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Searching over time: A study of attention using preview search.

by
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Contents

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Abstract

Attention is the mechanism that enables us to process the sensory information most relevant to our current goals. As our most dominant sense, the way in which we attend to the visual environment is a highly important and highly researched topic (Sperling, 1960; Eriksen & Eriksen, 1974; Posner, 1980). One such method of examining visual attention is using a visual search task, where participants must locate a specified target amid distractors and their reaction times and accuracy are recorded (Treisman & Gelade, 1980; Duncan & Humphreys, 1989; Wolfe, Cave & Franzel, 1989) to gain an understanding of how attention can be guided through an array of items. Using a particular variant of the visual search task known as preview search (Watson & Humphreys, 1997), the purpose of this thesis is to extend our understanding of visual attention by examining how and if we can ignore stimuli known to be irrelevant, and if prior knowledge and expectation can guide attention effectively. Chapter 1 examines the effect of a concurrent task on performance, and suggests the timing of a concurrent task as well as the modality impact the efficiency of search. Chapters 2 and 3 examine the role of prior knowledge and expectation on search and show that the usefulness of expectation depends on the type of prior knowledge (e.g. a property or the location of the stimuli). Chapter 4 examines the role of emotion and whether a negative face can be ignored, with the results suggesting preferential selection of faces viewed face-on, rather than in profile. Results of the experiments are discussed in relation to theories of preview search.

Introduction

1.1. Introduction

In every waking moment of every day, our senses are bombarded by an abundance of information. In order to achieve our behavioural goals, to be alerted to potential dangers and to proceed through life without needless distraction, we need a system in place so that we are not overwhelmed by all of this input and can select the information which is most relevant to our current task, be it driving a car, searching for our keys or writing a thesis. This system can be referred to as "selective attention".

Although attention cannot be defined by one simple definition, psychological research has focused largely on two models of selective attention. The first is the filter model, which argues that only a limited amount of task-relevant information can pass along a processing hierarchy, i.e. the basis of the "early/late" debate (Broadbent, 1952, 1953, 1958; Cherry 1953; Deutsch & Deutsch, 1963). The second is the resource model, which views attention as a limited pool of resources to be allocated to stimuli most relevant to our present goals i.e. perceptual load theory (Lavie & Tsal, 1994; Lavie, 1995). As will be examined later in this overview, these two models are not incompatible, but rather are additive in nature with the information being selected for processing and passing through the filter guiding how the limited resources should be deployed (e.g. guided search (Wolfe, Cave, & Franzel, 1989; Wolfe, 2007) and FIT (Treisman & Gelade, 1980)).

1.1.1. Early studies of attention – the filter model and early selection

Early research into attention began by looking at how, or indeed when an attentional filter might occur. This has been a subject of debate since the 1950s, when interest in attention research lost during the behaviourist movement was rekindled and cognitive psychology began. One of the first phenomena to be studied was Cherry's (1953) "cocktail party problem". This described how, at a cocktail party or in a busy room where numerous conversations are taking place at once, we appear to be quite capable of attending to just the one conversation we are having with the person in front of us, to the extent that we

could not say what any of the other conversations are about. In a similar vein, Broadbent (1952, 1953, 1958) carried out a series of studies (see also Cherry, 1953; Poulton 1953, 1956) using dichotic listening tasks, whereby participants were presented with two separate channels of auditory information (one in each ear) composed of two different passages being read aloud by two different speakers. They were asked to attend to only one of the audio channels. The findings showed that, when questioned, participants were able to report on the content of the attended channel, but could recall very little information from the unattended channel. They were, however, capable of reporting on some physical characteristics of the unattended channel, e.g. the pitch of the voice and whether it was male or female, or whether a tone had been played. Broadbent proposed that stimuli were chosen for processing early based on their physical characteristics or which channel the information was presented to and only minimal, low-level information from the unattended stimuli, such as its physical properties or what language it was in, passed into recognition. This theory became known as the "Filter model" or "early selection theory".

Although basic premises of early selection theory (such as selection based on physical properties, and the role of iconic or echoic memory in selecting stimuli to process) have received support over the years (Sperling, 1960; von Wright, 1968; Banks & Barber, 1977), there has also been a wealth of contradictory evidence. Early selection theory purports that items cannot be identified without having been attended to. In plainer terms, whilst we might be aware of a red object somewhere in our visual field or the sound of a male voice in a crowded room, we would need to direct our attention towards these stimuli before knowing that it was a red pencil or that the man was talking about his recent holiday. However, Moray (1959) suggested that some stimuli are so salient that even if we have not been attending to them, we are still able to identify them. For example, if someone was to say your name, you might temporarily attend to their conversation and miss what the person in front of you was saying. In studies where participants were conditioned to receive a small electric shock when presented with certain words, the unpleasant experience of the electric shock increased the saliency of the word to participants, with galvanic skin responses (GSR) being taken to indicate stress levels. When these words were subsequently presented to the unattended ear, participants showed an

increased GSR, despite not being able to recall hearing the words (Moray, 1969; Corteen & Dunn, 1974). This suggests participants were unconsciously attending to and processing the unattended word such that they showed a physical stress response, despite no conscious recollection.

Further studies (Gray & Wedderburn, 1960) suggested that the content of the unattended message in dichotic listening tasks could be processed if the content is meaningful in the context of the attended ear, i.e. interference of the unattended message increases if the message is similar in content to the attended ear. Participants combined the content from the unattended ear with that of the attended ear if it made an otherwise unintelligible sequence understandable, suggesting that, although not actively attended to, some of the content of the unattended message would "break through" into consciousness.

1.1.2. Alternatives to the filter model – attenuation theory and the late selection theory

Given the above contradictory findings, some alternatives to the early selection theory were suggested. Work by Treisman (1960) akin to that of Peters (1954) and Gray and Wedderburn (1960) showed that when the messages in a dichotic listening task switched so that the message presented to the unattended ear was suddenly presented to the attended ear and vice versa, participants tended to temporarily shadow the message of the unattended ear that was the natural continuation of what they had previously been following. On this basis, Treisman expanded on Broadbent's (1958) filter model to suggest that rather than the filter acting as a barrier through which stimuli either entirely pass through or not, the mechanism instead acts as an "attenuator", weakening the signals received from the unattended stimuli as opposed to blocking them altogether. In this way, unattended stimuli would be largely unidentified unless its content (by means of priming) is so relevant to the current task that the signals received are salient enough to pass through the filter into conscious processing.

Attenuation theory has received support from a variety of experiments. Aside from the aforementioned example, Treisman (1964a) found when the unattended and attended messages were identical, then as the onset of the unattended message was manipulated so the time between what was heard in the attended ear and what was heard in the

unattended ear became gradually closer, participants noticed that the unattended message was a repeat of the attended message. This finding is not merely due to low level priming based on the physical sounds of the words being similar, as bilingual participants could recognise it was the same message when the two were presented in different languages (Treisman, 1964b). Neurobiological studies have also shown decreasing activation for unattended stimuli as the attentional demand of the attended stimuli increases (Rees, Russell, Frith & Driver, 1999), and top-down sensitivity to goal-related stimuli (Knudsen, 2007).

Another alternative to early selection was proposed by Deutsch and Deutsch (1963). In their review of the behavioural evidence previously discussed here (Moray, 1959, 1969; Gray & Wedderburn, 1960), they proposed that all stimuli, including unattended stimuli, are perceived and identified and are then grouped or segregated into what is behaviourally relevant and what is not. Selection then occurs based on which stimuli are most relevant to current behavioural goals. Thus, rather than an early filter selecting items to be perceptually processed, all items are perceptually processed and the filter selects items to be committed to short-term memory or responded to. Their theory proposed that the lack of awareness of unattended stimuli need not be due to a lack of perception, but instead due to a lack of consolidation into memory for further processing or response (this view was articulated to a greater degree and supported by Duncan (1980) and Keele and Neill (1978)).

Support for a late selection theory of attention has largely been provided by studies using visual stimuli, chiefly congruency tasks using letters. These tasks require participants to respond to one of a set of predefined target letters amid a display of other, irrelevant letters (known as distractors or flankers). Throughout the literature the manner of presentation varies from a horizontal line of letters (Eriksen & Eriksen, 1974), a circle of letters (Eriksen & Hoffman, 1973), or grids of letters (Mewhort, Campbell, Marchetti & Campbell, 1981). In a number of these studies, the key variable was the identity of the flanker letters and whether they were one of the other predefined targets. Their results showed that when the target letter was among different target letters, response times were increased, suggesting that even though the flanker letters were unattended, they

must have been identified in order for the interference to take place with the processing of the target letter, a result which is incompatible with Broadbent's original model (1958).

Although late selection offers an explanation for some of the evidence contradicting early selection, the ideas from the model overextend the results from the experiments on which they were based. That is, the majority of the evidence in support of late selection comes from studies demonstrating people's inability to ignore certain stimuli (e.g. flanker letters, or words presented to an unattended ear), and that despite not attending to these stimuli, they nonetheless appear to be automatically processed, at least to the extent that they can interfere with processing of the target stimuli (Moray, 1959; Eriksen & Hoffman, 1973). To assume that the unintentional processing of unattended stimuli therefore means there are no limitations on attentional capacity to process stimuli appears too far-reaching a conclusion, particularly given the relative simplicity of the stimuli in the studies. Further evidence in opposition to a strict late selection model can be seen in neurophysiological studies. For example, a number of studies have shown single-cell activity tuned to a particular stimulus is significantly decreased when the stimulus is not being attended to, in comparison to a strong response when the stimuli is being attended to (Moran & Desimone, 1985; Treue & Maunsell, 1996; Chelazzi, Duncan, Miller & Desimone, 1998). Later studies using functional magnetic resonance imaging (fMRI) showed that, providing the attended stimuli or task was sufficiently demanding, the brain did not show any differential response to unattended words, even when the words were foveated (Rees, et al, 1999; Rees, Frith & Lavie, 1997; see the below discussion on load theory).

The early/late debate, then, has been a significant feature of attention research since its inception and remains so in the more recent attention literature. Although the late selection model provided a convenient solution at the time to some of the contradictory evidence to Broadbent's original filter model, the conclusions drawn by the model appear too far reaching for the empirical data on which they are based and, indeed, have later been refuted by neurophysiological studies. In comparison, Broadbent's early model and its later variations (such as Treisman's attenuation model) appear to have held up fairly well to scrutiny over the years, with modern literature still providing support for early, rather than late, selection (Paquet, 2001; Lien, Ruthruff, Kouchi & Lachter, 2010; Koch,

Lawo, Fels, & Vorländer, 2011; Yigit-Elliott, Palmer & Moore, 2011). For a comprehensive review of the topic, see Driver (2001) and Lachter, Forster and Ruthruff (2004).

1.1.3. A resource approach – Load theory

Thus far, this review has considered attention largely from the perspective of a selective mechanism that chooses which inputs to process further. In reviewing the literature gathered during the early/late debate, however, there appears to be a methodological divide between the early selection literature and the late selection literature. Early selection literature employed comparatively difficult tasks, requiring processing of complex audio passages or visual displays, sometimes with continuous response (e.g. shadowing tasks). In comparison, late selection literature tended to use relatively simple tasks, requiring participants to react to predefined targets, often in small or simple displays.

A new theory was therefore proposed by Lavie and colleagues (Lavie & Tsal, 1994; Lavie, 1995), which suggested that selection can occur either early or late depending on the perceptual complexity of the stimuli: in their initial experiments, the authors adjusted perceptual load to examine the effect it had on distractor processing. Perceptual load was manipulated by varying the number of digitally displayed items so that the display contained either just the target and the distractor (low load condition), or the target, the distractor and five other neutral letters (high load condition). The distractor letter was also manipulated so that it was either a compatible target letter (the same letter as the target), or an incompatible target letter (the opposite target letter). Results showed that the presence of an incompatible target distractor letter only interfered in the low load condition. In a second set of experiments, participants carried out a "go/no-go" task, responding if (i) a shape present in the display was blue but not red (low load condition); and (ii) if the shape was a red circle or blue square, but not if it was a blue circle or red square (high load condition). When required to combine features in the high load condition, participants showed signs of less distractor interference. Lavie suggested that under low load conditions, attentional resources were not sufficiently engaged by the task and thus the “leftover” attention automatically processed the irrelevant distractors to the detriment of the primary task. When the task required all attentional resources, however,

none could be spared to process distractor items, therefore the level of interference was reduced.

In this way, perceptual load theory provided an elegant potential solution to the early/late debate by accounting for the seemingly incompatible evidence from the prior literature on attention. In the case of early selection (Broadbent, 1958; Treisman, 1960; Sperling, 1970), the comparatively demanding nature of the task meant the perceptual load was higher and thus resulted in fewer resources being available to process any of the unattended stimuli. In the case of late selection (Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973; Mewhort et al, 1981; Duncan, 1980), the simpler task meant that perceptual load was low, resulting in some attention not being engaged in the relevant task and thus "spilling over" to the unattended stimuli. Research on perceptual load also signified a shift in attention theory from a capacity-limited process to that of an automatically deployed resource to be divided between tasks (this concept will be covered in greater detail in Chapter 1).

Although the importance of load in the ability to allocate attentional resources has since been supported in the literature (Lavie & Cox, 1997; Lavie & Fox, 2000; Do-Joon et al, 2004; Beck & Lavie, 2005), it is possible that there are other factors working alongside load affecting how resources can be deployed. It is possible, for example, that in Lavie and colleagues' studies, the saliency of the distractors may be contributing to the results, as opposed to load per se. Eltiti, Wallace and Fox (2005) tested this by varying the saliency of the incompatible distractor letter by altering whether it appeared by an onset (which has empirically been shown to capture attention; (Yantis & Jonides, 1990; Atchley, Kramer, & Hillstrom, 2000)) or an offset, as well as having high and low load conditions. Their findings suggested that saliency, rather than load, is responsible for distractor interference under low load conditions. Additional studies show that when the target location was validly cued so that participants knew where to focus their attention (Johnson, McGrath, & McNeil, 2002) and when the distractor appeared at a far distance from the target (greater than 2.7 visual degrees), the distractor effects are diminished (Paquet, 2001).

An alternative to load theory has recently been proposed by Tsal and Benoni (2010; Benoni & Tsal, 2010; Benoni & Tsal, 2013), known as dilution theory. Their work came as a reaction to a number of papers on load theory that varied set size as a means of manipulating

perceptual load (e.g. Lavie & Tsal, 1994; Lavie & Fox, 2000; Eltiti et al., 2005). Their argument was that the mere presence of additional neutral letters dilutes the effect of the distractor letter and thus if dilution could be made high whilst perceptual load was kept low, one would expect to see little effect of distractor interference: this is what their findings showed. By keeping load low by distinguishing the target and distractor by colour, but keeping dilution high by having additional, neutral letters in the display, their studies suggest previous literature supporting load theory may have in fact been confounding load with dilution (however, see Lavie & Torralbo, 2010 for a response to dilution theory).

It would appear, therefore, that although perceptual load theory is a well thought out model which can account for both early and late processing in attention, further work is required in this area to adequately define what perceptual load is and eliminate any potential confounds such as dilution, saliency, or expectancy.

1.1.4. Visual search – Feature Integration Theory

Thus far, the visual attention research literature that has been considered has focused largely on simple displays where participants had to respond to one or more target items at a predefined location, with reaction times being used as an indication of distractor interference. Treisman and Gelade (1980) developed a new theory of attention know as Feature Integration Theory (FIT) using a new research paradigm: visual search.

Broadbent's filter theory (1957) suggests that some simple physical features of stimuli (such as pitch for audio stimuli and colour or orientation for visual stimuli) could be coded "pre-attentively" at the same time (or in "parallel"), whilst more complex coding of information requires attention. When presented with an array of letters, therefore, one would know without having to examine all the items individually (or "serially") what colours and letters are present in the array. It then follows that if a target is defined by a physical property, e.g. a red item among green items, one would be able to say whether that item was present or absent in the array and, importantly, the speed at which one could do this would be independent of the number of irrelevant distractors in the array. This is what Treisman and Gelade (1980) found. Varying the number of items in the display between 1, 5, 15 and 30 items had little impact on how quickly participants could report

the presence or absence of the target. The efficiency of search in their studies was demonstrated by showing how search times varied as a linear function of set size by comparing the change in search times to the change in number of items (known as a "search slope"). In the instances mentioned above, search times did not vary significantly across different set sizes, giving rise to a relatively flat search slope of ~0ms/item.

