cm using E-Prime 1.1. software (Schneider, Eschman and Zuccolotto, 2002).

Design and Procedure

The experiment had a 3 x 2 x 3 x 4 factorial design where the factors were: 1) T1 spatial location (with three levels: T1 presented on the left, T1 presented at the centre, T1 presented on the right); 2) target load (with two levels: dual target report, single target report); 3) time interval (ISIs; with three levels: 50 ms, 150 ms, 450 ms); 4) target feature similarity (with four levels: T1 and T2 were different in colour and shape (DS_DC), T1 and T2 had the same shape but different colour (SS_DC), T1 and T2 has the same colour but different shape (DS_SC), T1 and T2 had the same shape and the same colour (SS_SC)).

The key factor manipulated here was the position where T1 fell on the screen: (a) approximately at 4º to the right of fixation (ipsilesional); (b) approximately 4º to the left of fixation (contralesional); or (c) at fixation, subtending 3° x 3° of visual angle (centre). The position of T2 was always at the centre of the screen. Both targets were always followed by a mask and a blank screed appearing respectively for 50 ms (Figure 6.2.).

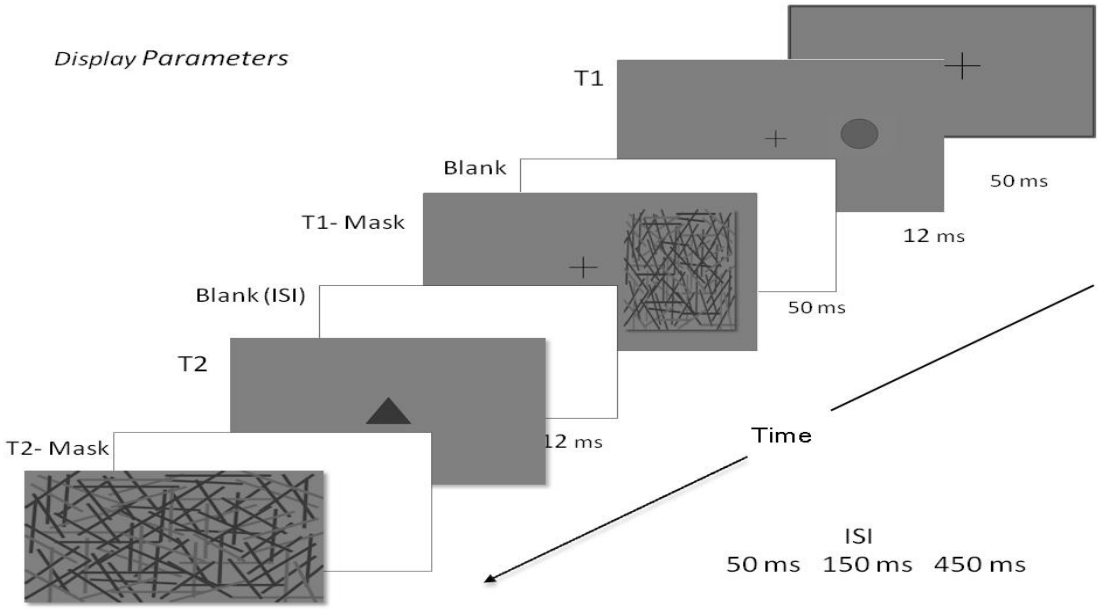


Figure 6.2. Illustration of the sequence of events in a trial. Here the example shows when T1 was presented on the right side of the screen (ipsilesionally) paired with the corresponding mask (note that T1 was also presented at the centre with a central mask or on the left- contralesionally- with a pared left mask). The same display was used for both the dual target task (T1-T2) and the single target task (T2 only).

The locations of the masks were paired to the positions where the target appeared. MP was encouraged to look at fixation at all times and report the colour and the shape (conjunction report) of both T1 and T2 in the dual target condition (T1-T2) and to ignore T1 and report only the colour and the shape of T2 in the single target (or control) condition (T2 only). A trial was only initiated when MP reported being fixated on a central fixation cross (160 mm x 180 mm) presented for 2000 ms. After a key press, a sequence of two targets (T1 and T2) followed by two masks was shown at the centre of the screen (with the exception of when T1-mask paring was lateralised) on a grey background. During the interval between the T1-mask pairing and the T2-mask pairing, a blank screen was presented which lasted alternatively 50, 150, and 450 ms (ISIs) (see Fig.6.1.). For each of the three ISIs and the T1 location condition there were 72 data points. MP performed 648 trials for the dual target task (report of both T1 and T2) and 648 trials for the single target task (report of T2 alone). The

different combinations of colour and shape led to four different target similarity conditions which were respectively: 1) T1 and T2 had different shape and colour (DS_DC); 2) T1 and T2 had the same shape but different colour (SS_DC); 3) T1 and T2 had different shape but the same colour (DS_SC); 4) and T1 and T2 were identical (SS_SC). Because the possible combinations of dissimilar colours and shapes were greater than possible combinations in the other conditions, here the number of trials in which T1 and T2 had the same colour and/or shape were repeated twice (to attempt to equate trial numbers). Similarly to Chapter 2 (Correani & Humphreys, submitted), different permutations of colour and shape were generated to create 72 trials for each ISI at each T1 position. The DS_DC condition had 254 trials, the DS_SC condition had 81 trials, the SS_DC condition had 221 trials, and the SS_SC condition had 89 trials. The order of the different ISIs was counterbalanced across the four different target similarity conditions and the three T1 positions.

Due to the large number of trials the experiment was split into ten different sessions with a time-gap of at least a few days in between them. Before each session MP received 10 practice trials. Target exposure time was set at 12 ms which was established to avoid ceiling performance. The experimenter initiated each trial once MP was ready and focusing on the screen. Each response was recorded manually by the experimenter and no time pressure was given.