A target which is defined by a combination of features, however, would require attention to be deployed to each item individually, or in series, to integrate the pre-attentively coded physical features. For example, when searching for a red horizontal target among red vertical and green horizontal distractors, it is no longer sufficient to know that a "red" or "horizontal" item is present as these features are shared with the distractor items. Instead, one must attend to each item location to determine whether any of the items contain both "red" and "horizontal" features. Using this logic, Treisman and Gelade (1980) proposed that (i) increasing the number of distractor items would cause a linear increase in the time taken to locate the item; and (ii) the amount of time taken to determine a target is absent would, on average, take twice as long as to determine a target is present. The latter is because each item must be examined and rejected before a target-absent response can be made, whereas a search can be terminated as soon as the target has been found in a target-present display and on average people will search through half of the items before the target is found. Treisman and Gelade's results support these predictions; as set size increased there was a corresponding increase in search times, giving rise to steeper search slopes of ~29ms/item for a target-present display, and ~67ms/item for a target-absent display.

Work by Treisman and colleagues (Treisman, 1986; Treisman & Schmidt, 1982) have since provided support for FIT using experimental paradigms aside from visual search, giving strength to the theory and its premises. However, several exceptions have been reported which do not strictly conform to FIT predictions. For example, studies suggest that if one of the features by which the target is defined is motion, e.g. motion and form, (McLeod, Driver & Crisp, 1988) or motion and colour (Nakayama & Silverman, 1986), search is conducted in parallel. As a result of these and other findings (discussed in the next section) some alternative models of attention in visual search were suggested in opposition to FIT.

It is important to note though that although these theories purport to be in opposition to FIT, many of the theories retain its fundamental premises, such as the parallel coding of physical feature across different feature maps or, where parallel search cannot reliably locate the target, the need to attend serially to items based on top-down knowledge of target properties.

1.1.5. Visual search – alternates to FIT

As previously discussed, certain instances of feature conjunctions allow search to proceed in parallel, a finding that contradicts the theory of FIT. One possible explanation of these results focuses on how distractors can be segregated into perceptual groups based on similarities of features. In the above examples, it is likely that participants are able to attend effectively to the moving items because they form a perceptual group that appears to move as one unit. Within that group, then, the target has a unique feature (in these examples, its shape) and thus a parallel search is sufficient to indicate whether the target is present or not.

The concept of search efficiency being dependent on one's ability to segment items based on perceptual properties was developed further by Duncan and Humphreys (1989; Humphreys, Quinlan & Riddoch, 1989). In a series of search experiments, they showed that even when the target is defined by a unique feature (which should, according to FIT, result in a parallel search), search slopes increase linearly if the target is similar to the distractors. Further, if similarity among distractor items decreases (e.g. a display where distractor items are a mixture of "T"s which are upright or tilted 90o, in comparison to a display where the distractor items are all upright "T"s), search also tends to be more serial. Duncan and Humphreys (1989) proposed that items with similar features were perceptually grouped which is beneficial in the instance of distractor-distractor similarity as these items could then be rejected as a group requiring little or no focal attention. However, where the distractors were similar to the target, or where distractors were heterogeneous, each item will have to be attended to individually until it can be accepted or rejected as the target. On this basis, they suggested that search is not a strict dichotomy between parallel and serial modes, but rather is a continuum based on the perceptual properties of the stimuli.

A further alternative to FIT is the Guided Search (GS) model proposed by Wolfe and colleagues (Wolfe et al., 1989; Wolfe, 1994; Wolfe & Gancarz, 1996; Wolfe, 2007). Much like FIT, GS has a preattentive and attentive stage, with basic information from the preattentive stage (e.g. colour, form, motion, etc.) being used to guide attention towards the location of salient items in the attentive stage. The efficiency of search is thus dependent on the quality of guidance. For example, in search of a target defined by a single feature (e.g. the colour red), attention would be deployed towards the red target before it is deployed to any distractors, resulting in an efficient search, independent of set size. In contrast, tasks which have no preattentive information, or a combination of preattentive information, would require attention to be deployed to several items before the target is found, giving rise to a more serial search.

Wolfe proposed that an item is either accepted or rejected as a target if it reaches a certain threshold of activation through the accumulation of stimulus information (Wolfe, 2007). That is, information is gathered from items until either one item exceeds the threshold for target detection (based on its physical properties), or all items reach the threshold for "distractor". GS therefore is effective in explaining some of the search phenomena encountered by FIT and perceptual grouping. In examples of parallel search in FIT, the target (defined by its singleton feature) very quickly surpasses the target threshold, whilst the distractors quickly surpass the distractor threshold and are rejected (in the case of a target-absent search). In a similar way, targets that are dissimilar to distractors and distractors that are similar to each other (Duncan & Humphreys, 1989) also reach their respective thresholds quickly and give rise to an efficient search. In contrast, distractors in conjunction searches, heterogeneous distractors, or distractors which are similar to the target will require information to be sampled (and thus for attention to be deployed) for longer before the target or distractor thresholds are reached, making search inefficient and dependent on the number of items.

Although a large amount of literature on visual search exists (with FIT, perceptual grouping and GS being just three prominent examples), two concepts remain constant across the literature: (i) under certain conditions search is efficient and, to a certain degree, independent of the number of search items; (ii) the less distinct search items are, the less

efficient the search and increasing the number of items correspondingly increases the time taken to complete the search. What causes search to be efficient or inefficient and whether search efficiency is dichotomous or continual remain subjects of debate.

1.1.6. Priming and visual search

Throughout search literature, participants are required to locate a defined target among distractors and, in many tasks, the target and the distractors are the same from trial to trial (Treisman & Gelade, 1980; Duncan & Humphreys, 1989; McLeod, Driver & Crisp, 1988; Nakayama & Silverman, 1986). In a separate line of research, Maljkovic and Nakayama (1994, 1996) showed that keeping target features consistent from trial to trial facilitates target processing. For example, in their 1994 study, Maljkovic and Nakayama found participants performed a target discrimination in a singleton target search task faster when a feature of the target (e.g. its colour or spatial frequency) remained constant across trials than when it was not (i.e. the target was a different colour from trial to trial (Hillstrom, 2000; Goolsby & Suzuki, 2001)). In early search literature, this priming effect did not appear to be well accounted for. That is, despite researchers comparing search performance from task of constant target features and task where target features changed across trials, there was little reference to the possible impact of priming on results.

In order to address this shortcoming, Kristjánsson, Wang and Nakayama (2002) examined the effects of priming in a present/absent conjunction search task. Participants were instructed to find either a red vertical or red horizontal target among either green vertical or red horizontal distractors (red vertical target) or green horizontal and red vertical distractors (red horizontal target). In one condition, the target was the same on every trial (i.e. all red vertical bars). In the remaining two conditions, the target either changed ("switched") on every trial, or had continuous "streaks" of one target before it switched to the other (i.e. ~8 sequential trials of red vertical target followed by ~8 sequential trials of red horizontal targets). Their results showed that search was best when the target remained constant across trials and was worse when the target switched from trial to trial. This cannot simply be put down to target expectancy as in the switch condition participants would have been aware that the target was more likely to be in the alternative orientation

to the preceding trials (Sigurdardottir, Kristjánsson & Driver, 2008). Instead, the authors suggested that this demonstrates participants were "primed" by the feature of the target on the prior trial, and thus attention was guided towards the target.

The effects of priming in visual search have since been substantiated by a number of authors (Wolfe, Butcher, Lee & Hyle, 2003; Olivers & Meeter, 2006; Becker, 2008; Kristjánsson, 2009). Traditional theories of search (such as FIT or early GS models (Treisman & Glade, 1980; Wolfe et al., 1989; Wolfe, 1994)) tended to focus on current target properties as a means of guiding attention. For example, in traditional singleton search, it is the colour of the target in contrast to that of the distractors which grabs attention and enables speeded responses (Treisman & Gelade, 1980; Treisman & Sato, 1990). However, priming theories suggest that it is not simply the features of the current target which are important, but also the features of previous targets that guide search both implicitly and explicitly (Turk-Browne, Yi & Chun, 2006), and even when the repeated feature is not relevant to the task (for example, an orientation discrimination task is facilitated when the target colour is constant (Kristjánsson, 2006)). Priming in search is not limited to stimuli features across a small number of consecutive trials. Chun and Jiang (1998) found that when a small number of search arrays were repeated over a large number of trials (that is, the spatial relationships between the target and distractors were repeated), search for a target was expedited in the repeated displays in comparison to novel displays. This was termed "contextual cueing" and occurred even when participants were unable to recognise explicitly any of the repeated displays when questioned (Chun & Jiang, 1998). Their results also suggested that contextual cueing is not due simply to low-level feature priming; in their second experiment, the shape of the distractors changed after three blocks of trials, so that any effect of feature priming would be eliminated (Chun & Jiang, 1998). Despite this, the contextual cueing effects continued for the repeated displays in new distractor trials, indicating that the priming of the search array could survive feature changes.

1.1.7. Attending to new items and ignoring old items: the characteristics of preview benefit

To search any display efficiently, one must prioritise the selection of new items and deprioritise the selection of old items. As an example, if one were looking for a grey journal that had recently put on a desk, one might begin by directing their attention to any grey, rectangular objects. If, however, one knew that their diary and an external computer hard drive (both also grey and rectangular) were almost always on my desk just to the left of my keyboard and in the top right hard corner, they may prioritise other areas of the desk before these as a priori knowledge tells me what they were looking for is unlikely to be in these places. These attentional biases in search are the foundation for preview search.

Preview search was first studied by Watson and Humphreys (1997) by using an adaptation of Treisman and Gelade's (1980) conjunction search task to see if manipulating when search items appear can have an impact on search efficiency. Using a search task with a conjunction target, they segregated the display such that half the distractor items appeared one second before the remaining distractor items and the target. The segregation was such that if, say, the target was a blue "H" among green "H"s and blue "A"s, the blue "A"s would appear first, followed by the green "H"s and target blue "H". Here, the final display was equivalent to Treisman's conjunction search, but the second display of items to appear (known as the "search display") was equivalent to Treisman's singleton search. The authors proposed that if participants could not inhibit the items in the initial display (the "preview items"), then search would proceed serially, equivalent to Treisman and Gelade's (1980) conjunction condition. Conversely, if participants could successfully inhibit the preview items, search would proceed in parallel, equivalent to Treisman and Gelade's (1980) single feature condition. Their findings showed that if the preview items were allowed to be viewed for an adequate amount of time (approximately 400ms or more), then searching was performed in parallel, independent of the number of distractors, as evidenced by very shallow or flat search slopes. From this, the authors concluded that participants were searching through the search display only and ignoring items from the preview display. This benefit in search efficiency was termed the "preview benefit".

The mechanisms responsible for preview benefit can largely be categorised into two main schools of thought: an automatic mechanism as a result of bottom-up attentional capture by the onset of the new stimuli (Yantis & Jonides, 1990; Müller & Rabbitt, 1989; Donk & Theeuwes, 2001) and a voluntary mechanism, resulting in either top-down inhibition of the old items (Watson & Humphreys, 1998, 2000; Olivers, Watson & Humphreys, 1999; Gibson & Jiang, 2001; Kunar, Humphreys & Smith, 2003a) and/or a top-down expectancy for the properties of the new stimuli (Braithwaite & Humphreys, 2003; Braithwaite & Humphreys & Hodsoll, 2003; Braithwaite, Humphreys, Watson & Hulleman, 2005). Since the inaugural preview experiment, a number of characteristics of preview benefit have been established in the literature, which has fuelled this debate. These characteristics and their theoretical implications are discussed here.

Firstly, preview benefit can be simultaneously applied to a number of items at once. The role of attentional capture by new items was first studied in depth by Yantis and Jonides (1990; Jonides & Yantis, 1988). Their studies consisted of a triangular display of items around a central fixation point composed of shapes resembling figure of eights comprised of horizontal and vertical lines. For the search task, several of these lines would disappear such that the figure of eight-like stimuli became letters. In the offset condition, a predetermined target letter appeared out of the offsetting figure eights, whereas in the onset condition the target letter appeared in a previously unoccupied location. Response times to the target in the latter condition were faster and search times were independent of the number of display items. In comparison, when targets appeared as the result of an offset of items already present in the display, response times were slower and increased with the number of displayed items.

When required to respond to a single target, Theeuwes, Atchley and Kramer (1998) found attention could be preferentially directed to at least 15 new items under preview conditions. Moreover, Watson and Kunar (2012) showed prioritisation of six or seven new items under more demanding conditions where participants were required to respond to all the new items (by pointing to as many of them as possible). Theeuwes et al.'s (1998) and Watson and Kunar's (2012) finds are in contrast, studies previously carried out by Yantis and Jones (1991) suggested that only a small number of new items (three or four)

could be preferentially attended to because of attentional capture by abrupt onset. This apparent contradiction suggests that the ability to prioritise so many new items under preview conditions cannot arise solely due to attentional capture by new items. Instead, it suggests that alongside new items capturing attention, the old, previewed items undergo some form of inhibition or visual marking which allows them to be effectively ignored by the time the new items appear.

Secondly, the preview benefit is affected by the luminance of items. In support of the onset capture theory, Donk and Theeuwes (2001) proposed that if there was no abrupt onset of new items to capture attention by means of a change in luminance at the location of the new items (that is, the new stimuli which appeared were of the same luminance as the background), there would be no preview benefit: this is what they found. When the new search items were equiluminant with the background, no preview benefit was observed. Further, the effect of attentional capture in preview search is not simply limited to abrupt luminance onsets, as Pratt, Theeuwes and Donk (2007) found that an abrupt luminance offset at the location of new items can also give rise to a preview benefit. However, it would be incorrect to say that no preview benefit is obtained under conditions of equiluminance: Braithwaite et al. (2005) found that a preview benefit could be established with equiluminant stimuli if the duration of the preview period is increased from the usual 1000ms to 3000ms. Their findings suggest that under equiluminant conditions additional time is needed to build up a representation of items so that they can be effectively inhibited.

Thirdly, and following on neatly from the above, preview benefit is time dependent. In their original paper, Watson and Humphreys (1997) found there was a lower limit on the duration of the preview before search items appeared of ~400ms in order for there to be a benefit. This appears to contradict the theory of onset capture, as Event Related Potential (ERP) studies suggest the amount of time needed to visually process new stimuli is approximately 50 – 150ms (e.g. Luck & Hillyard, 1994), i.e. much faster than 400ms. Watson and Humphreys (1997) also found that even when the duration of the preview exceeded the 400ms minimum, if the preview items were offset for a period of 250ms before reappearing with the search items, the preview benefit was abolished as the

duration of the offset is sufficiently long for the preview items to be reclassed as a new onset item. In contrast, Kunar et al. (2003a) found that having viewed the preview for 450ms (sufficient time for the preview benefit to be established), and the items having then offset for 250ms (which abolishes the preview benefit, as per Watson and Humphreys (1997)), if the preview items then reappeared for a very short duration of 150ms (the temporal "gap" condition), a preview benefit still occurred, despite 150ms being well below the usual minimal threshold for preview duration. If the preview benefit were due to attentional capture of new items, then:

i) a reduced preview duration as in Watson and Humphreys (1997) should not impact the benefit, as the new items appearing should, in theory, be considered new onsets, even at relatively short durations (Luck & Hillyard, 1994; Watson & Humphreys, 1997)

ii) any prior benefit obtained from the preview items before their offset in Kunar et al. (2003a) should have no impact on search efficiency following their subsequent reappearance before the search items appear. These findings suggest instead that a certain amount of time is needed in which to attend to the preview items and inhibit them and also that the benefit of a sub-duration preview is modulated by an earlier preview of the items. Both argue against a simple capture theory, indicating that a different mechanism (for example, the controlled inhibition of items) is necessary in order for the preview benefit to occur.