Results

Two different analyses were performed on MP's accuracy of target identification:

1) First, MP's performance was compared when he reported only T2 and when he reported T2 after T1 (with performance then contingent on the correct report of T1). Here the data were averaged across the target similarity conditions

2) Second, an analysis was performed on the dual target report (T1-T2) data only, to test for effects of T1-T2 similarity on target report. Data were then averaged across the three different ISIs.

1) Overall AB and T1 position

T1-T2 vs T2 only: A log linear analysis was performed on the data based on Target report (T1-T2 and T2 only) x T1 position (centre, left/contralesional, right/ipsilesional) x ISI (50 ms, 150 ms, 450 ms) x correct response (corrects and errors) design. The best fitting model included three 3-way interactions involving the correct-error factor. These interactions were between (i) target report, T1 position and correct response, χ^2 (2) = 17.83, $p < 0.001$; (ii) target report, ISI and correct response, χ^2 (2) = 37.86, $p < 0.001$, and (iii) T1 position, ISI and correct response, χ^2 (4) = 23.94, $p< 0.001$ (χ^2 = 8.40, $p = 0.08$, for the overall model). For MP T1 accuracy was above 90%.

The target report x ISI x correct response interaction reflects the AB: the difference between T2 report only and T1-T2 report was greater at the short ISI and decreased as the ISI increased (Figure 6.3.).

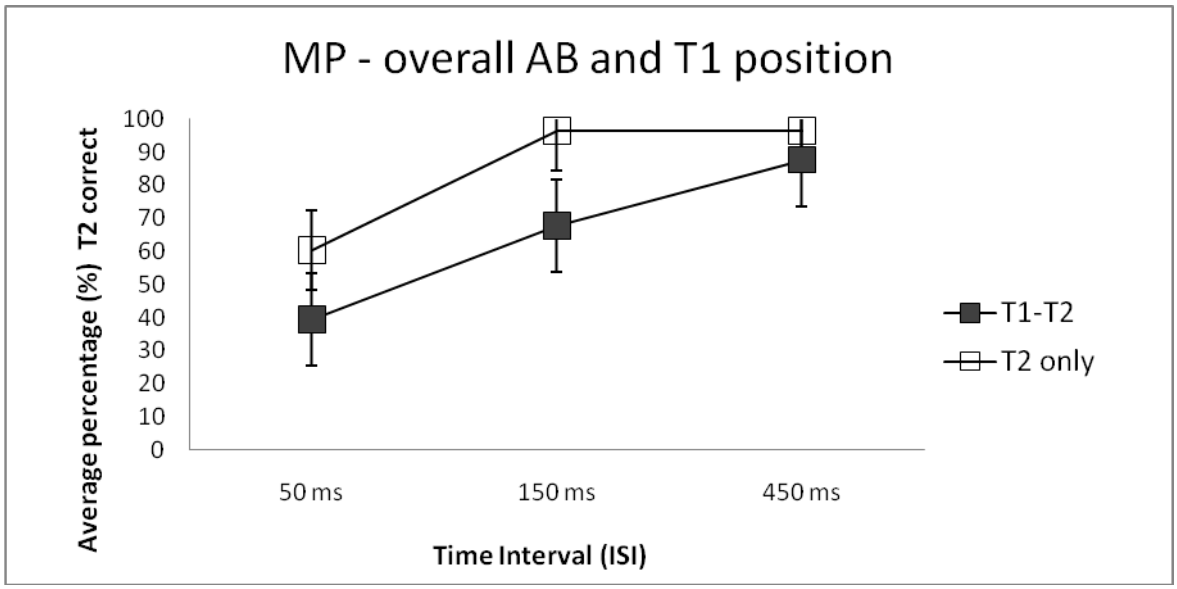
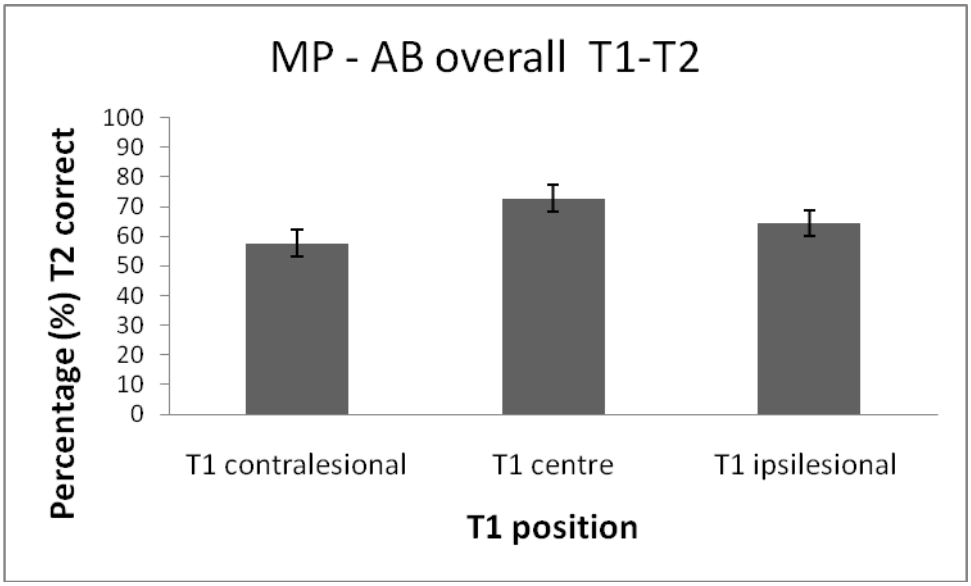


Figure 6.3. MP performance (% correct) in reporting T2 after a correct report of T1 (T2 contingent on T1) across the three time intervals (ISI) in both the dual target report condition (T1-T2) and in the single target condition (T2 only) is shown (overall AB). Data were averaged across the three positions where T1 was presented (for the purpose of the data illustration) and across the four target similarity conditions.

The target report x T1 position x correct response interaction was due to the effect of target position being greater in the T1-T2 condition than in the T2 only condition. For the T1-T2 condition there was a reliable effect of position (χ^2 (2) = 12.50, $p < 0.01$). For the T2 only condition this effect was only borderline (χ^2 (2) = 5.66, p =0.06) (see Figure 6.4.).

a)



b)

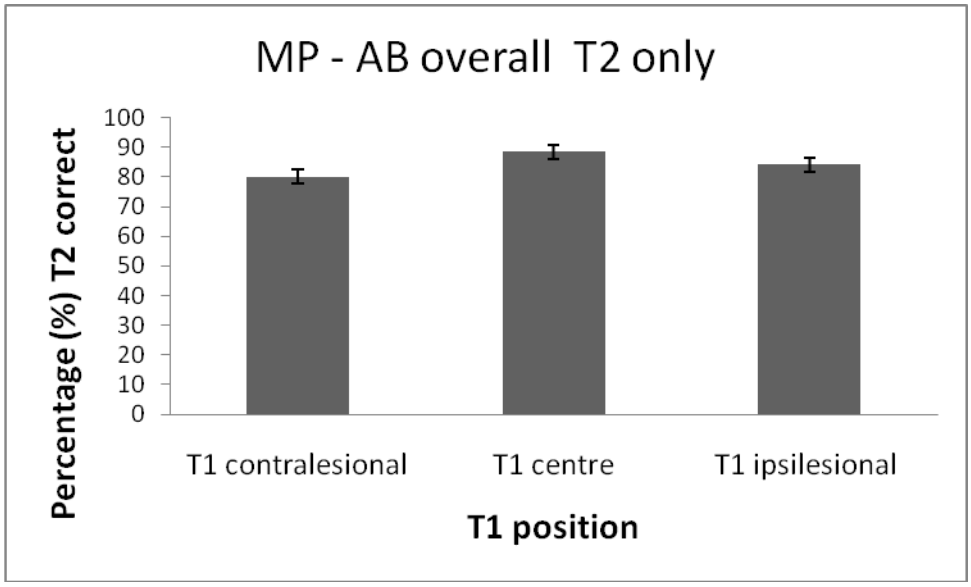


Figure 6.4. MP performance (% correct) in reporting T2 after a correct report of T1 (T2 contingent on T1) in both the (a) dual target report condition (T1-T2) and in the (b) single target condition (T2 only). The position where T1 was presented on the screen was manipulated as follows: (i) T1 at the centre of fixation; (ii) T1 presented contralesionally (left of fixation) and (iii) T1 presented ipsilesionally (right of fixation). Data were averaged across the ISIs (for the purpose of the data illustration) and the four target similarity conditions.

The interaction between T1 position, ISI and correct response arose because the effect of position was greatest at the middle ISI (150ms). With an ISI of 50ms, there was no difference between the different T1 locations (χ^2 (2) =2.91, p =0.23). With an ISI of 150ms the effect of T1 position was reliable (χ^2 (2) = 10.10, $p < 0.01$). Report was better when T1 was at the centre relative to when it was in the left field (χ^2 (1) = 10.20, $p < 0.001$). Report when T1 was in the right field (ipsilesional) fell between the other conditions and did not differ from either (largest difference p=0.103). With an ISI of 450ms, there was again a trend for an effect of T1 position (χ^2 (2) =5.34, p =0.07) (see Figure 6.5.). Taking the data across the two longer ISIs, T2 identification was worst when T1 was in the left field (contralesional) compared with when it was at the centre (χ^2 (1) =11.52, p<0.001) and when it was in the right field (χ^2 (1) =6.79, p<0.01). Performance did not differ when T1 was at the centre and when it was in the right field (χ^2<1.0).

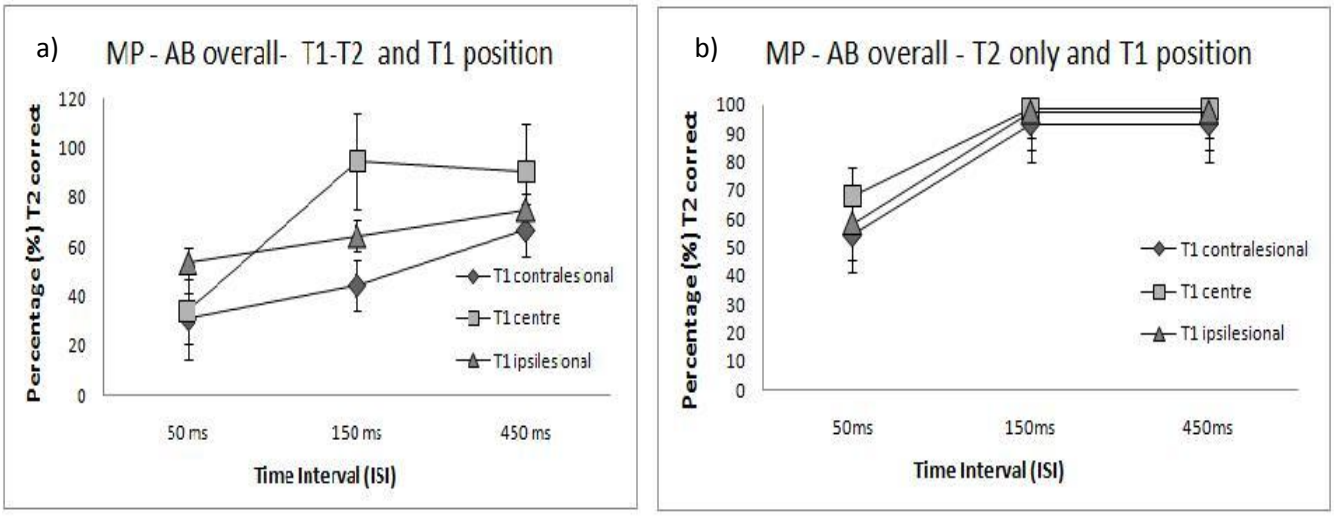


Figure 6.5. MP performance (% correct) in reporting T2 after a correct report of T1 in the a) dual target report (T1-T2) and in the b) single target report (T2 only) across the three time intervals (ISIs) and the three T1 position: T1 presented at the centre; T1 presented on the contralesional side (left); and T1 presented on the ipsilesional side (left).