Lastly, the preview benefit is sensitive to location or identity changes in the previewed items. Research has shown that changes in the shape of preview items (Watson & Humphreys 2002), their spatial configuration (Kunar, Humphreys & Smith, 2003b), their luminance (Braithwaite et al., 2005), or their semantic meaning (Osugi, Kumada, & Kawahara, 2010) will disrupt the preview benefit. This suggests that preview benefit utilises a form of visual template to memorise and subsequently inhibit previewed items. Such a template would be sensitive to changes occurring at the locations of old items, so that changes such as those described above would cause the template to be "updated" in memory and thus the preview benefit would need to be re-established. It is interesting,

however, how other studies have shown that such changes in previewed items do not disrupt the benefit as much when they are induced either by occlusion (Kunar, Humphreys, Smith & Watson 2003; Watson & Kunar, 2010), a voluntary eye-blink (von Mühlenen, Watson & Gunnell, 2013), or when participants are specifically instructed to direct their attention away from a given property of the previewed items (in this instance, their colour; Osugi & Kawahara, 2013). These results indicate that although updates in the memory template may be driven by bottom-up (i.e. external, attention capturing) changes in stimuli, the effect of bottom-up changes can be modulated by top-down attentional expectancy or control, by means of either an eye-blink (visual changes are naturally suppressed by an eye-blink (Volkmann, Riggs & Moore, 1980), transient occlusions (items coming in and out of view via means of occlusion occurs naturally in everyday visual life), or by deliberate guidance of an attentional set.

These characteristics of preview benefit, as established by the literature, indicate the importance of an inhibitive mechanism in preview search. However, the results do not suggest that there is no effect of onset capture in preview search; indeed, it would be difficult to explain the results of Donk and colleagues (Donk & Theeuwes, 2001; Donk & Verberg, 2004; Pratt et al., 2007) without accepting that new item onsets facilitate search. It is unlikely, however, that onset capture alone can explain the results of the preview literature. Further, evidence from preview search using a sensitivity analysis as opposed to a standard reaction time analysis showed that preview benefit was most robust under conditions where both attentional capture by the onset of stimuli and memory-based top-down inhibition were able to occur (Barrett, Shimozaki, Jensen & Zobay, 2016). Interestingly, their findings showed that under conditions where the preview items offset and onset again with the search items (thus onset of new items could not be used to capture and guide attention), a reduced preview benefit did still occur, suggesting that top-down inhibition could be used to guide attention and suppress the capture of attention by irrelevant items.

An interesting recent study by Mavritsaki and Humphreys (2016) used a computational model known as the spiking search over time and space (“sSoTS”) model (Mavritsaki, Heinke, Humphreys & Deco, 2006; Mavritsaki, Allen, & Humphreys, 2008; Mavritsaki et al.,

2011), built to perform search paradigms similar to the temporal gap condition of Kunar et al. (2003a). The model showed that whilst a form of temporal binding by new onsets was necessary to produce the effects seen in the original gap condition of Humphreys and Watson (1997), it was also necessary to introduce a form of old item memory and continued inhibition across temporal gap in the model to replicate the findings of Kunar et al. (2003a). This suggests that whilst temporal grouping of items into old and new onsets can explain some characteristics of preview search, it is not until an element of inhibition is introduced that the characteristics can be fully explained.

The literature on preview search has historically been split into two dichotomous groups – those who favour a bottom-up, onset capture explanation of the benefit, and those who favour a top-down, attentional guidance approach. More recently, research has shown that in fact it is a combination of both mechanisms which allows preview benefit to occur most successfully (Barrett, et al., 2016). From this arose the theory that there are two distinct memory systems involved in preview search (Yamauchi, Osugi & Murakami 2017): a high-capacity memory system which tracks the differences between old and new items, and a limited-capacity system which marks the locations of old items. This theory explains how the benefit can survive some changes in the visual display provided the number of preview items is below the limited-capacity marking their locations (Al-Aidroos, Emrich, Ferber, & Pratt, 2012), but why other events, such as making a saccade (Emrich et al., 2008), or localising and responding to new items (Watson & Kunar, 2012) will reduce or abolish the preview benefit. Yamauchi et al. (2017) using a singleton distractor in a preview search demonstrated that these two memory systems, whilst distinct, do compete for attentional resources in preview search, as the preview benefit degraded in conditions with a singleton distractor. Therefore whilst both memory systems, and indeed both bottom-up and top-down mechanisms, produce the most efficient preview search when they are working cohesively, if either system or mechanism is occupied by other tasks or stimuli, the preview benefit will suffer.

1.1.8. Different forms of inhibition in search

Inhibition in attention literature can be studied using a number of approaches, from behavioural (i.e. recording reaction times to targets at 'inhibited', compared to neutral, locations), to neural (i.e. recording the firing level of neurons coding for 'inhibited' locations). Although a neural approach provides a more direct method of examining the effect of inhibition on specific areas of the brain, a behavioural approach allows for a more practical understanding by showing the impact of inhibition on our ability to perform certain tasks. Further, a behavioural approach is less time consuming and consequently a larger volume of data can be gathered, making the results more generalisable. In this thesis, inhibition will be considered largely from a behavioural perspective.

The role of top-down inhibition in visual attention was studied by Posner and colleagues (Posner & Cohen, 1984; Posner, Rafal, Choate & Vaughan, 1985) and later developed by Klein (1988) in their work on inhibition of return (IOR). Their experiments consisted of a simple display with a central fixation point and two peripheral equidistant locations from the fixation point marked by a square. One of the locations was cued by an increase in luminance of the square, following which a target would either appear at the cued location (valid condition) or at the other location (invalid condition). The time between the cue and the appearance of the target was varied. Their results found that when the cue was valid and the interval between cue and target was less than ~300ms, reactions to the target were facilitated. However, if the interval was longer than ~300ms, reactions to the target were found to be were slower. The authors suggested that the cue initially captures attention and draws it to that location, hence facilitating the subsequent processing of a target appearing very shortly after at that location. However, as the time between a valid cue and the target appearance increases, people withdraw their attention from the location and back to fixation. As a result, the time taken to respond to a target appearing at the cued location increases. The authors suggested this was to avoid re-orienting attention to a place which has already been processed (however, see Martín-Arévalo, Kingstone and Lupiáñez (2013) for an argument against the inhibition of the return of attention; and Tipper, Driver and Weaver (1991) for an object-centred approach to IOR).

This bias in attention has been found in visual search tasks. In their study, Klein (2000) included a condition where a probe dot would appear in the search display and participants had to later identify whether or not the probe was present. When the probe appeared at a previously occupied location, detection of the probe was impaired in comparison to when the probe appeared at an unoccupied location (although see Wolfe & Pokorny (1990) who failed to replicate this finding). Based on these findings, Klein proposed that IOR arises due to a mechanism which inhibits attention from returning to a location already attended to and rejected, so that attention can be prioritised towards novel, unattended locations (however, see Müller and Mühlenen (2000) for evidence that the inhibition is object, not location, based).

Evidence for the importance of general inhibition in preview search was shown by Watson and Humphreys (1997), who found that when the preview duration was decreased to less than 400ms, the benefit was disrupted (1997). The authors suggested that these findings show participants need sufficient time to view and intentionally inhibit previewed items before the onset of the search items. If the preview benefit simply relied on attentional capture of new items, such a slow time course should not be found. However, this was later challenged by Donk and Verburg (2004) who argued the abrupt onset of the preview items captured attention and still held attention by the time the search items appeared. By manipulating the appearance of preview items so that they did not appear with an abrupt onset (Yantis & Jonides, 1990), they showed a preview benefit could be obtained with a preview as short as 50ms, supporting the attentional capture model.

Further, the effect of abrupt onsets appears to be involuntary in nature, as even under conditions where the target is more likely to appear among old items, new items are still processed as a priority (Donk & Theeuwes, 2003). Additional work from the authors also demonstrated the sensitivity of the preview benefit to changes in luminance: a preview benefit was found when a change in luminance occurred when new search items appeared by offsets rather than onsets (Pratt et al., 2007).

Evidence supporting the importance of location inhibition in particular comes from Watson and Humphreys (1998), who found that when previewed items moved in a uniform manner during the preview phase the benefit was disrupted, suggesting that inhibition at the

locations of the previewed items is of importance. Further evidence from studies of probe dot detection show the importance of location inhibition. For example, Watson and Humphreys (2000) later found a probe was detected less accurately when it appeared next to a previewed item in the preview condition as opposed to the same item in a conjunction condition (all items in the display presented simultaneously). Whilst it could be argued that their findings were due to anticipation of new items (turning attention away from previewed stimuli), this seems unlikely as Humphreys, Stalmann and Olivers (2004) found probe detection was worse when it appeared at the locations of old items relative to a neutral location and better when appearing next to a new item than when appearing in a neutral location. This was not due to differences in luminance across the display as differential masking was controlled. If attention was being prioritised during the preview to potential new item locations then probe detection should have been equal at both new item, and neutral, locations.

Additional probe studies suggest that previewing items produces a decrease in visual sensitivity to visual contrasts at the locations of the previewed items. For example, Agter and Donk (2005) used a similar probe-task procedure to aforementioned studies, except that the dependent variable was the time taken to detect the probe. The results showed that reactions times were slowed when detecting a probe at the location of old items in comparison detecting a probe at the location of new items. The differences observed in time taken to detect a probe between old and new item locations provides evidence for active suppression of old items during preview search. This notion was supported by Allen and Humphreys (2007), who found an increase in contrast detection threshold in a valid preview condition compared to a "dummy" preview condition where the target item could as equally likely appear in the location of an old item. The authors proposed that the change in contrast detection threshold of stimuli presented near to the locations of the previewed items indicated that the items had been actively ignored (see also Osugi and Murakami (2014), for further evidence of decreased contrast sensitivity at the locations of preview items).

Evidence for feature inhibition, as opposed to location inhibition, has also been shown to contribute towards the preview benefit (Gibson & Jiang, 2001). In their study using moving

previewed items, Watson and Humphreys (1998) found that although under normal conditions there was no preview benefit, if the previewed items could be grouped and rejected by a single feature (e.g. colour), a preview benefit can occur, suggesting that preview item features can also be inhibited. Further evidence for feature inhibition can be seen in Olivers and Humphreys (2003), who found that participants were less efficient at finding a target which shared a feature with the old preview set. Experiments by Braithwaite et al. (2003) and Braithwaite et al. (2005) varied the ratios of stimulus colours across the preview condition (e.g. a preview with 66% red items and 33% green items followed by a display containing 33% red items and 66% green items and vice versa) and found that, if the target was the same colour as the majority of the previewed distractors, it was harder to detect. Further, Braithwaite et al. (2005) found that a probe was less likely to be detected when it appeared on a distractor which shared the colour of the majority of preview items.

1.1.9. Preview search and secondary tasks

Evidence supporting preview item inhibition also comes from a variety of dual-task studies. In their original paper, Watson and Humphreys (1997) used rapid serial visual presentation (RSVP) as a secondary task whilst participants had to verbally shadow a stream of digits presented to them at a fixation point. The onset of the RSVP stream coincided with the onset of the preview items and it stopped with the onset of the new search items. Despite the previewed items being displayed long enough for a preview benefit to normally occur, search in the preview condition was no longer as efficient as in a single-feature baseline, with participants showing a systematic increase in reaction times as more items were added to the display. Their findings suggest that attention is needed during the preview period and that a secondary task that also requires attention will disrupt the benefit. If the preview benefit were due to bottom-up attentional capture of new items, the presence of a secondary task should have no impact.

Further evidence of the effect of a dual-task on the preview benefit was presented by Olivers and Humphreys (2002). Participants were asked to identify two targets in a RSVP stream which were presented at various inter-stimulus intervals (ISI). Previous research

shows that, if the second target is shown within a 500ms ISI of the first target, then detection of the second target is disrupted, a phenomenon known as the attentional blink (Raymond, Shapiro & Arnell, 1992). On some trials, Olivers and Humphreys (2002) did not present a second target, but instead presented a preview display. This was then followed by a full search display in which participants had to detect a target. Their findings show a decrease in search efficiency if the preview display fell within the attentional blink period, but no decrease in efficiency if the preview fell outside of the attentional blink period (i.e. at an ISI of > 500ms). It is important to note that whilst the preview display sometimes fell within the attentional blink period, the full search display never did. If preview benefit was not reliant on inhibition of old items then it should not matter if the preview fell within the attentional blink period. This, however, was not the case. Their data clearly show that when participants' attention was focused on responding to the initial task, the preview benefit diminished.

Research suggests that the type of dual-task used and its timing are also of importance in regards to disrupting the preview benefit. Humphreys, Watson and Jolicœur (2002) found that when the dual-task (in this case, keeping a stream of digits in working memory) occurred alongside the preview display, the preview benefit was disrupted regardless of whether the secondary task was visual (within modality) or audio (between modality). However, if the dual-task onset was delayed, such that participants had a brief time (1000ms) to view the preview without the dual-task, it was only when using a visual based dual-task that the preview was disrupted. Search slopes in the delayed audio dual-task condition were as efficient in the preview as in the single feature baseline condition. The authors suggested that preview benefit requires two components in order to be fully established: an initialisation component, in which participants generate the intention to inhibit the previewed items and develop an attentional bias towards the new items; and a maintenance component, which keeps the representations of the locations of the previewed distractors active. The former, the authors proposed, uses modality-independent resources, thus abolishing the preview in both visual and audio based dual-tasks. The latter uses only visual resources, thus enabling a preview benefit in the audio dual-task condition only (Humphreys et al., 2002).

1.2. Outline of this thesis

The mechanisms underlying preview benefit and how these relate to theories of active suppression and bottom-up capture of attention is an ongoing area of research. The purpose of this thesis is to further explore these mechanisms, to increase understanding of the limitations of attention, whether prior knowledge of a search display can facilitate response and whether search strategy can be voluntarily controlled or whether this is an automatic process. The role of inhibition and the need to attend to preview items is considered in Chapter 1 through use of secondary tasks. As early as Jonides (1981), there was evidence that carrying out an attention demanding secondary task can disrupt processing of items in a primary task. Evidence from preview search indicates that secondary tasks disrupt the preview benefit (Watson & Humphreys, 1997, 1998; Allen, Humphreys & Matthews, 2008). Of particular interest is the disruption caused by different timings and modalities of the secondary task (Humphreys et al., 2002) and whether this can be extended to different secondary task timings (e.g. around the search task). The difficulty, or load, of the secondary task is also taken into consideration to see if this differentially disrupts the preview benefit based on timing or modality. If active attention is important in ignoring the preview items and thus generating a preview benefit, the secondary task should cause preview search slopes to become steeper in comparison to conditions without a secondary task. Further, if active attention is also required to rehearse or maintain a working memory secondary task which is presented before the onset of the preview, and if this is modality specific, a visual working memory task should disrupt the preview benefit more than an audio working memory task. However, the demands on attention resources by the secondary task and how this effects timing and modality also needs to be taken into consideration (McCann & Johnston, 1989; Ruthruff, Miller & Lachmann, 1994). If the working memory task also interacts with timing and modality, the difference in preview benefit will only arise when the difficulty of the working memory task is lowered.

Chapter 2 examines the role of visual repetition on preview search. Based loosely on the concept of Chun and Jiang's (1998) contextual cueing, the experiments consider the role of

location inhibition across both preview displays and regular conjunction displays. If people are able to inhibit the location of search items (as suggested by the preview benefit) and if people are able to learn the repeated location of certain items in the display (as in contextual cueing) then having a conjunction display where half the items (the items which are preview items in preview conditions) appear in the same locations from trial to trial, then search in the conjunction condition should be more efficient than in a regular conjunction condition where the location of the distractor items is not repeated, and could possibly be as efficient as search under preview conditions..

Chapter 3 examines the effect of cueing a feature of the target in preview search and whether prior knowledge of the target's colour is additive or reductive to the preview benefit. Cues can be used to facilitate visual processing (Posner, 1980) and visual search (Treisman, 1986) and the ratio of items of certain colours can be used to predict likely target colour in preview search (Braithwaite et al., 2003; Braithwaite et al., 2005). However, in preview benefit where the role of inhibition appears to be important, does an informative colour cue make little difference as inhibition can take place regardless? Or does knowledge of the target colour help guide search to all items of that colour, whether or not they were present in the preview? If so, do people have a preferential search strategy to adopt, or can they utilise both effectively? If inhibition of preview items is the dominant strategy in preview search, an informative colour cue should have minimal impact on search efficiency. However, if the cue guides attention to items of that colour, search efficiency may actually decrease as each colour-cued item is attended to individually. If these strategies are not cohesive and therefore only one can be utilised, is there a preference as to which strategy to use and, if so, why? The results suggest that when given a choice of strategies for preview search, participants prefer an anticipatory strategy (looking through items of the cued target colour) than an inhibitory strategy (ignoring the preview items), even when an anticipatory strategy is less efficient.