Target similarity and T1 position (T1-T2 contingent data)

A log linear analysis was performed with the factors Target similarity (conditions DS_DC; SS_DC; DS_SC; SS_SC), T1 position (centre, left/contralesional, right/ipsilesional) and correct response (error and correct). The best fitting model revealed two interactions involving the correct response factor: T1 position and correct response, χ^2 (2) = 105.15, $p < 0.001$; and target similarity and correct response, χ^2 (3) = 10.69, $p < 0.05$ (χ^2<1.0 for the overall model). The effect of T1 position x correct response was due to T2 report being worst when T1 was in the left/contralesional field (see above). The similarity effects were due to report being worse when the colours of T1 and T2 differed relative to when they were the same (Figure 6.6.) [DS_DC vs. DS_SC, χ^2 (1) = 15.69, $p < 0.001$; DS_DC vs. SS_SC, χ^2 (1) = 11.56, $p = 0.001$; SS_DC vs. DS_SC, χ^2 (1) = 12.79, $p < 0.001$; SS_DC vs. SS_SC, χ^2 (1) = 9.03, $p < 0.005$]. No significant difference in performance was found between the two shape conditions where the target colour was the same [DS_SC vs. SS_SC, χ^2 (1) = .378, $p = .539$] and no difference was found between the two shape conditions where the colour was different [DS_DC vs. SS_DC, χ^2 (1) = .216, $p = 0.001$]. The effects of T1-T2 similarity and T1 position did not interact.

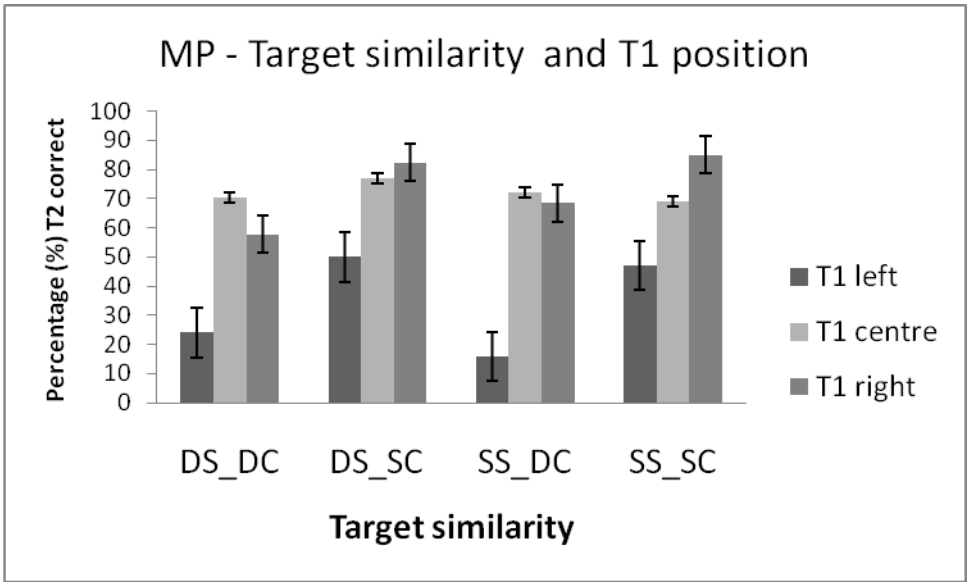


Figure 6.6. Performance of MP in the T1-T2 condition only across the four different target similarity conditions (DS_DC, T1 and T2 had different shape and colour; DS_SC, T1 and T2 had different shape but same colour; SS_DC, T1 and T2 had the same shape and different colour, SS_SC, T1 and T2 were identical) for the three conditions where T1 was presented either at the centre or on the right or left of fixation.

Discussion

In the present experiment MP showed an overall AB effect where the report of a second target (T2) was worse after the report of a first target (T1) compared to when T2 was reported alone (control condition). The report of T2 was also affected by the position at which T1 was presented. Report of T2 was worse when T1 was presented on the contralesional side (left of fixation) compared to when it was appearing at the centre, and compared with when T1 was appearing in the ipsilesional side (right of fixation). The effect of T1 position tended to emerge at the later ISIs (150 ms), particularly when T1 was in the contralesional field, and performance at the shortest ISIs (50 ms) was not affected by T1 location, presumably reflecting a general worse performance across all T1 position presentation. MP data are consistent with the

literature on the AB in neglect patients which suggest that brain lesioned patients show a more prolonged and profound AB (Husain et al., 1997).

Moreover MP increased AB when T1 appeared on the contralesional field (even with performance scored for T2 being contingent on the correct report of T1) can be attributed to slow consolidation of the information in that field (left). MP also showed to some degree a worse report of T2 when T1 was in the ipsilesional (right) field compared with when T1 was in the centre, at least in the intermediate ISI (Figure 6.5.). This result goes against one account of a special bias in neglect patients which stresses the importance of an over-investment of attention (hyperattentional hypothesis) directed towards the ipsilesional side of the visual field, (Ladavas et al., 1990; Gainotti et al., 1991; Smania et al., 1998). If this was the case, the report of T2 should be best after an ipsilesional (right) stimulus, which is thought to be consolidated more quickly than when it falls at the centre. Instead it seems there is some delay in consolidating a peripheral rather than a central item, but this effect is considerably more pronounced when T1 is in the contralesional field (left).

MP results go also against a disengagement account of a spatial bias in neglect patients (Posner, Cohen and Rafal, 1982; Posner, Walker, Friedrich and Rafal, 1987). According to this account neglect patients perform poorly in reporting items presented in the contralesional field because they are unable to disengage attention from the ipsilesional side. Again if this was the case MP should have showed a more pronounce AB when T1 was presented ipsilesionally due to the fact that he was supposedly not capable to disengage attention from T1 presented in the ipsilesional field and then re-engage attention to T2 presented centrally. Again this was not the case. MP's AB was worse if T1 was presented contralesionally.