Finally, Chapter 4 considers the role of facial orientation in (i) detecting expression, and (ii) ignoring negative emotions, by use of a preview search task. Previous literature suggests emotional faces (particularly fearful faces) are more difficult to reject than neutral or positive faces (Hansen & Hansen, 1988), but work by Bruce, Valentine and Baddeley (1987)

indicates how well we receive and process facial information is dependent on how the face is rotated (e.g. looking straight forward or in profile). This chapter firstly examines whether processing or making judgements about faces differs depending on whether the face is straight on (i.e. not rotated) or rotated through to 90o (in profile, looking to either the left or the right). If the rotation of the face has an impact on our ability to process them (particularly the emotional expression of the face) then differences in reaction times or judgement times should arise when the face is rotated compared to when it is not. Furthermore, if our ability to process emotional faces is impaired when they are rotated, and inhibition is key to preview search, using negatively valenced faces as preview items should be less disruptive when the faces are rotated in comparison to when they are not. Using previews consisting of either fearful or neutral faces that are straight on or in profile and comparing the levels of disruption to the preview benefit, the ability to ignore emotional, rotated faces is examined.

In the discussion, the results are discussed with respect to the current literature on preview search, with explicit reference as to where and how the work supports or conflicts present theories. The findings will then be considered in view of wider theories of visual attention, and further research possibilities will be discussed.

Chapter 1 – The effect of dual-task on preview search

Research using preview search (Watson & Humphreys, 1997) shows a secondary task will often disrupt the preview benefit, suggesting the preview requires active attention to be inhibited. Results of this Chapter suggest that preview benefit is disrupted to the same extent by working memory stimuli which are the same as the preview items (Experiment 2) and by tasks of the same modality (e.g. visual or audio, Experiment 3). This was extended to show the amount of disruption by both modalities was affected by the timing and difficulty of the secondary task (Experiment 4).

2.1. Introduction

The ability (or lack thereof) to perform two or more tasks simultaneously is something we encounter every day. Whilst some tasks such as walking and talking or drinking a cup of coffee whilst watching the news do not seem to cause us any difficulty at all, other tasks such as talking on a mobile phone whilst driving or trying to listen to two people at once can be extremely challenging and result in poor performance of both. With the rise of technology and multimedia entertainment ever increasing the frequency at which we multitask (Cardoso-Leite et al., 2015; Kamal & Dong, 2017; Carrier, Rosen, Cheever & Lim, 2015), the question of how, and even if, attention can be divided and the impact this has on performance has become a subject of growing interest for psychologists for some years. Three of the factors that have an impact on dual-task performance are timing (Telford, 1931; Pashler, 1990), the demand the tasks place on attentional resources (Sullivan, 1976; Lavie, 1995) and task modality (McLeod, 1977).

Previous literature has shown that the presence of a dual-task in preview search causes disruption to the preview benefit (Watson & Humphreys, 1997; Olivers & Humphreys, 2002). The timing and the modality of the dual-task also modulates the extent of disruption to the preview benefit (Humphreys et al., 2002). This chapter examined the content, timing and difficulty of the dual-task and how this had an effect on the preview benefit. Experiment 2 used dual-task stimuli that were either processed identically to that of the preview set or not (by virtue of the faces being inverted or upright) to see if identical stimuli would be more disruptive than similar, but not identical, stimuli. Experiment 3 used a dual-

task of a separate modality (audio dual-task) to see if this would cause as much disruption as a task of the same modality (visual dual-task). The effect of the attentional demand (or load) of the dual-task was then then examined in Experiment 4, by repeating only four "tunes" created by the tones of the dual-task, as opposed to a different sequence of tones on each trial.

2.1.1. Dual-task and the bottleneck model of attention

As early as 1931, research showed the limitations of human attention in attempting to carry out more than one task at the same time. Telford (1931) showed that when two stimuli are presented in rapid succession, response to the second stimulus is slowed as the time between its onset and the onset of the first stimulus is decreased. Whilst Telford's study used two visual stimuli which required the same response (a button press) to both, the slowing, known as the psychological refractory period (PRP), can be seen in tasks using stimuli of different modality (Creamer, 1963; Borger, 1963) and when the required responses to the two stimuli differ (Pashler, 1990; Pashler, Carrier, & Hoffman, 1993; Osman & Moore, 1993), suggesting the delay is not simply due to the inability of neurons to fire to the same stimuli twice in rapid succession (as the term PRP implies).

To explain the PRP and attentional limits, an early theory of attention as a single, central processor was proposed, the bottleneck theory, in which attention acts as a mediator between input stimuli processing and response production (Pashler & Johnston, 1989; Pashler, 1994; Marois & Ivanoff, 2005; Tombu et al., 2011). The theory proposes that although stimuli from multiple sources can be perceived simultaneously, they must pass through this central processor in order to determine response to the stimuli.

Traditional views of response bottleneck suggest that it is the selection of an appropriate response that causes the attentional bottleneck (Welford, 1952; Karlin & Kestenbaum, 1968; Smith, 1969), but a recent review by Klapp, Maslovat and Jagacinski (2018) suggests instead that it is due to the initiation and timing of task response, and its level of complexity that differentially causes the bottleneck (Maslovat et al., 2013; Bratzke, Rolke, & Ulrich, 2009). The bottleneck model received support from studies utilising early dichotic listening tasks (e.g. Broadbent, 1952; Cherry, 1953), which showed that when presented with two

relatively complex tasks (in this instance listening to two different passages of prose at the same time), participants had great difficulty following the content of what was being said unless their attention was specifically directed to one input over the other (i.e. the left ear rather than the right). Such an explanation fits well with early work on the PRP. For example, Pashler and Johnston (1989) found that when response to the first stimulus was not required, the slowing in response to the second stimulus was no longer observed. Furthermore, the observation of a PRP under changing stimulus and response modalities implies that the same channel is used for processing and responding to all stimuli, as opposed to there being multiple channels across modalities. However, these findings largely appear only in relation to simple reaction time tasks which, it is argued, are subject to temporal uncertainty (see Pashler (1994) for discussion).

2.1.2. Dual-task and resource capacity

The selection response bottleneck theory of attention is based in part on the assumption that stimuli input response can only pass through the bottleneck in a serial manner (e.g. response processing for one task must be entirely completed before response processing can begin for the second task). However, there is evidence that stimuli from a second task can begin being processed alongside stimuli from the first task in parallel, but actual selection of response can only occur after task 1 has been completed (Pashler & Johnston, 1989; Fischer, Miller & Schubert, 2007; Fischer & Schubert, 2008; Janczyk, Pfister, Hommel & Kunde 2014).

As an example of parallel processing, several studies have demonstrated the effects of what is termed “Crosstalk” (Ferreira & Pashler, 2002; Ko & Miller, 2014), where the stimuli used for the secondary task can have an impact (either beneficial or detrimental) on the processing of the primary stimuli. This results in both changes in reaction times to the primary task, but also in changes to reaction times in the secondary task, i.e. increases in reaction times to task one result in a corresponding increase in reaction times for task two. Crosstalk effects are not compatible with bottleneck theories such as the response selection bottleneck, but instead support the concept of attention capacity being shared

across multiple tasks (for a full review of serial and parallel input processing, see Fischer & Plessow (2015)).

Further challenges to the bottleneck theory have however been shown in both dichotic listening tasks and PRP tasks using cross-modal stimuli. Pashler (1989) found that when participants were required to respond to a tone as the primary task and perform a choice reaction task (present/absent visual search) as the secondary task, search performance was as good when the two tasks overlapped as it was when there was a long delay between the tone and the search task. Further, Allport, Antonis and Reynolds (1971) found that when participants were required to shadow an audio message whilst performing a task that was completely different (e.g. sight-reading music) their performance was as good when performing tasks simultaneously as it was when each was performed individually. It would appear, then, that whilst some tasks require a single, central processor which is subject to a bottleneck (as early PRP and dichotic listening tasks suggest), this is not necessarily required in all circumstances.

An alternative explanation for the role of attention in dual-task studies is that of an attentional finite resource which, if exceeded, causes delays in processing. According to this explanation, multiple items can be dealt with simultaneously without interference, providing that none of the items on their own or in combination place demands on attention which exceed its capacity. When capacity has been exceeded, stimuli can then only be processed one at a time, causing delays in responses to secondary tasks. This can explain the differences in the previously mentioned PRP studies. Where one of the tasks is more cognitively demanding or requires a greater degree of judgement (e.g. mentally rotating an object or determining which of two bars of similar length is the longest), PRP effects are seen even in choice reaction time tasks (McCann & Johnston, 1989; Ruthruff, Miller & Lachmann, 1994). In comparison, a simple visual search (as used by Pashler (1989)) may not have been as demanding on attention resources, allowing both tasks to be performed concurrently with little cost to performance. The lack of interference caused by sight-reading piano music as a secondary task in Allport et al., (1972) can also be accounted for by task demands; perhaps playing a musical instrument is an example of an implicit memory? Certain mechanical tasks such as walking, driving a car or riding a bike can, once

learnt to a sufficient degree, become somewhat automatic in nature, requiring little attention to be successfully carried out (Reber, 1989). That is, they become implicit. It is likely, therefore, in Allport et al. (1972), that the secondary task caused less interference because it placed little demand on participants' attentional resources (see also Strobach, Liepelt, Schubert and Kiesel (2012) and Goh et al. (2012) for the effect of practice on dual-task performance).

2.1.3. Dual-task and modality

Sensory processing is very rarely received from one channel alone. Under normal circumstances we do not, for example, just see an insect flying around us, but we also hear it buzzing or feel it sting. Studies on cross-modal spatial attention show facilitated response times to a target presented in the same location as a cue of different modality. For example. a cue in the left ear would facilitate discrimination responses to visual stimuli presented in the left visual field (Spence & Driver, 1996; Spence & Driver, 1997; Spence, Nicholls, Gillespie & Driver, 1998; Eimer, Van Velzen & Driver, 2002; Störmer, McDonald & Hillyard, 2009), as well as shorter reaction times to a target's change in brightness when paired with a congruent change in pitch from a concurrent audio cue (Klapetek, Ngo & Spence, 2012). Conversely, it is more difficult to attend to one location in one modality whilst attending to another location in another modality (Driver & Spence, 1998). It would therefore appear that, whether it is limited by a single bottleneck or by a multi-channel resource, attention in one modality is influenced by attention in another.

Whilst the above studies examined the effects of multiple modalities on spatial attention, other studies have sought to understand the impact of modality of an irrelevant, secondary task. Here, studies show that tasks involving input (the task stimuli) or output (response) of the same modality produce worse performance in comparison to tasks utilising different modalities (McLeod, 1977; Duncan, Martens & Ward, 1997). In the previously mentioned Allport et al. (1972) article, the authors included a condition which directly compared the effect of secondary task modality on the primary audio shadowing task. In one condition (akin to that of Moray (1959)), the secondary stimulus was a list of words presented to the unattended ear, and tested in a forced choice recognition task after approximately one

minute of performing the shadowing task. In another condition, the same words were presented to the participants visually and again tested in a forced choice task. Whilst performance in the visual word condition was not as good as in the music sight reading condition, it was significantly better than when the words were presented aurally. Their work challenged the "single channel" theory of attention proposed by Broadbent (1952) and other limited capacity theorists (Deutsch & Deutsch, 1969; Kahneman, 1970), suggesting that attention could be deployed across multiple channels of different modalities.

Research suggests that certain types of dual-task modalities are more compatible than others. For example, over a number of studies Hazeltine and colleagues (Hazeltine, Ruthruff & Remington, 2006; Hazeltine & Ruthruff, 2006; Hazeltine & Wifall, 2011) compared dual-task performance across different modality pairings. For example, one group of participants performed two tasks, one which required a manual button press in response to visually presented words (a visual-manual task) and another required spoken word responses to different auditory tones (an audio-vocal task). A second group of participants performed a task where spoken word responses were required for visually presented words (a visual-vocal task) and a task where a manual button press was required in response to auditory tones (an auditory-manual task). Their results showed that participant groups performing the visual-vocal and auditory-manual tasks had much greater dual-task interference than the other participant group. These findings suggest that the inclusion of a secondary task alone does not account for the wide range of performance costs seen. Instead, the compatibility between the two modalities and other environmental factors of the stimuli (such as an audio-vocal task requiring participants to repeat the target word, as opposed to saying a different word) are also critical in understanding dual-task behaviour (Halvorson & Hazeltine, 2015).

2.1.4. Dual-task and preview search

The majority of work on the impact of a secondary task on preview search used a visual secondary task (Watson & Humphreys, 1997; Olivers & Humphreys, 2002; Allen et al., 2008) and found that a secondary task has a detrimental effect on the preview benefit.

However, research varying the modality of the secondary task (Humphreys et al., 2002) suggests that not only is the modality of the secondary task important, but the timing of the secondary task is too. Although their research provides an interesting insight into the interaction of timing and modality of a dual-task in preview search, it provides evidence from only two instances of timing. Their research suggests that initial processing of stimuli is particularly disruptive regardless of modality. But what happens when the secondary task is presented prior to the onset of preview items and tested after the search has taken place? Is the element of rehearsal required to maintain the secondary task items in working memory sufficient to disrupt the preview benefit? And, if so, is this true for auditory dual-tasks or just visual dual-tasks?

2.1.5. The purpose of this chapter

The purpose of the experiments in this chapter, therefore, was to further the work presented in Humphreys et al. (2002) regarding the effects of secondary task timing and modality on the preview benefit and to establish an understanding of the effects of secondary task demand and content (that is, whether the task is a spatial discrimination or identity discrimination task). If attention is required to maintain the contents of a secondary task in memory, then a visual secondary task should disrupt the preview when it temporally surrounds the search task (i.e. the secondary task stimulus is presented for memorisation prior to the search task, and tested after the search task has been completed). If the attention required to maintain the secondary task content is sufficient to interfere with the initiation of the preview benefit (Humphreys et al., 2002), then an auditory working memory task should also disrupt the benefit when it surrounds the search task.

If the attentional demand of the secondary task has an impact on our ability to perform two tasks concurrently (McCann & Johnston, 1989; Ruthruff, et al, 1994; Lavie, 1995; Strobach, et al., 2012), it is possible that a sufficiently demanding task will disrupt the preview benefit regardless of its modality. In contrast, if the demands of the secondary task are lessened through repetition and practice (Schumacher et al., 2001; Ruthruff, Johnston & Van Selst, 2001), then preview search should be more efficient when the

secondary task becomes more automatised. Results from Experiment 4 support this and indicate the importance of attentional demand of secondary tasks in preview search.

2.2. Experiment 1

The purpose of Experiment 1 was to validate the stimuli used in the experiments in this chapter. In order to examine the effect of stimuli content, stimuli were designed that could be used for identity-based tasks as well as location-based tasks. It was therefore decided that faces would be used for the preview half of our stimuli set and houses as the remaining half (Allen et al., 2008). Previous literature on preview benefit suggests that a display period of approximately 500ms is necessary for the participant to process and inhibit the preview set (Watson & Humphreys, 1997; Kunar et al., 2003a). Studies have shown, however, that faces elicit faster electrical responses in the brain (known as N170) than other non-face stimuli (Bentin et al., 1996; Eimer, 1998, 2000a, 2000b, 2000c; George et al., 1996). Further, Watson and Blagrove (2010) found that, under some circumstances, a preview search task using faces was equally efficient when the preview was 250ms as when it was 1000ms (although, it should be noted that the authors used schematic faces with either a positive or negative valance). It is therefore important to establish whether this is also true for the stimuli used in these experiments. Experiment 1a examined the difference between preview durations using a search task without a dual-task. Experiment 1b examined the difference when there was a dual-task.

2.3. Experiment 1a

The purpose of Experiment 1a was to replicate the preview benefit effect using the stimulus set we intended to use throughout this chapter. Every experiment took place at the Department of Experimental Psychology, University of Oxford and received ethical approval by the Medical Sciences Inter Divisional Research Ethics Committee on 7 February 2013 (reference: MSD-IDREC-C1-2013-19). Before taking part in any experiment, all participants read and signed a consent form explaining the nature of the experiment, how the data would be used, and their right to withdraw. In order to determine the number of participants to use in the experiments, the number of participants across 74 studies from

20 papers on preview search was calculated (details of the papers can be found at Appendix 1). The number of participants ranged from 3 to 48, with a mean of 14.43. To err on the side of the caution and ensure there was sufficient data, 20 participants took part in each experiment with the exception of Experiments 1a and 1b. As Experiments 1a and 1b were merely designed to replicate previous studies on preview search and validate the stimuli, 12 participants were deemed sufficient in this instance.

2.3.1. Participants

Twelve participants (10 female) took part in exchange for a payment of £5. Participants were aged between 20 and 30 (Mean = 25.5 years, SD = 3.4 years) and reported having normal or corrected-to-normal vision. One participant was left-handed.

2.3.2. Stimuli

Stimuli used were the same as those used in Allen et al. (2008): faces and houses. The faces used in this study were 41 monochrome images of real faces. These were spatially clipped to remove the hair. Houses were 40 monochrome photographs of houses typical of Birmingham (England) houses and were clipped to match the shape and average luminance of the set of face images. Stimuli were drawn at random and presented in a 14 x 11" grid at random at any one of 27 locations. Stimuli used here differed from Allen et al. (2008) in three ways:

1. The stimuli used here were all of one colour (red) using a colour filter (RGB value 255,0,0). As Allen et al. (2008) used red faces and blue houses as their stimuli, it has been argued that the preview benefit in their non-working memory condition could be due to colour inhibition of the preview items as opposed to location inhibition (Watson & Blagrove, 2010). In order to eliminate this possibility, all the stimuli (faces and houses) were red.

2. As there was no longer a colour/shape conjunction to define the target, participants were instead instructed to look for a red male face among red houses and red female faces.

3. Half of the items were smaller than the other half in order to make the displays more visually complex so that the task was sufficiently difficult. Half the stimuli were 4 x 4° (at a normal viewing distance of 57cm) whilst the other half were 3 x 3°. The target was 3 x 3° on 50% of the trials.

2.3.3. Design and procedure

A custom computer program written in ePrime (Psychology Software Tools, Inc.) was used to generate displays and record responses. The program was run on a PC connected to a 15" LCD monitor running at 60Hz. Participants performed a search task to find a red male face (target) amid distractors and to indicate whether the target was to the left or right of a white fixation dot in the middle of the screen. If the target was to the left of the fixation dot, participants were instructed to press the "z" key on a standard keyboard. If the target was to the right of the fixation dot, participants were instructed to press the "m" key. The target was present in all trials and participants' reactions times (RTs) and accuracy were recorded.

Participants completed four separate conditions: a half element baseline (HEB) condition, a long preview condition, a short preview condition and a full element baseline (FEB) condition. In the HEB condition participants were asked to locate the target amid either 3 or 7 red house distractors. This is similar to the singleton conditions in Treisman and Gelade's (1980) experiments where the target was of a different class to the distractors and should not therefore produce any search slope. In the FEB condition participants had to locate the target amid 4 or 8 red female face distractors and 3 or 7 red house distractors (giving total set sizes of 8 or 16 items) (Figure 1). This condition is akin to the conjunction conditions of Treisman and Gelade (1980). In the preview conditions an initial preview display of either 4 or 8 red female face distractors appeared for 1000ms (long condition) or 250ms (short condition) before being joined by a search display of a further 3 or 7 red houses and the target (giving an overall display of 8 or 16 items). Participants were encouraged to fixate on the white dot in the middle of the screen during the preview element of the preview condition, but were free to move their eyes once the search items appeared. Although the final search displays in the preview condition is identical to those

in the FEB, the time segmentation should enable participants to inhibit the initial preview display and produce shallow search slopes.

The experiment duration was approximately half an hour. Participants completed 320 trials each, split evenly across the conditions to give 80 trials in each condition. Each condition also began with an additional 10 practice trials. Conditions were blocked and counter-balanced across participants. Participants were told to respond as quickly and accurately as possible. No feedback was given for either correct or incorrect responses.

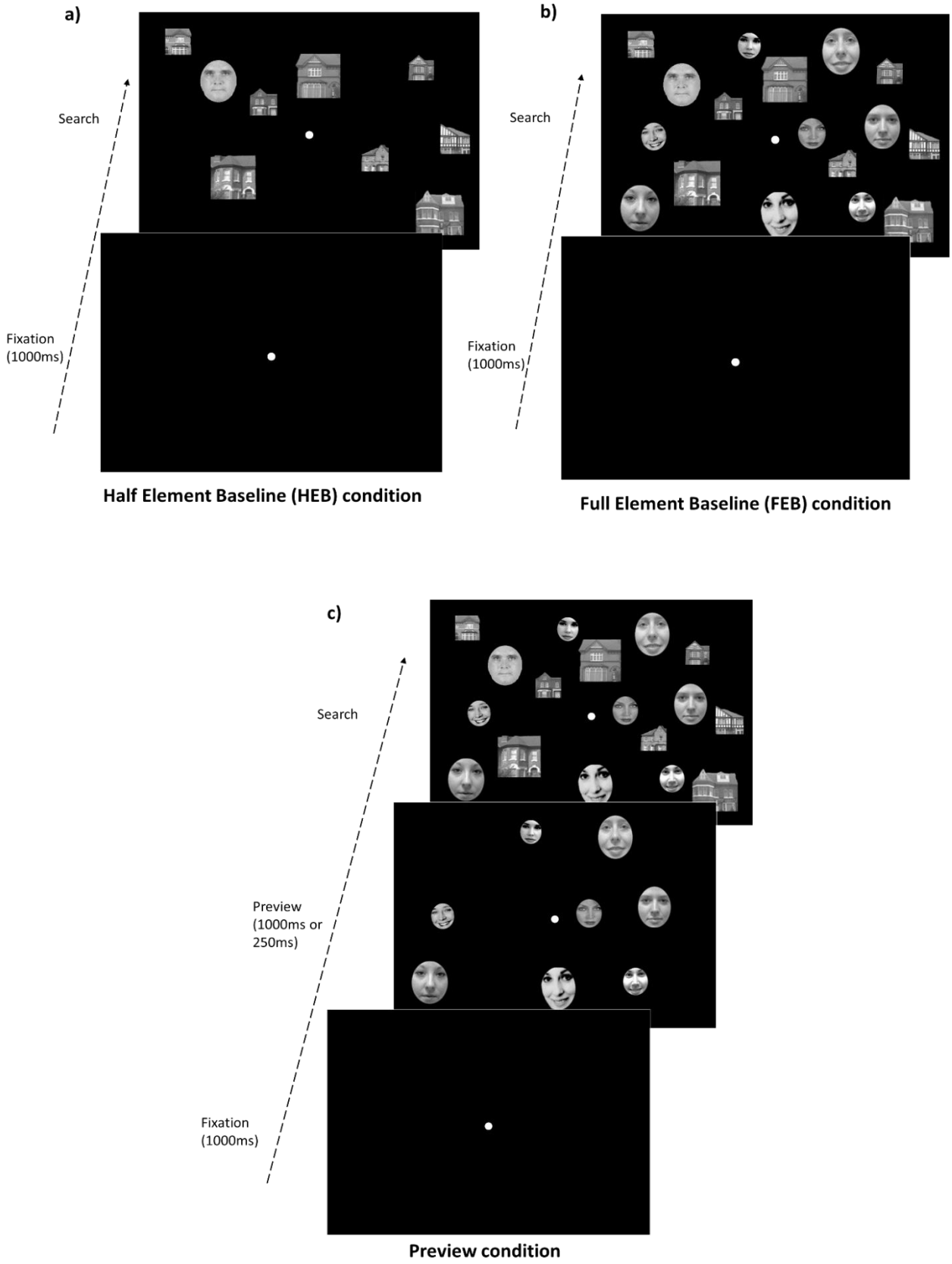

Figure 1. A typical trial in the HEB (a), FEB (b) and preview conditions (c) for Experiment 1a, higher set size. Arrows indicate the direction of time.

2.3.4. Results and discussion

Mean correct RTs (in milliseconds) for each participant were calculated for each condition of the search task. Outliers were eliminated using the modified recursive method described in Van Selst and Jolicoeur (1994) to 3 standard deviations ("SDs"; 6.7% of the data). Table 1 shows the mean RTs and SD values of the mean for each set size by condition. Figure 2 shows the search slopes for each condition, with error bars representing the standard error mean (SEM).

Table 1. Mean RTs and SDs across set size and condition for Experiment 1a.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	739	156.90
16	995	259.24
Long Preview		
8	474	86.78
16	497	82.30
Short Preview		
8	591	181.45
16	739	287.99
HEB		
4	383	42.46
8	393	47.94

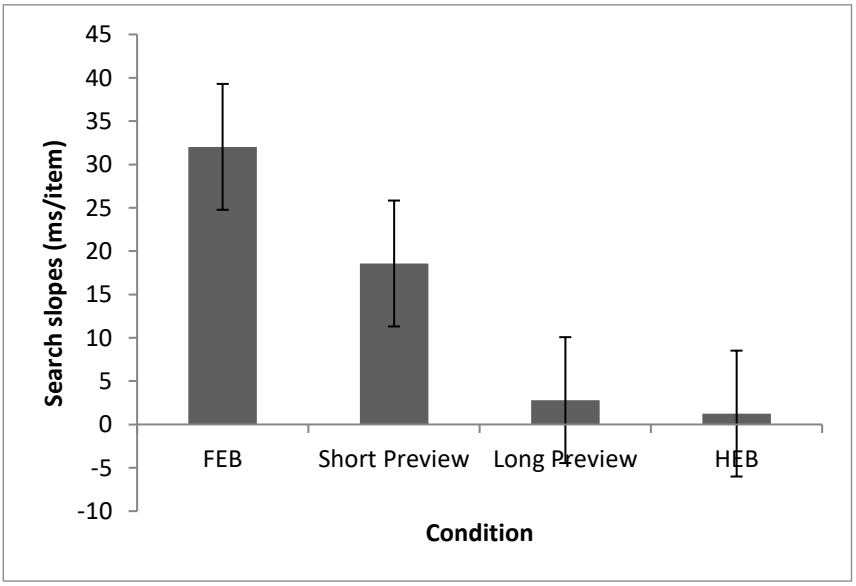

Figure 2. Search slopes across condition for Experiment 1a. Error bars represent SEM.

Long preview x short preview. Of importance, mean correct RTs were entered into a 2 x 2 analysis of variance (ANOVA) with within subject factors of condition (long preview and

short preview) and set size (8 and 16). RTs were significantly faster in the long preview condition, $F(1,11) = 13.24$, MSE = 29.37, $p < 0.01$, partial $\eta^2 = 0.55$, and at the lower set size, $F(1,11) = 23.67$, MSE = 3.71, $p < 0.01$, partial $\eta^2 = 0.68$. The condition x set size interaction was significant, showing that search was significantly more efficient in the long preview condition than in the short preview condition, $F(1,11) = 14.01$, MSE = 3.40, $p < 0.01$, partial $\eta^2 = 0.56$. A post-hoc analysis of observed power indicated that power in all cases was > 0.90. As a higher power value indicates the likelihood the outcome is a result of a genuine effect as opposed to type II error, a value > 0.85 can be considered a good indication that the result is reliable. Below this, results should not necessarily be considered unreliable, but further testing would need to be carried out to verify the result. For the sake of completeness, a more thorough analysis of the data including error rates can be seen below.

Full factor ANOVA. RTs for correct trials were entered into a within participant ANOVA, with factors of condition (FEB, HEB, long preview and short preview) and set size (8 and 16). There was a main effect of condition, $F(3, 33) = 34.56$, MSE = 30.89, $p < 0.01$, partial $\eta^2 = 0.76$, and set size, $F(1,11) = 59.72$, MSE = 4.81, $p < 0.01$, partial $\eta^2 = 0.84$. The condition x set size interaction was also significant, $F(3,33) = 25.94$, MSE = 3.13, $p < 0.01$, partial $\eta^2 = 0.65$, showing search slopes were greater in the FEB than in the preview and HEB conditions. Observed power was 1 for all values. Of importance when establishing whether or not a preview benefit occurred was the difference between the preview conditions with the HEB and the FEB. For a full preview benefit to occur the search slopes in the preview conditions should be significantly lower from that of the FEB and equivalent with that of the HEB. The data were therefore entered into separate ANOVAs, reported below, to examine this more closely.

Long preview x FEB and HEB. A 2 x 2 ANOVA with main effects of condition (long preview x FEB) and set size (8 x 16) was carried out. RTs were significantly longer in the FEB than the long preview condition, $F(1,11) = 61.99$, MSE = 28.16, $p < 0.01$, partial $\eta^2 = 0.85$, and were faster when there were 8 items than when there were 16, $F(1,11) = 68.73$, MSE = 3.39, $p < 0.01$, partial $\eta^2 = 0.86$. The condition x set size interaction was also significant, $F(1,11) = 43.45$, MSE = 3.77, $p <0.01$, partial $\eta^2 = 0.8$, showing RT increased more in the FEB at set

size 16 than in the long preview condition. A further 2 x 2 ANOVA with main effects of condition (long preview x HEB) and set size (8 x 16) was carried out. RTs were significantly shorter in the HEB than in the long preview, $F(1,11) = 30.32$, MSE = 3.78, $p < 0.01$, partial $\eta^2 = 0.73$, and at set size 8, $F(1,11) = 50.26$, MSE = 63.22, $p < 0.01$, partial $\eta^2 = 0.82$. The condition x set size interaction, however, did not reach statistical significance, $F(1,11) = 4.76$, MSE = 97.74, $p = 0.05$, partial $\eta^2 = 0.33$. All significant values had observed power of 1. Although it is difficult to draw conclusions from a null effect which is only just insignificant, the difference between the FEB and preview search slopes and the similarity between the preview and HEB search slopes indicate a full preview benefit took place.

Short preview x FEB and HEB. A 2 x 2 ANOVA with main effects of condition (short preview x FEB) and set size (8 x 16) was carried out. Both main effects were significant: RTs were slower in the FEB than in short preview condition, $F(1,11) = 9.38$, MSE = 52.27, $p < 0.01$, partial $\eta^2 = 0.46$, and were slower at set size 16 than set size 8, $F(1,11) = 54.29$, MSE = 9.06, $p < 0.01$, partial $\eta^2 = 0.83$. The interaction was also significant with RTs increasing more across set size for the FEB than for the short preview, $F(1,11) = 7.01$, MSE = 4.97, $p = 0.02$, partial $\eta^2 = 0.34$. Observed power for set size was 1, but for the main effect of condition and the two-way interaction it was 0.81 and 0.67 respectively, indicating a possibility of type II error and therefore an area for further testing. A further 2 x 2 ANOVA with main effects of condition (long preview x HEB) and set size (8 x 16) was carried out For the HEB comparison, there were also main effects of condition and set size, $F(1,11) = 22.02$, MSE = 41.99, $p < 0.01$, partial $\eta^2 = 0.67$, and $F(1,11) = 20.40$, MSE = 3.67, $p < 0.01$, partial $\eta^2 = 0.65$, respectively. The interaction was also significant, $F(1,11) = 17.32$, MSE = 3.33, $p < 0.01$, partial $\eta^2 = 0.61$. Where there is a significant difference in search slopes between the FEB and the preview condition, but the slopes are also significantly different between the preview condition and the HEB (as seen here), Watson and Humphreys (1997) reported a "partial preview benefit" had occurred. Observed power for all values were > 0.97.

Search errors. Mean percentage error rates for the search tasks are shown in Table 2. All were low (all ≤ 3%) and there was no indication that there is any speed-accuracy trade-off. Entered into a 4 x 2 ANOVA, only the main effect of condition was significant, $F(3,33) = 7.54$, MSE = 3.04, $p < 0.01$, partial $\eta^2 = 0.41$, as error rates were marginally higher in the

FEB and HEB conditions, but this was not considered high enough to indicate a speed-accuracy trade-off.

Table 2. Mean percentage error rates with standard error for Experiment 1a.

	Set Size			
Condition	8	SE	16	SE
FEB	2.64%	1.19%	1.93%	0.78%
Long Preview	1.36%	0.54%	1.13%	0.55%
Short Preview	0.42%	0.31%	1.30%	0.94%
HEB	3.00%	0.81%	2.99%	0.75%

The results indicate that a full preview benefit can be found when using faces despite a lack of colour segregation, in contradiction to Watson and Blagrove (2010). Further, the results replicate the previous literature on the preview benefit and indicate that, although faces can be processed faster than other objects (Bentin et al., 1996; Eimer, 1998, 2000a, 2000b, 2000c; George et al., 1996), using them as preview stimuli did not enable a preview benefit to fully form after only 250ms (short preview condition).