Finally MP showed an effect of target similarity for the colour. His report of T2 was worse if T1 and T2 had different colours compared to when the two targets had the same shape, which did not produce any significant difference in performance. One possible interpretation of this final result is that there a beneficial effect when the colour of T1 and T2 are the same - this is in accordance with effect of colour grouping on report, observed in patients with extinction (e.g. Gilchrist, Humphreys and Riddoch. al., 1997; Humphreys, 1998). This result is not consistent with studies that show a greater level of extinction in patients who were presented with two stimuli simultaneously which had the same to-be-reported attribute (colour) compared to when stimuli had different attributes (repetition blindness), (Baylis et al., 1993). Further research is required to establish the conditions under which feature similarity is beneficial for patients reporting visual stimuli, and those conditions where it is detrimental. For now, the results indicate beneficial effects of similarity with temporally separated items.

Chapter 7

GENERAL DISCUSSION

Abstract

The major conclusions of this thesis are summarised here with particular focus on the multiple factors influencing temporal coding and selection which have emerged throughout this work. In addition, I review the possible theoretical implications of the work for understanding the Attentional Blink as a paradigm to study visuo-temporal attention in both brain damaged patients and normal individuals

The work presented in this thesis has attempted to shed light onto the mechanisms thought to be responsible for modulating temporal coding and selection in vision. Each chapter of this thesis analysed different factors that may contribute to temporal selection, namely: temporal binding, feature similarity, task switching, visuo-spatial integration and working memory. In addition, by examining the AB in different brain lesioned groups, the thesis throws light on the neural mechanisms underlying temporal coding and selection. All the experiments reported here have used a simplified version of the AB (the attentional dwell time paradigm, Duncan et al., 1994) involving the presentation of only two targets followed by two masks. This procedure minimizes the contribution of factors such as distractor interference. By using this procedure, the present study gives a 'cleaner' insight into the temporal limitations of visual processing than is perhaps the case in other studies using RSVP paradigms.

Review of chapters

In Chapter 2 I investigated the effects of primary frontal and parietal lesions on the AB, where feature similarity between targets was manipulated and the role of feature binding was studied too (conjunction vs. single feature report). The magnitude of the AB was measured in relation to measures of visuo-spatial selection and selective attention across the patients. There was no significant difference between the frontal and parietal groups, but an AB was found for the patients as a whole group compared to an age-matched control group. The patients not only required a longer exposure time compared to controls for the targets to be identified at around the same level but they also showed a more prolonged and deeper AB, measured as the correct report of a second target (T2) following the correct report of a first target (T1), compared to the report of the second target alone (control condition). This effect was particularly

exaggerated when the patients were required to bind target features together compared to when they had to report only one feature at the time for both targets (conjunction report vs. feature report). The specific problem in feature binding showed by the patients was confirmed by an error analysis performed on the data which revealed an increased proportion of illusory feature swaps between the two targets (illusory conjunction errors) and temporal swaps (reporting T2 as T1 and vice versa) which are classically considered a sign of poor temporal binding in normal subjects (Treisman and Schmidt, 1982). Moreover both the parietal and the frontal patients showed a detrimental effect of shape dissimilarity across all the feature targets report conditions. However there was no evidence of repetition blindness (Baylis et al., 1993). Finally no evidence emerged for a correlation between measures of biased spatial attention (neglect and extinction) a measure of the magnitude of the AB. On the other hand the AB did correlate with impaired selective attention, measured as the ability to select targets and not distractors in an independent auditory discrimination task (www.bucs.bham.ac.uk). These results suggest that the AB is not necessarily related to spatial biases characteristic of neglect as suggested in previous literature (Husain et al., 1997) but it does reflect poor selection ability.

In Chapter 3 the effect of task switching on temporal selection was considered and again a group of posterior parietal and frontal patients was tested and compared to an age-matched control group. Within a two-target detection AB procedure a fixed alternative-run paradigm was introduced in the design: performance in two initial blocks of trials where no task switch was required (repeat trials) was compared to two second blocks where a task switch was required (e.g., first report colour then shape, or vice versa). Target similarity was not manipulated. The results showed a detrimental effect of task switching for the patients compared to the control group, with again no

difference between parietal patients and frontal patients. This result matches with findings of a greater AB effect when a task switch is required both in normal subjects (e.g. Chun and Potter, 2001) and in studies using brain damaged patients (e.g. Husain et al., 1997). Moreover the absence of a significant difference between the parietal and frontal group suggests that task switching and task set-reconfiguration may involve a fronto-parietal networks as suggested by previous studies (e.g. Sohn et al., 2000), particularly under temporal constrains. In addition the patient group and to a lesser extent the control group as well found it particularly difficult to perform the task switch in which they were required to report the shape of the first target and the colour of the second target, suggesting that a process of colour selection prioritization may have taken place (e.g. Anderson et al., 2010). Finally a correlation was found between a measure of the switch cost and measure of impaired selective attention in the patients. This suggests that the difficulty shown by the patients in selecting targets and not distractors under normal conditions may tap similar processes to those involved in task switching.