2.4. Experiment 1b

Experiment 1b tested whether the results in experiment 1a could be replicated when using a dual-task alongside the search task.

2.4.1. Participants

Twelve participants (7 female) took part in exchange for £5. Participants were aged between 19 and 30 (Mean = 22.6 years, SD = 3.9 years) and reported having normal or corrected-to-normal vision. All participants were right-handed.

2.4.2. Stimuli

Stimuli were the same as those used in Experiment 1a. The dual-task was a working memory task consisting of six red female faces drawn from the same 40 red female faces

used in the search task. All stimuli used in the working memory task were the same size (4 x 4°).

2.4.3. Design and procedure

The experiment duration was approximately half an hour. The overall design of the experiment was identical to that used in Experiment 1a with the addition of a working memory task. Items in the working memory task were displayed on a white background to differentiate them from the items in the search task (which were displayed on a black background). The procedure was the same as that used in Experiment 1a but with the working memory task taking place around the search task (see Figure 3). For the working memory task, participants viewed a display of six red female faces (1000ms) and were asked to memorise their layout (as in Allen et al. (2008)). The procedure then continued for the visual search task, as in Experiment 1a. This was followed by a second display of red faces which was either identical to the first display (on 50% of trials, "identical" trials) or different (one face was in a different location on the screen; remaining 50% of trials, "different" trials). Participants were told to press the "s" key if the displays were the same or the "d" key if they were different. Participants were told to prioritise this working memory task over the visual search task and to aim to be as accurate as possible.

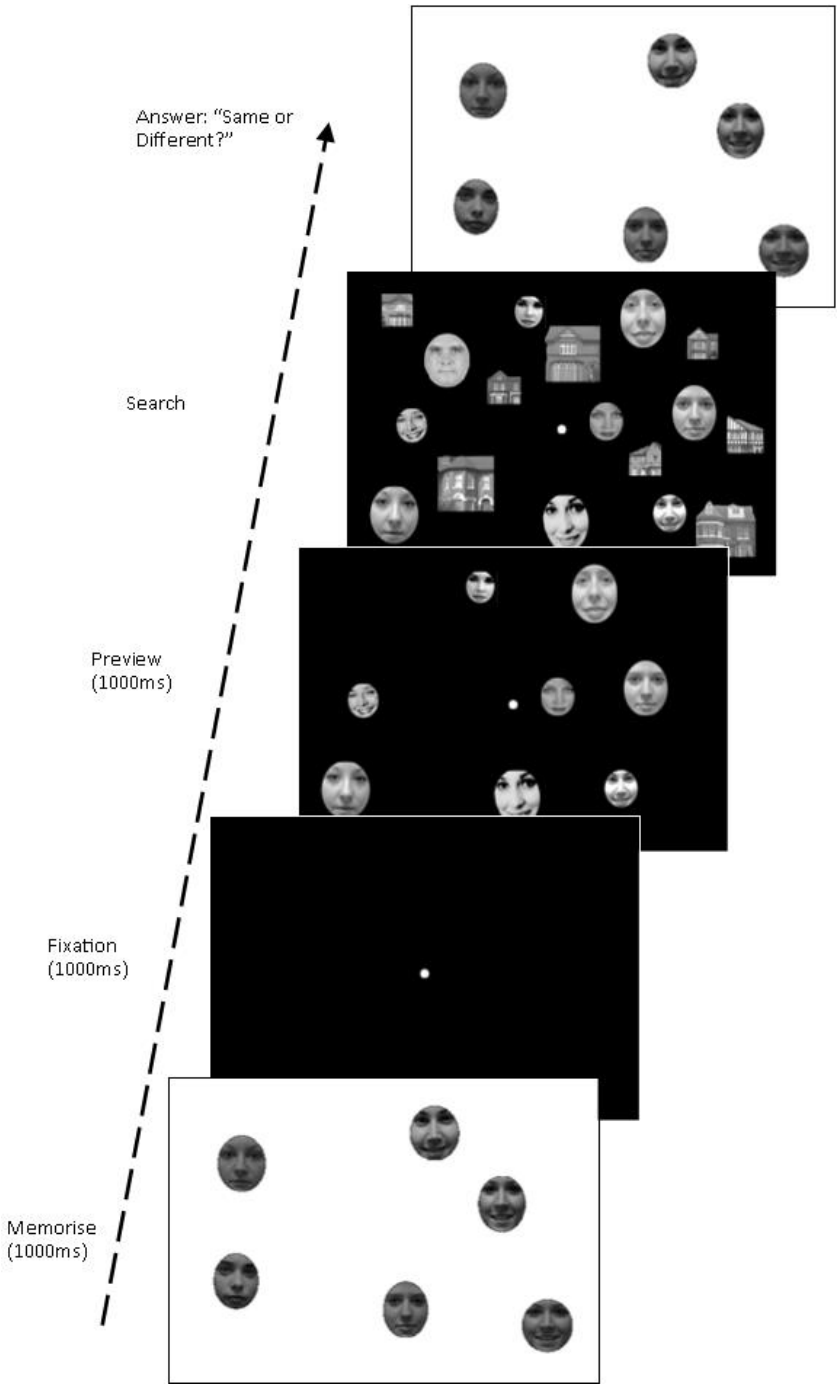

Figure 3. Typical trial for Experiment 1b. Long preview condition, higher set size. HEB, FEB and short preview conditions were the same as those in Experiment 1a but with working memory slides in the first and the last presentations.

2.4.4. Results and discussion

Mean correct RTs for each participant were calculated for each condition of the search task. Outliers were eliminated using the same method described in Experiment 1a (8% of the data). Figure 4 shows search slopes for each condition and Table 3 shows the mean RTs and SDs values for each set size by condition.

Table 3. Mean RTs and SDs across set size and condition for Experiment 1b.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	857	130.01
16	1087	203.71
Long Preview		
8	581	103.41
16	687	162.28
Short Preview		
8	700	143.58
16	856	214.35
HEB		
4	618	109.55
8	625	111.83

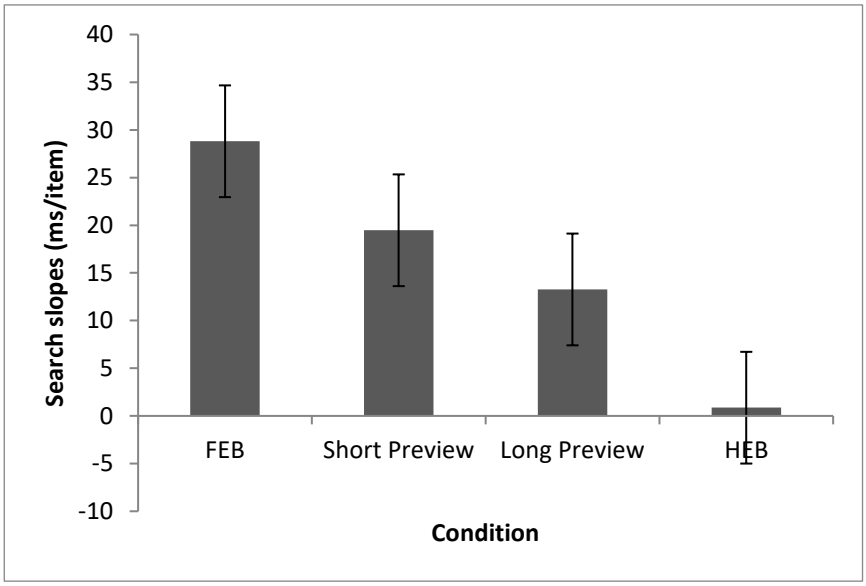

Figure 4. Search slopes for each condition for Experiment 1b. Error bars represent SEM.

Long preview x short preview. Of importance, mean correct RTs were entered into a 2 x 2 ANOVA with within participant factors of condition (long preview and short preview) and set size (8 and 16). RTs were significantly slower in the short preview condition than in the long preview condition, $F(1,11) = 32.09$, $MSE = 7.78$, $p < 0.01$, partial $\eta^2 = 0.75$, and at the

higher set size, $F(1,11) = 35.28$, MSE = 5.84, $p < 0.01$, partial $\eta^2 = 0.76$. The two-way interaction was also significant; search was still significantly more efficient in the long preview condition than in the short preview condition, $F(1,11) = 10.78$, MSE = 0.69, $p < 0.01$, partial $\eta^2 = 0.54$. Observed power for all values > 0.85, suggesting a slight chance of type II error. For the sake of completeness, a more thorough analysis of the data including error rates and working memory accuracy can be found below.

Full factor ANOVA. Mean correct RTs were entered into an ANOVA with within participant factors of condition (FEB, HEB, long preview and short preview) and set size (8 and 16). Both main effects were significant: RTs were slower in the preview and FEB conditions, $F(3,33) = 43.01$, MSE = 14.89, $p < 0.01$, partial $\eta^2 = 0.84$ and were slower when there were 16 items as opposed to 8, $F(1,11) = 74.53$, MSE = 5.02, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interaction was also significant, $F(3,33) = 26.56$, MSE = 1.99, $p < 0.01$, partial $\eta^2 = 0.71$. Observed power in each case was 1. As with the previous experiment, the data were then split into separate ANOVAs to examine the effect of the working memory task and the duration of the preview on the preview benefit.

Long preview versus FEB and HEB. A 2 x 2 ANOVA with main effects of condition (long preview x FEB) and set size (8 x 16) was conducted. RTs were significantly slower in the FEB condition, $F(1,11) = 69.65$, MSE = 19.74, $p < 0.01$, partial $\eta^2 = 0.86$ and when there were 16 items as opposed to 8, $F(1,11) = 86.17$, MSE = 3.94, $p < 0.01$, partial $\eta^2 = 0.89$. The two-way interaction was significant also, $F(1,11) = 20.21$, MSE = 2.29, $p <0.01$, partial $\eta^2 = 0.65$, suggesting search was less efficient in the FEB than in the long preview condition. Observed power > 0.98 in each case. An additional 2 x 2 ANOVA with main effects of condition (long preview x HEB) and set size (8 x 16) was carried out. There was a main effect of set size, $F(1,11) = 37.34$, MSE = 1.03, $p < 0.01$, partial $\eta^2 = 0.77$, but no main effect of condition $F(1,11) = 0.15$, MSE = 13.08, $p = 0.71$, partial $\eta^2 = 0.01$. The condition x set size interaction was statistically significant, $F(1,11) = 19.66$, MSE = 1.45, $p < 0.01$, partial $\eta^2 = 0.64$, replicating previous findings from experiment 1a that the long preview condition was not as efficient as the HEB when participants also performed a secondary attention-demanding task. Observed power on significant values were all > 0.98, thus indicating the effect of type II error was negligible.

Short preview versus FEB and HEB. Data were entered into a 2 x 2 ANOVA with main effects of condition (short preview x FEB) and set size (8 x 16). Both main effects were significant. RTs were longer in the FEB than in short preview condition, $F(1,11) = 32.22$, $MSE = 14.03$, $p < 0.01$, partial $\eta^2 = 0.75$, and were longer at set size 16, $F(1,11) = 73.59$, $MSE = 6.08$, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interaction was also significant; RTs increased more across set size for the FEB than for the short preview, $F(1,11) = 7.1$, $MSE = 2.37$, $p = 0.02$, partial $\eta^2 = 0.39$. However, observed power in the two-way interaction was 0.68, indicating the presence of type II error. A further 2 x 2 ANOVA with main effects of condition (short preview x HEB) and set size (8 x 16) was carried out. Again, both main effects were significant: $F(1,11) = 14.53$, $MSE = 20.34$, $p < 0.01$, partial $\eta^2 = 0.57$, and, $F(1,11) = 41.67$, $MSE = 1.88$, $p < 0.01$, partial $\eta^2 = 0.79$, for condition and set size respectively. The two-way interaction was also significant as RTs were slower across set size for the short preview condition, $F(1,11) = 23.51$, $MSE = 2.83$, $p < 0.01$, partial $\eta^2 = 0.68$. Observed power was > 0.93 in all cases.

Search errors. Mean percentage error rates for the can be seen in Table 4. All were low (< 2%). When entered into a 4 x 2 ANOVA, no main effects of condition $F(3,33) = 1.07$, $MSE = 4.29$, $p = 0.38$, partial $\eta^2 = 0.09$, or set size, $F(1,11) = 0.13$, $MSE = 1.73$, $p = 0.73$, partial $\eta^2 = 0.01$. The two-way interaction was also not significant, $F(3,33) = 0.47$, $MSE = 2.68$, $p = 0.71$, partial $\eta^2 = 0.04$, again suggesting that there was no speed-accuracy trade-off.

Working memory accuracy. Mean percentage accuracy rates for the working memory task can be seen in Table 5. The overall average was 67.75% and there were no significant differences between either condition, $F(3,33) = 0.74$, $MSE = 56.97$, $p = 0.54$, partial $\eta^2 = 0.06$, or set size, $F(1,11) = 0.02$, $MSE = 33.48$, $p = 0.9$, partial $\eta^2 = 0.02$, and there was no significant interaction, $F(3,33) = 0.69$, $MSE = 37.51$, $p = 0.57$, partial $\eta^2 = 0.06$, suggesting working memory accuracy was not affected by condition or set size.

Table 4. Mean percentage error rates with standard error for Experiment 1b.

	Set Size			
Condition	8	SE	16	SE
FEB	1.51%	0.76%	1.78%	0.87%
Long Preview	0.93%	0.55%	1.55%	0.79%
Short Preview	0.87%	0.39%	0.42%	0.32%
HEB	0.90%	0.46%	0.84%	0.49%

Table 5. Mean percentage WM error rate for Experiment 1b.

	Set Size	
Condition	8	16
FEB	1.51%	1.78%
Long Preview	0.93%	1.55%
Short Preview	0.87%	0.42%
HEB	0.90%	0.84%

The results from Experiments 1a & 1b replicate results found previously regarding the preview benefit, the effects of a dual-task on the preview benefit, and the effect of preview duration on the preview benefit (Watson & Humphreys, 1997; Kunar et al., 2003a; Olivers & Humphreys, 2002). We have shown here that it is possible to obtain a full preview benefit when using face stimuli, despite there being no colour segregation between the previewed and new distractors. Initially this would appear to contradict Blagrove and Watson (2010); using schematic faces in a preview task, they found that a full preview benefit could not be obtained using face stimuli unless the preview was a shorter duration than normal (250ms as opposed to 1000ms). It is important to note a number of differences in the experimental design between Experiment 1 and those in Blagrove and Watson (2010), however. Firstly, their stimuli were all faces, whereas the stimuli here were a combination of faces and houses. It is possible the shape difference here between the red male face target and the distractor houses was partly responsible for the full preview benefit. Secondly, the studies of Blagrove and Watson looked at the effect of emotion on the preview benefit, therefore at least one item in their displays was either positively or negatively valenced. In contrast, the faces used in the present studies were a mixture of positively valenced (smiling) or neutral and the target male face was always neutral. This should not, however, make much

difference as Blagrove and Watson (2010) reported little or no effect of emotional valance on the preview benefit. Lastly, stimuli used in Blagrove and Watson's (2010) studies were schematic faces, rather than real human faces. Whilst research indicates no significant difference in our ability to process or extract emotion from real or schematic human faces (Aronoff, Barclay & Stevenson, 1988; McKelvie, 1995; Sagiv & Bentin, 2001), it is still important to note that the reduced complexity of the Blagrove and Watson displays could have meant there was not enough of a visual distinction between the target and the search distractors that it appeared with to enable it to stand out. Search therefore would proceed more serially as participants must check each item in turn before accepting or rejecting it.

In Experiment 1b, participants were instructed to prioritise the working memory task over the preview task. As research suggests participants perform better on the task they are asked to prioritise in a dual-task study (Broadbent, 1958), it is possible that a preview benefit may be seen under working memory task conditions if participants are told to prioritise the preview task. However, previous studies suggest that this is unlikely. In their original paper, Watson and Humphreys (1997) instructed participants that when the preview items appeared, they were to focus on these instead of attempting to complete the working memory task: in their case, is was an RSVP task which participants were told to shadow, thus when preview items appear participants may have otherwise been attempting to continue reporting digits. Despite being told to focus on the preview and abandon completing the secondary task if they had not yet managed to name all digits, interference of the secondary task was still found. It does not, therefore seem probable that instructing participants to focus on the preview task would prevent secondary task disruption from occurring, although this possibility should be explored in future research to eliminate this potential confound.