In Chapter 4 I presented a cross-modal manipulation of the AB where patients were presented with a synchronized auditory stimulus coinciding with either the first target (T1) or the second target (T2), as opposed to a condition in which no sound was applied when the visual stimuli occurred. Again no significant difference was found between the parietal and the frontal patients, although they performed significantly worse as a group compared to controls. Moreover the patients found it more difficult to report T2 when it followed T1 compared to when it was reported alone and this effect was greater for the frontal compared to the parietal patients. This at least emphasises that an increased AB is not solely linked to impaired parietal damage. The report of T2 when following T1 was not ameliorated by a synchronised tone presented

with it. This result goes against findings shown in previous studies on normal participants in which an auditory stimulation synchronised with T2 helped the recovery of the blink (e.g. Vroomer and Gelder 2000; Olivers and Van de Burg, 2008). Surprisingly report of T1 tended to ameliorate if the tone was coinciding with the presentation of T2, while the report of targets synchronized with the auditory tone tended to be poor. This last result also tended to occur with the controls as well as the patients. The poor report of a target synchronized with the blink may reflect the capacity required to process both stimuli together, which may be lacking in both older adults (the controls, here) and the patients. The better report of T2 following the cue on T1 may be due to an effect of arousal, - performance on the second target improving when arousal is temporarily increased by the cue. There was also a positive correlation found between the measure of target report when a sound was coincident with its presentation and a measure of selective attention. Both poor selection and the detriment from synchronized cueing may reflect a resource limitation in patients, which makes target-distractor generally more difficult and which stimulus selection is impaired when attentional resources are temporarily committed to processing the tone rather than a synchronized visual target. Another interpretation of the results can be made however, linked to the idea that the auditory cue leads to an integrated representation of tone and visual stimulus (Olivers and Van der Burg, 2008) – which is that the tone synchronizes processing of the mask and target as a single event, making target selection difficult. The present data do not separate these accounts.

Chapter 5 assessed an influence of WM load on temporal coding and temporal selection. This is the only chapter in this thesis which presented data solely from a population of young normal participants. The experiment tested the potential benefit or cost of a cognitive load on normal temporal selection. The experiment follows

previous controversial findings which stressed either a beneficial effect of a memory load on the report of T2 in the AB, (e.g. Olivers and Meeter, 2008) or a detrimental effect (e.g. Visser 2010). Here a memory load was applied on a simplified two-target AB task. Moreover, similarly to Chapter 2, feature binding and target feature similarity were also manipulated, to assess if these factors had greater effects under load conditions. Performance was worse at the shortest lag (50 ms) but this was the case for both the dual target report as well as the single target report task. Moreover participants performed worse when they had to report both the colour and the shape of the targets (conjunction report) compared to when they had to report only features. This held also for the single target report condition (report of T2 only) and was exacerbated under high memory load. The cost of reporting T2 alone here may arise because, under the present two-target AB procedure, T1 selection occurs automatically and requires that a response to T1 must be inhibited. This intakes time and requires the presence of sufficient cognitive resources – something that is disrupted by the working memory load in normal participants (e.g. Nieuwenstein et al., 2009). One interesting point here is that, in all the neuropsychological studies presented in this thesis, there was no evidence for a drop in T2 report compared to the T1-T2 condition (indeed patients showed a larger cost in the T1-T2 condition compared with controls). It is difficult to maintain a general resource limitation account of both the patients' performance and the performance of young controls under load conditions. It may be that the ability to inhibit a response to T1 was relatively preserved in the patients but this specific process was disrupted by the memory load in the young controls. Finally in contrast with the literature on repetition blindness (Kanwisher, 1987, Kanwisher et al., 1995) performance was worse when targets had different rather than the same perceptual identities. Again this was the case particularly when participants had to report the conjunction of target features under a

high memory load. Feature similarity had also an impact on the recall of digits representing the memory load. Colour similarity between T1 and T2 had a detrimental effect on the report of the digit load, which may reflect a trade-off in attention between target attributes and the memory attributes (with greater attention to colour than shape in the AB procedure).

Finally in Chapter 6 a neuropsychological study was conducted in which temporal constraints on visual attention were used to probe the nature of the processing deficit in a patient with unilateral neglect. The patient, MP, was tested using a simplified version of the AB. The location at which T1 was presented on the screen was varied (at a central location, in the ipsilesional or the contralesional field) as well as the perceptual similarity between targets. MP showed worse performance in the dual target report condition compared to the single target report condition. Performance in the dual target report was specifically disrupted by T1 being presented on the contralesional side (left) compared to when T1 was at fixation or presented ipsilesionally (in his right field), particularly at an intermediate time interval between targets (150 ms). Moreover MP showed a somewhat worse performance also when T1 was presented in the ipsilesional field (right) compared to when it was presented centrally (again most pronounced at the intermediate ISI). These last two pieces of evidence go against both a disengagement account of neglect (e.g. Posner et al., 1982) as well against the account of neglect stressing an exaggerated investment of attention in the ipsilesional visual field (e.g. Ladavas et al., 1990). A disengagement account predicts that the AB should be worst with an ipsilesional T1 due to the problem in disengaging attention from this side of space. The 'exaggerated ipsilesional processing account' predicts that performance might be best when T1 is in the ipsilesional field because the resources devoted to that side will lead to the rapid consolidation of T1 in

working memory. The finding that the AB was worst for contralesional stimuli, though, fits better with there being slow consolidation of contralesional stimuli in working memory. The drop for an ipsilesional compared with a central T1 might then reflect the generally increased difficulty in coding a peripheral relative to a central stimulus. Finally MP showed a particularly impaired report of T2 following T1 if the two targets had a different colour, which goes against evidence of a detrimental effect of stimulus feature repetition (e.g. Baylis et al., 1993). Possible theoretical implications will be discussed in the next section.

Overall the results found in the present thesis have suggested some important points which have theoretical and methodological implications for understanding temporal selection, suggesting both the multi-componential nature of the AB and the critical role of selective attention in the temporal selection process.

Multiple components in temporal selection

The thesis has provided evidence for the involvement of multiple components in temporal selection. First of all, in two sections of this thesis (Chapter 2 and 5), evidence was provided for an involvement of temporal binding in the AB. Data from both brain damaged patients (Chapter 1) and normal individuals (Chapter 5) demonstrated that the deficit in reporting a second target following a first one was exaggerated when the task was to report a conjunction of two perceptual characteristics of a stimulus (e.g. colour and shape- conjunction report). This evidence could be attributed to conjunction report generally being worse than single feature report, and hence reflecting a general effect of task difficulty more than binding per se. Against this, attempts were made to equate overall levels of performance in the

patient and control groups (e.g., in Chapter 2), yet the patients were selectively worse than the controls in the conjunction condition. This suggests an effect of binding over and above task difficulty per se.