The results of Experiments 1a & 1b also indicate that despite the use of face stimuli as preview items, preview search was significantly more efficient at preview durations longer than 250ms. This included conditions which had a working memory task alongside the preview. In order to see if a secondary task has an effect on preview benefit, the no working memory condition must be able to produce an efficient preview search, else the effects seen may be due to the inability to form a preview under shortened preview conditions

rather than because of the secondary task. The search methodology explored in Experiments 1a and 1b was therefore found to be suitable for requirements, hence consequent experiments presented in this chapter were commenced using previews of 1000ms.

2.5. Experiment 2

Experiment 2 examined the effect of dual-task content on the preview benefit by comparing search efficiency when the secondary task stimuli was neutrally identical to the preview items (i.e. both tasks use upright faces as stimuli), to search efficiency when the secondary task stimuli was similar, but not identical (i.e. preview contained upright faces whereas the secondary task contained inverted faces. Visual working memory can aid search both by maintaining a record of distractor stimuli which has already been attended to and rejected so that this information is not searched through again (Watson & Humphreys, 1997; Al-Aidroos et al., 2012), and by maintaining a template of the target (Woodman & Arita, 2011; Carlisle, Arita, Pardo, & Woodman, 2011). A number of studies have demonstrated that maintaining an item (such as a target template) in visual working memory subsequently guides attention towards items which have similar features (Duncan, 1989; Desimone & Duncan, 1995; Woodman & Luck, 2007; Woodman, Luck & Schall, 2007). For example, Downing (2000) conducted experiments where participants were required to hold an object in visual working memory and then perform a probe detection task with a choice of two objects, one novel object and one the same as the visual working memory item. Participants were quicker to identify the probe when it was next to an item held in visual working memory, indicating that attention is preferentially allocated towards stimuli matching the content of working memory.

Similar work using search tasks and working memory content was conducted by Soto and colleagues (Soto, Heinke, Humphreys & Blanco, 2005; Soto, Humphreys & Rotshtein, 2007; Soto, Hodsoll, Rotshtein & Humphreys, 2008). In their studies, participants were presented with a coloured shape (e.g. red triangle, blue square, green hexagon) to hold in working memory and then perform a search task for a tilted bar among vertical bars. The tilted target bar and the vertical distractors were all contained within a shape. The target

could either be in the shape held in working memory (valid trials), in a different shape, but the working memory shape was also present in the display (invalid trials) or in a different shape and the working memory shape was not present in the display (neutral trials). Relative to neutral trials, the authors found search was faster in the valid trials and slower in the invalid trials. They suggested that participants' attention was biased towards the content of the working memory task.

More recently, Dube, Basciano, Emrich and Al-Aidroos (2016) examined whether the inhibitory effects of working memory (as demonstrated in preview search) could co-occur with the facilitatory effects of working memory (as demonstrated by attentional guidance towards items which share target features). By using a preview search with a variable target across trials, Dube et al. (2016) demonstrated that inhibition could take place whilst a target template was simultaneously held in visual working memory. Further, in a second experiment they included a random singleton distractor which, on some trials, shared its colour with the target. On these trials, response times to the target were slowed, indicating that the target template facilitated the processing of the singleton. They concluded, therefore, that both inhibitory and facilitatory effects of visual working memory could take place simultaneously.

The purpose of Experiment 2 was to see whether holding items in visual working memory that are similar to the preview distractors in a preview search causes attention to be inefficiently biased towards the preview items. Here, the content of the working memory task (female faces) did not match the target of the search, but instead matched the preview items. However, the working memory items were not exactly the same as the preview items, but were instead from the same stimulus category as the preview items. In order to assess whether the content of working memory had an effect on the preview benefit, there needed to be a comparable working memory condition with stimuli similar in visual complexity, but processed differently to the standard working memory items. Previous literature has shown that the way in which we process inverted faces is not the same as how we process upright faces. For example, upright faces are processed more holistically, combining the pattern of features in order to generate identity (Farah, Wilson, Drain & Tanaka, 1998; Leder & Bruce, 2000; Itier & Taylor, 2002). Therefore the current experiment

had two preview/working memory conditions: a condition which employed upright faces in the working memory task and a condition where the faces were inverted (processed differently to upright faces, but matching the preview set in visual complexity).

If the content of the working memory task affected the preview benefit, then one of two things could happen:

(1) The upright condition would show less of a preview benefit than the inverted condition due to the similarity of the upright previewed stimuli to the working memory stimuli and participants would be unable to inhibit items high in similarity to the ones they were actively trying to remember, or;

(2) The upright condition would show a greater benefit than the inverted condition, as the upright previewed stimuli may engage attention faster and be processed more successfully owing to similar stimuli in the working memory task biasing attention towards them. On the other hand, if the content of the working memory were to not affect the preview benefit (e.g. because just the locations of the preview items are inhibited) then there would be no difference between the upright and inverted conditions.

2.5.1. Participants

Twenty participants (17 female) took part in exchange for £7.50. Participants were aged between 20 and 32 (Mean = 23.92 years, SD = 4.57 years) and reported having normal or corrected-to-normal vision. 6 participants were left-handed.

2.5.2. Stimuli

Stimuli were the same as those used in Experiments 1a and 1b.

2.5.3. Design and procedure

The experiment lasted approximately 45 minutes. The design and procedure were the same as in Experiment 1b, but without the shorter preview condition and with a working memory/preview condition that used images of inverted faces.

2.5.4. Results and discussion

Outliers were eliminated using the same method as the previous experiments (6.4% of the data). Table 6 shows the mean RTs and SDs for each set size by condition. Figure 5a shows the search slopes for each condition for the no working memory trials and Figure 5b shows the search slopes for each condition for the working memory trials.

Table 6. Mean RTs and SDs across set size and condition for Experiment 2.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	838	175.29
16	1181	356.53
Preview		
8	524	115.53
16	538	127.66
HEB		
4	387	45.34
8	399	44.32
WM FEB		
8	965	205.56
16	1206	269.28
WM Inverted		
8	742	301.03
16	828	351.60
WM Preview		
8	690	254.71
16	758	298.96
WM HEB		
4	634	150.65
8	650	152.85

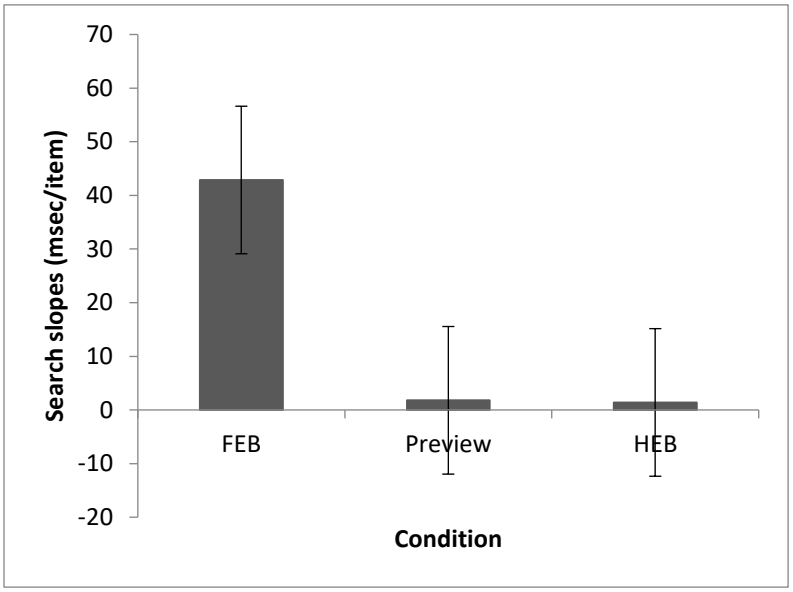

Figure 5a. Search slopes across condition for no working memory trials for Experiment 2. Error bars represent SEM.

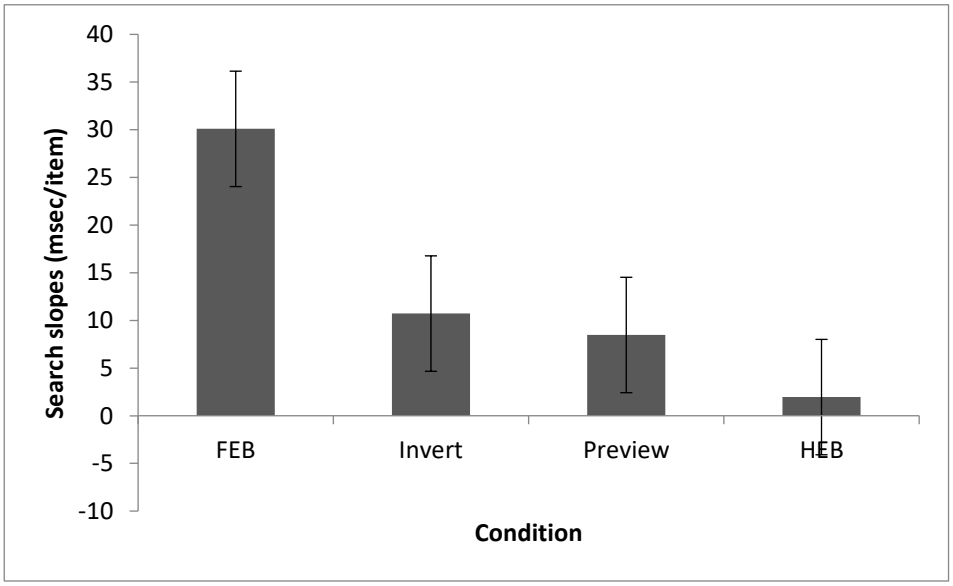

Figure 5b. Search slopes across condition for working memory trials for Experiment 2. Error bars represent SEM.

No working memory preview x working memory preview. Of key importance, the data for the no working memory preview condition and the collapsed data (see analysis below) for the working memory preview conditions were entered into a 2 x 2 ANOVA with main effects of working memory (working memory x no working memory) and set size (8 x 16). Both main effects were significant, $F(1,19) = 18.18$, $MSE = 57.58$, $p < 0.01$, partial $\eta^2 = 0.53$,

and F(1,19) = 22.69, MSE = 2.26, p < 0.01, partial η^2 = 0.54, for condition and set size respectively, and the two-way interaction was significant, F(1,19) = 22.13, MSE = 1.19, p < 0.01, partial η^2 = 0.54, again indicating a likely disruption to the preview benefit by the working memory task. Observed power for all values was > 0.98.

Inverted preview x upright preview. Results for the upright working memory preview condition and the inverted working memory preview condition were entered into a 2 x 2 ANOVA with main factors of working memory type (upright x inverted) and set size (8 x 16). There was a significant effect of condition, F(1,19) = 6.83, MSE = 10.72, p = 0.02, partial η^2 = 0.26, and of set size, F(1,19) = 26.84, MSE = 4.39, p <0.01, partial η^2 = 0.59, but the two-way interaction was not significant, F(1,19) = 0.87, MSE = 1.86, p = 0.36, partial η^2 = 0.04. This suggests there was no significant difference between search efficiency in either working memory preview conditions. As there was no significant difference in search slope between the upright and inverted preview working memory conditions, the two conditions were collapsed for the remaining analyses.

The difference in search slopes between the working memory preview conditions and the no working memory preview condition indicate that the working memory task had disrupted the preview benefit. However, the lack of a significant difference between the search slopes of the inverted working memory preview condition and the upright working memory preview condition suggests that the similarity between the stimuli in the working memory task and the preview stimuli does not have a direct impact on search performance (at least, not in this instance, but see Experiments 3 – 4b for the impact of modality). For the sake of completeness, a more thorough analysis of the data can be seen below.

Full factor ANOVA. Mean correct RTs were entered into a 2 x 3 x 2 analysis of variance with within participant factors of working memory (working memory x no working memory), condition (FEB x HEB x preview) and set size (8 x 16). There were main effects of condition, F(2,38) = 101.53, MSE = 60.33, p < 0.01, partial η^2 = 0.84, set size, F(1,19) = 122.41, MSE = 6.96, p < 0.01, partial η^2 = 0.87, and working memory, F(1,19) = 22.43, MSE = 91.14, p < 0.01, partial η^2 = 0.54. The working memory x condition interaction was significant, F(2,38) = 8.06, MSE = 22.19, p = 0.01, partial η^2 = 0.30: RTs tended to be progressively slower for preview and FEB conditions when preforming a working memory task. The condition x set

size interaction was also significant, $F(2,38) = 65.06$, $MSE = 7.02$, $p < 0.01$, partial $\eta^2 = 0.77$, but the working memory x set size interaction was not significant, $F(1,19) = 0.32$, $MSE = 3.34$, $p = 0.58$, partial $\eta^2 = 0.02$. The three-way interaction was significant, $F(2,38) = 12.06$, $MSE = 3.22$, $p < 0.01$, partial $\eta^2 = 0.39$. Observed power for all significant values was >0.94, suggesting the impact of type II error was minimal.

No working memory preview x FEB and HEB. A 2 x 2 ANOVA comparing the no working memory preview condition and the no working memory FEB condition was conducted. RT were significantly faster in the preview condition than the FEB, $F(1,19) = 68.06$, $MSE = 67.36$, $p < 0.01$, partial $\eta^2 = 0.78$, and at the lower set size, $F(1,19) = 61.56$, $MSE = 10.37$, $p < 0.01$, partial $\eta^2 = 0.76$. The two-way interaction was also significant, $F(1,19) = 45.94$, $MSE = 11.75$, $p < 0.01$, partial $\eta^2 = 0.71$. Observed power was 1 for all values. A further 2 x 2 ANOVA comparing the no working memory preview condition and the no working memory HEB condition was carried out. RTs were significantly faster in the HEB condition, $F(1,19) = 43.9$, $MSE = 8.67$, $p < 0.01$ partial $\eta^2 = 0.76$, and at the lower set size, $F(1,19) = 8.18$, $MSE = 0.42$, $p = 0.01$, partial $\eta^2 = 0.39$. The two-way interaction for the HEB comparison was not significant, $F(1,19) = 0.13$, $MSE = 0.38$, $p = 0.72$, partial $\eta^2 = 0.01$, suggesting that a full preview benefit had occurred. Observed power for condition was 1, but was only 0.77 for set size.

Working memory preview x FEB and working memory preview x HEB. A 2 x 2 ANOVA comparing the working memory preview condition and the working memory FEB condition was conducted. RTs were significantly slower in the FEB than in the collapsed preview conditions, $F(1,19) = 60.95$, $MSE = 34.86$, $p < 0.01$, partial $\eta^2 = 0.76$, and at the higher set size, $F(1,19) = 124.16$, $MSE = 4.32$, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interaction was also significant, $F(1,19) = 31.86$, $MSE = 3.71$, $p < 0.01$, partial $\eta^2 = 0.63$. Observed power was 1 in all cases. A further 2 x 2 ANOVA comparing the working memory preview condition and the working memory HEB condition was also conducted. RTs were slower in the collapsed preview conditions than in the HEB, $F(1,19) = 5.64$, $MSE = 49.21$, $p = 0.02$, partial $\eta^2 = 0.23$ and at set size 16, $F(1,19) = 34.61$, $MSE = 1.52$, $p < 0.01$, partial $\eta^2 = 0.65$. The two-way interaction was significant, $F(1,19) = 15.14$, $MSE = 1.68$, $p < 0.01$, partial $\eta^2 = 0.44$, suggesting the preview benefit had been disrupted by the working memory task. Observed

power for set size and the two-way interaction were high (both > 0.96), but was lower for condition (0.62).

Working memory FEB x no working memory FEB. As the search slopes for the working memory FEB and no working memory FEB appeared to be quite different, the data were entered into a 2 x 2 ANOVA with within participant factors of working memory (working memory x no working memory) and set size (8 x 16). There was no main effect of working memory, $F(1,19) = 1.89$, MSE = 61.01, $p = 0.19$, partial $\eta^2 = 0.09$, but there was a main effect of set size, $F(1,19) = 92.48$, MSE = 18.43, $p < 0.01$, partial $\eta^2 = 0.83$. The set size x working memory interaction was also significant, $F(1,19) = 6.3$, MSE = 8.27, $p < 0.01$, partial $\eta^2 = 0.25$. Observed power for the set size effect was 1, but was only 0.67 for the interaction. It does not appear that the working memory task differentially impacted the FEB condition, but the difference in search slopes appears to have been caused by the wider range of RTs in the no working memory condition across set size. It is not clear why this is the case, indicating an area for potential future research.