These data are consistent with accounts of the AB stressing the importance of binding type/token for stimulus consolidation into WM (e.g. Bowman and Wyble, 2007). Other recent evidence pointing to the important of binding in temporal selection comes from Popple and Levi (2007). These authors tested normal participants with a classic AB paradigm where they varied the colour between target and distractors (red and gray) and the ISIs between T1 and T2. They looked at approximate responses to T2 (i.e. comparing correct reports of T2 with responses to T2 +/- 3 frames positional errors in time) as a function of its temporal position (+/- 3 distractor frames) in the RSVP. These authors reported that T2 was often confused with items presented closely in time after it, which was demonstrating a high rate of temporal binding errors under these conditions. The results presented in this thesis with normal participants (Chapter 5) may be partially interpreted accordingly with this view, if temporal limitation affecting the correct type/token binding is even greater due to (i) the multiple feature identity of the targets; and (ii) the extra cognitive load posed by the memory task. Moreover this interpretation can be sustained by the occurrence of a greater proportion of illusory conjunction errors as well as temporal binding errors in the patient data reported in Chapter 2.

In addition to effects of binding, effects of task switching were also apparent. In Chapter 3, a greater AB effect was observed under switch than non-switch conditions, and this effect emerged most strongly for patients relative to controls despite attempts to match their overall performance. Other results found in the thesis indicated that task switch may be an important factor for the correct identification of the second target. In

Chapter 5 for instance the memory task applied to the AB could be interpreted as a disruption in the ability to ignore T1, so that, under load conditions, performance was particularly poor when participants had to ignore T1 and report only T2 (single target report). This may be taken as a sign of a poor ability to maintain the task set required in WM (to ignore T1 as well as report T2), when the memory task also had to be held. This then appeared to generate problems in switching to a second task set (ignore T1) relative to T2 identification.

In several part of the thesis (Chapter 2, 3, 4), the data also highlight the importance of target selection. In particular, the magnitude of the AB in patients was related to the general ability to select between targets and distractors (as shown in the auditory selective attention task of the BUCS test battery). Patients found with poor (non-spatial) selection showed a larger AB, and they were also more impaired by task switching under AB conditions. These data point out the importance of being able to use a correct task-set to select target and reject distractors (or masks in the case of the current paradigm) as a contributory factor to the AB. On the other hand, there was no evidence here for the AB being related to unilateral neglect in patients. Previous studies have reported an association between neglect and poor temporal selection (e.g., Husain et al., 1997). However, these studies did not take into account more general attentional abilities in the patients, and the neglect patients reported there could have had impaired selection as well as neglect, but the contribution of poor selection would have gone undetected. There are other possibilities too, though. One is that there is a contrast between relatively acute and more chronic stages of neglect. The patients tested here were chronic sufferers of neglect. The patients in the original study of Husain et al. (1997), (for instance) were in a more acute stage. It could be that the syndrome of neglect initially does include a disturbance of temporal selection but

this resolves in the patients who recover, so that is a less clear relation between temporal selection and neglect in chronic patients. A further possibility is that the data are due to a contrast between RSVP and minimal blink conditions (as here). Possibly, the relation between the AB and neglect stems specifically from the challenge of rejecting distracters similar to targets and/or avoiding masking from these items. This component of the AB is minimized here. Other evidence in the thesis indicated that poor consolidation in WM was a contributory factor for a decrement in performance in the patients. For instance in Chapter 6, the neglect patient MP showed the largest AB when T1 was presented in his contralesional field. This is consistent with there being slow consolidation of items appearing in the contralesional field. As I have noted, the result is not consistent with the pronounced AB reflecting a deficit in disengagement of attention, or in devoting more resources, to the ipsilesional side. Moreover poor consolidation may be also an important factor responsible for the effects of a decrement of performance in reporting both T1 and T2 when an auditory cue was presented simultaneously as shown in Chapter 4. The auditory cue appeared to reduce attentional resources necessary for stimulus selection and consolidation.

Taken together then the results point to performance in the AB procedure being dependent on several processes: (i) binding the elements together and to time; (ii) task switching; (iii) the ability to select targets and not other irrelevant stimuli (e.g., masks), and (iv) the time to consolidate stimuli in working memory.

Methodological issues

In contrast to previous neuropsychological studies, an attempt was made here to equate performance across the different patient groups and controls by varying the exposure duration of the stimuli (Chapters 2 and 3). Previously, the performance of patients has typically been worse overall than that of controls, and it is then difficult to assess whether effects of a given variable (e.g. the ISI between T1 and T2) are a selective deficit (e.g., in temporal selection) in the patients, or if they are simply due to overall performance being different. Under the conditions used in Chapters 2 and 3 here, the patients had longer stimulus exposure to better equate their overall performance with controls. What is interest in this case is not so much the general level of performance across different patient groups, but rather how the pattern of performance changed when a factor of interest varied across experiments (e.g. lesion type, inter-stimulus intervals-ISIs, the requirement to bind different features, task switching). Under these circumstance, the greater effect of these variables on the patients than on age-matched controls can more readily be attributed to selective deficits in binding and task switching (for example). However it must be pointed out that in the attempt to equate performance some individual differences in performing the task can be masked-out. For example, by using different exposures, it is possible that participants were exposed to different constraints on report, and hence a deficit in some constraints (e.g. dealing with brief visual presentations) is not observed in the patients because it is masked by the longer exposure durations. It is interesting then to note the data on patients in Chapter 4 where target exposure time was maintained to be constant across all participants (including in the condition where no sound was presented along with the visual targets). As previously reported, the patients had a pronounced AB under these conditions (with constant exposures). Also, the AB was

related to variations in selection rather than neglect, consistent with the earlier chapters.

Relations to theories of the AB

Finally consideration needs to be given to the possible link between different accounts of the AB and the results presented in this thesis. As argued throughout the General Discussion, the results in this thesis suggest the involvement of multiple components which may influence the occurring of the AB including: (i) the binding of the perceptual characteristics of targets and distractors (or masks) in their correct temporal location (see Chapters 2 and 5), which corroborates the hypothesis that binding is a crucial element in the AB (Bowman and Wyle, 2007); (ii) maintaining and implementing (or engaging and disengaging) a task-set to correctly select targets among distractors (see also Di Lollo et al., 2005, for a similar prior account with control participants); and (iii) the time to consolidate the information in WM (e.g. Chun and Potter, 1995). I did not find any evidence matching the over investment hypothesis (Olivers and Meeter, 2008). Most notably, a dual task load disrupted the AB in control participants. On an over-investment account the load might lessen the AB by preventing attentional over-investment occurring. Clearly this was not what occurred.

A particular mention must be made in regards to the interference theory of the AB (Raymond et al., 1994). The two-target paradigm used in the present study was chosen so that no distractors would be present and hence there should be no contribution to the AB of interference between T1 and post-T1 items (distracters as well as targets). This means that interference has been stressed less as a possible factor than might be its due – and under the conditions normally used to elicit the AB, item interference between targets and distracters could be vital. It is also possible, as I have noted, that

there could be some interference here from masks rather than distracters – though the evidence of (e.g.,) temporal binding errors across the masks suggests that there are problems post the selection of T1 and T2, and the masks do not interference with selection in the first place.

The neural basis of temporal selection

The present results do not fit with the idea that the posterior parietal damage is the sole responsibility of temporal selection, since few differences were evident between parietal patients and patients with lesions involving frontal cortex. The results are more consistent with a fronto-parietal network (Corbetta and Shulman, 2002) more generally governing selection. It should be noted, however, that the patients' lesions were in some cases very large and in some cases encroached beyond parietal and frontal regions. It is possible that the damage outside the fronto-parietal network could have contributed to performance. The present study did not make use of a 'patient control' group (with lesions outside the fronto-parietal network), where this could have been tested. Nevertheless, the correlation analyses point to there being systematic variation between impairments in selective attention and the AB (e.g., Chapter 2). To the extent that damage to the fronto-parietal network is associated with impaired selective attention, these data support the argument that the fronto-parietal network is crucial. Also previous neuropsychological studies have emphasised the importance of lesions within the fronto-parietal network for generating a pronounced AB (e.g., contrasting effects of inferior and more superior parietal damage; Shapiro et.al. 2002) – again highlighting the critical role of this network. The PPC group used in this thesis did include two patients with relatively more superior lesions than the others (MH and PF, with lesions involving the IPS and the superior parietal lobule) but omitting these patients made little difference to the results (e.g., in Chapter 2 the

differences between the frontal and PPC patients were still not reliable with these patients removed; $F<1.0$). Thus there was no evidence here to differentiate between patients. In at least some prior studies of spatial binding, it has been noted that deficits in selection are more apparent in parietal than frontal patients (Humphreys et al., 2009). I have reported evidence for binding being selectively affected in patients relative to controls here, but also that parietal and frontal patients do not differ. The contrast between the present data and the previous results would occur if the frontal lobes are more involved in temporal binding than spatial binding, while the posterior parietal cortex is involved in both. To test this it would be good to contrast spatial and temporal binding within the same patients. In addition it would be interesting to run experiments similar to those reported here but with using more standard RSVP procedure rather than the 2-item presentations employed. It may be that different parts of the fronto-parietal network are recruited when distracters specifically must be rejected, and in this case a more specific parietal deficit may emerge. However the group of patients used in the present work was not big enough to generate a finer differentiation in correlations of the deficit in temporal selection and the type of lesion presented. Nevertheless it should be noted that the overall contrast between patients with primarily frontal and patients with primarily parietal deficits did not approach significance, so there at present no base for the argument that differentiation does occur in the present results. Clearly, more questions than answers remain. Further research will be needed to explore these issues in the future where a third control patient group could be added with focal lesions to the temporal lobe (for instance) for comparison against the other patient groups.

Attentional Blink or divided attention?

A frequent finding in the present work is that patients never return to asymptotic accuracy in the standard AB analysis; that is, they rarely recovered from the blink even at quite long lags (e.g. 1350 ms). This result could suggest a possible difference in the time course of attentional allocation. It could be argued that the deficit in reporting a second target following a first one could be the result of a divided attention cost or more general dual-task interference (e.g. Pashler, 1994). However, this is not likely to be the case for several reasons. First of all in all chapters with the exception of Chapter 3, the task performed on T1 and T2 were identical, so that the dual task nature of the AB procedure was reduced. Equally, with the exception of Chapter 4 in which no overall effect of time interval between T1 and T2 was found, all the remaining chapters (Chapters 2, 3, 5, and 6) showed an effect of time: performance was generally worse at short lags. If performance was solely due to subject an effect of divided attention, then performance should not have changed across the time intervals.

Another alternative interpretation is that the data stem from the so called Psychological Refractory Period (PRP) where a decrement in performance is observed if the SOA between two sets of stimuli reported concomitantly, is reduced. It might be argued, for example, that the patients have a prolonged central bottleneck period, which leads to the extended slow release of attention after the processing of T1. Against this, though, it should be noted that the AB in the patients was more pronounced under particular conditions (e.g., when reporting conjunction rather than feature stimuli), all of which should have tapped any central resource bottleneck. In addition, previous work on the AB suggests that the time interval effect is not always as an indispensable aspect of the AB deficit (for instance Olivers at al. 2006; Duncan

et al. 1994). Nevertheless in further manipulations of the present paradigm it would be interesting to increase the number of time intervals between the targets in order to charter when the attentional blink effect fully recovers in the patients.

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