Search errors. Mean percentage error rates for each condition and set size are shown in Table 7. As in the previous experiments, error rates for the search tasks were low (all ≤ 1.50%). Entered into a 3 x 2 x 2 ANOVA with within participant factors of condition (FEB, collapsed preview and HEB), working memory (no working memory x working memory), and set size (8 x 16) the only effect or interaction to reach significance was the main effect working memory $F(1,19) = 11.13$, MSE = 1.76, $p < 0.01$, partial $\eta^2 = 0.37$, as search accuracy was higher in the working memory conditions than the no working memory conditions. This suggests that there may have been a small speed-accuracy trade-off in the no working memory conditions, but given that the error rates were no greater than 1.50%, the impact of this on the overall results would be negligible.

Working memory accuracy. Working memory accuracy for each condition are shown in Table 8. Overall accuracy for the working memory task was 67.24%, which is similar to Experiments 1a and 1b. Entered into a 4 x 2 ANOVA with main effects of condition (FEB, inverted preview, upright preview and HEB) and set size (8 and 16), the main effect of condition was not significant $F(3,57) = 1.02$, MSE = 54.56, $p = 0.39$, partial $\eta^2 = 0.05$, and the two-way interaction was not significant, $F(1,19) = 2.54$, MSE = 41.59, $p = 0.06$, partial

$\eta^2 = 0.12$. However, there was a main effect of set size $F(1,19) = 6.80$, MSE = 43.22, $p = 0.02$, partial $\eta^2 = 0.27$. Interestingly, the lower set sizes had worse working memory accuracy than the higher set sizes. As the lower set sizes tended to also be faster, it is possible that participants prioritised search at these set sizes, but the reason for this difference remains unclear and should be addressed in subsequent studies.

Table 7. Mean percentage error rates with standard error for Experiment 2.

	Set Size			
Condition	8	SE	16	SE
FEB	1.29%	0.3%	1.50%	0.42%
Preview	1.14%	0.48%	1.21%	0.51%
HEB	1.31%	0.51%	1.60%	0.62%
WM FEB	0.67%	0.33%	1.04%	0.35%
WM Inverted	0.39%	0.22%	0.80%	0.35%
WM Preview	0.38%	0.21%	1.37%	0.47%
WM HEB	0.94%	0.35%	0.50%	0.29%

Table 8. Mean percentage WM accuracy across condition and set size for Experiment 2.

	Set Size	
Condition	8	16
WM FEB	69.57%	67.99%
WM Inverted	65.21%	67.22%
WM Preview	63.88%	68.83%
WM HEB	64.50%	70.00%

The lack of significance between the upright and inverted working memory conditions (see Figure 5b) for preview search suggests that, regardless of whether the stimuli in the working memory task and the preview were identical or different (upright or inverted), the disruption to the preview benefit was equal. This suggests that the efficiency with which the preview set is processed is not affected by the content of the stimuli. Participants' attention may still have been biased towards the preview set in the upright working memory condition more so than in the inverted condition due to the stimulus similarity (as suggested by Downing (2000)), but this appears to have given neither a direct benefit nor hindrance to how well participants were subsequently able to ignore the previewed items.

The results thus far have not addressed which phase of the preview benefit is being disrupted by the secondary tasks. Humphreys et al. (2002) proposed that it is possible to distinguish between an initialisation phase and a maintenance phase of preview search on the basis of selective dual-task interference effects. Their study required participants to memorise a stream of digits presented as either a visual stream or an audio stream. The onset of the digit stream either coincided with the onset of the preview items or began a second after the preview items had onset. The authors found that preview benefit was disrupted by the visual dual-task regardless of when the items onset, whereas the audio task only disrupted the preview when it onset as the items appeared. They argued therefore that the preview could be split into two separate phases: an initialisation phase, where the active intention to inhibit the previewed items takes place, and a maintenance phase, where the inhibition is maintained through to the search taking place. Initiation is indifferent to the modality of the secondary task, with both audio and visual tasks causing disruption, maintenance is modality specific, with only visual tasks causing disruption.

From these results it follows that, if participants are unable to initialise inhibition of the preview, then the preview benefit should be as disrupted by a working memory task from a different modality (e.g. an audio task) as by a visual working memory task, since the tasks may require a common pool of resources used to set-up inhibitory processing. If, however, it is the maintenance phase only which is affected by the current working memory task then an audio task will not cause as much disruption to the benefit. Experiment 3 addressed this by used an audio working memory task that temporally surrounded the search task (as opposed to beginning with the search task or just after the search task, as in Humphreys et al. (2002)) to examine which phase of the preview is disrupted.

2.6. Experiment 3

Experiment 3 examined whether an audio working memory task would disrupt the preview benefit as much as a visual based working memory task, to indicate whether the initialisation phase or the maintenance phase of the preview benefit is being disrupted by a secondary task which temporally surrounds the preview search.

2.6.1. Participants

Twenty participants (13 female) took part in exchange for £7.50. Participants were aged between 18 and 40 (Mean = 25.11 years, SD = 5.24 years) and reported having normal or corrected-to-normal vision. All participants were right-handed.

2.6.2. Stimuli

Stimuli were the same as that used in Experiments 1a, 1b and 2.

2.6.3. Design and procedure

The experiment lasted approximately 45 minutes. The design and procedure were identical to that of Experiment 2 apart from the working memory task. Here, participants were shown a white screen whilst a sequence of 6 tones, each lasting approximately 250ms (such that the entire sequence duration was 1500ms) was played over speakers. The tones were chosen at random from a selection of 20 unique tones that ranged in frequency from 100Hz to 1000Hz at gradients of 50Hz, i.e. 100Hz, 150Hz, 200Hz etc. Again, for each trial, participants were instructed to indicate whether the sequence of tones was the same or different when played the second time by pressing the "s" or "d" keys for same or different respectively. If different, one of the tones would be a different frequency from that played previously whilst the other 5 remained the same. The volume was kept constant between participants, and all participants reported having normal hearing.

2.6.4. Results and discussion

As with the previous experiments, outliers were eliminated using the Van Selst and Jolicoeur (1994) method (6.84% of the data). Table 9 shows the mean correct RTs and SDs for each condition by set size. Figure 6a shows the search slopes for each condition for the no working memory conditions and Figure 6b shows the search slopes for each condition for the auditory working memory conditions.

Table 9. Mean RTs and SDs across set size and condition for Experiment 3.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	772	139.71
16	1037	237.51
Preview		
8	457	78.60
16	478	92.91
HEB		
4	398	48.62
8	404	47.39
WM FEB		
8	867	179.71
16	1119	266.76
WM Preview		
8	629	191.73
16	690	235.42
WM HEB		
4	493	84.20
8	509	91.21

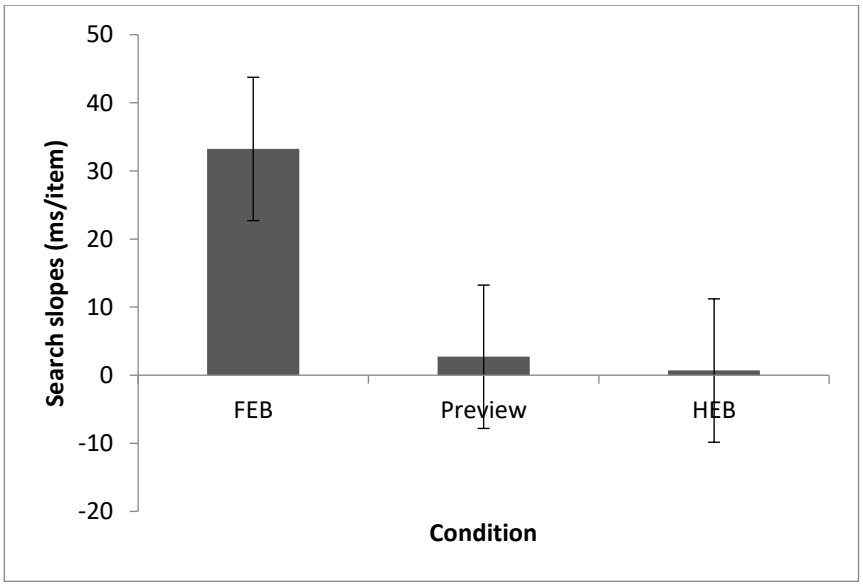

Figure 6a. Search slopes across condition for no working memory trials for Experiment 3. Error bars represent SEM.

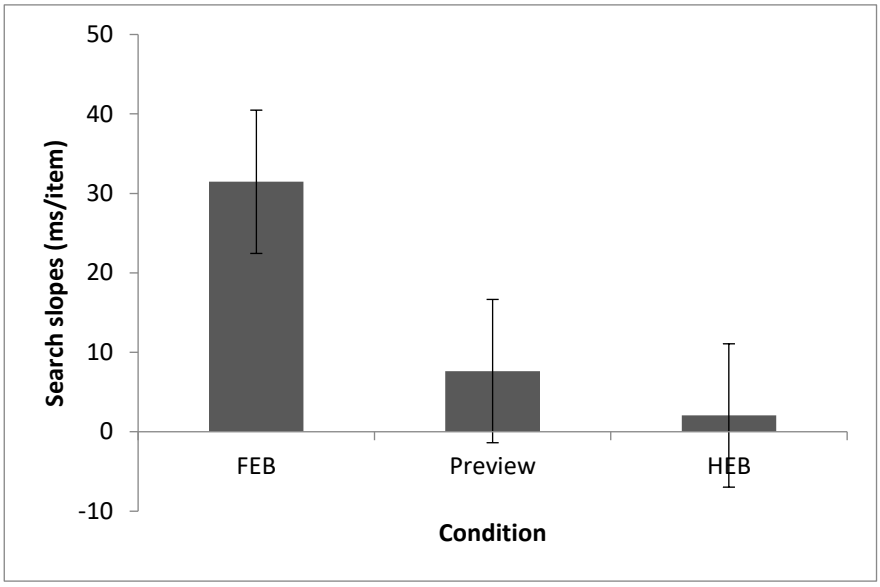

Figure 6b. Search slopes across condition for no working memory trials for Experiment 3. Error bars represent SEM.

No working memory preview x working memory preview. Of importance, the data for the no working memory preview condition and the data for the working memory preview condition were entered into a 2 x 2 ANOVA with main effects of working memory (working memory x no working memory) and set size (8 x 16). Both main effects were significant, $F(1,19) = 31.14$, $MSE = 23.79$, $p < 0.01$, partial $\eta^2 = 0.62$, and $F(1,19) = 17.27$, $MSE = 1.98$, $p < 0.01$, partial $\eta^2 = 0.48$, for condition and set size respectively, and the two-way interaction was significant, $F(1,19) = 7.53$, $MSE = 1.11$, $p < 0.01$, partial $\eta^2 = 0.27$, again indicating a possible disruption to the preview benefit by the working memory task. Observed power was > 0.98 for the main effects, but was only 0.71 in the two-way interaction. For completeness, a more detailed analysis of the data have been carried out below.

Full factor ANOVA. A 2 x 3 x 2 ANOVA was carried out with within participant factors of working memory (working memory x no working memory), condition (FEB x HEB x preview) and set size (8 x 16). There were main effects of working memory, $F(1,19) = 34.16$, $MSE = 28.22$, $p < 0.01$, partial $\eta^2 = 0.64$, and condition, $F(2,38) = 190.23$, $MSE = 28.66$, $p < 0.01$, partial $\eta^2 = 0.91$, and set size, $F(1,19) = 130.38$, $MSE = 130.32$, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interactions of working memory x condition $F(2,38) = 6.83$, $MSE = 9.57$, $p < 0.01$, partial $\eta 2 = 0.26$, and condition x set size, $F(2,38) = 117.56$, $MSE = 3.11$, $p < 0.01$,

partial $\eta^2 = 0.86$, were both significant, but the working memory x set size interaction was not, $F(1,19) = 1.43$, MSE = 1.62, $p = 0.26$, partial $\eta^2 = 0.07$. The three-way interaction also did not reach significance, $F(2,38) = 2.65$, MSE = 1.42, $p = 0.09$, partial $\eta^2 = 0.12$. Observed power for all values was > 0.90.

No working memory ANOVAs. Data for the no working memory conditions were entered into two 2 x 2 ANOVAs with main effects of condition (FEB x preview; HEB x preview) and set size (8 x 16). In both ANOVAs there were main effects of condition, $F(1,19) = 159.17$, MSE = 24.42, $p < 0.01$, partial $\eta^2 = 0.89$, and $F(1,19) = 17.84$, MSE = 5.21, $p < 0.01$, partial $\eta^2 = 0.47$, for FEB and HEB conditions respectively, and set size, $F(1,19) = 113.55$, MSE = 3.64, $p < 0.01$, partial $\eta^2 = 0.86$, and $F(1,19) = 27.83$, MSE = 0.13, $p = 0.01$, partial $\eta^2 = 0.59$, respectively. The two-way interaction for the FEB comparison was significant, $F(1,19) = 95.90$, MSE = 3.11, $p < 0.01$, partial $\eta^2 = 0.84$, and the two-way interaction for the HEB comparison was also significant, $F(1,19) = 5.57$, MSE = 0.24, $p = 0.03$, partial $\eta^2 = 0.22$, again suggesting that a partial preview benefit had occurred. Observed power for significant values were all > 0.97.

Working memory ANOVAs. As before, data for the working memory conditions were entered into two 2 x 2 ANOVAs with main effects of condition (FEB x preview and HEB x preview) and set size (8 x 16). There were again main effects of condition, $F(1,19) = 162.84$, MSE = 13.64, $p < 0.01$, partial $\eta^2 = 0.93$, and $F(1,19) = 25.47$, MSE = 19.99, $p < 0.01$, partial $\eta^2 = 0.57$, (for FEB and HEB respectively), and set size, $F(1,19) = 90.54$, MSE = 5.48, $p < 0.01$, partial $\eta^2 = 0.83$, and $F(1,19) = 17.32$, MSE = 1.76, $p < 0.01$, partial $\eta^2 = 0.47$, respectively. Both two-way interactions were significant, $F(1,19) = 58.4.52$, MSE =3.11, $p < 0.01$, partial $\eta^2 = 0.75$, and $F(1,19) = 7.86$, MSE = 1.28, $p = 0.01$, partial $\eta^2 = 0.29$, implying the preview benefit had been disrupted by the working memory task. Observed power for all values were > 0.98 with the exception of preview x HEB two-way interaction, which was 0.75.

Visual working memory x audio working memory. The working memory/preview data were then compared to the visual working memory/preview data of Experiment 2. A 2 x 2 mixed design participants ANOVA was conducted with main effects of working memory task (the between subjects factor: visual x audio) and set size (the within subjects factor: 8 x 16). Whilst set size was significant, $F(1,38) = 43.65$, MSE = 0.22, $p < 0.01$, partial $\eta^2 = 0.69$, there

was no main effect of working memory F(1,38) = 1.52, MSE = 12.55, p = 0.24, partial η^2 = 0.07, and the set size x working memory task interaction was not significant, F(1,38) = 1.10, MSE = 1.57, p = 0.31, partial η^2 = 0.06. This suggests that, under these circumstances, the level of disruption to the preview benefit was not significantly better in the audio working memory condition compared to the visual working memory condition, despite it being a working memory task of a different modality to the primary (search) task.

Search errors. Mean percentage error rates for the search tasks are shown in Table 10. All error rates were low (all < 5%). When entered into a 3 x 2 x 2 ANOVA with main effects of condition (FEB, preview and HEB), working memory (working memory x no working memory) and set size (8 x 16), none of the main effects or interactions reached significance, all Fs < 2.1, all ps < 0.1, with the exception of the working memory x set size interaction, F(1,19) = 6.51, MSE = 6.76, p = 0.02, partial η^2 = 0.26. The observed power on this was only 0.68, therefore this could be due to type II errors and additional trials would be needed to verify this result.

Working memory accuracy. Mean percentage accuracy rates for the working memory task are shown in Table 11. These were similar to those of the previous experiments and were quite high (66.9%). Here accuracy was significantly higher in the FEB compared with the other search conditions, F(2,38) = 14.74, MSE = 48.92, p < 0.01, partial η^2 = 0.44, and the condition x set size interaction was also significant, F(2,38) = 7.42, MSE = 37.83, p < 0.01, partial η^2 = 0.28, although the main effect of set size was not significant, F(1,19) = 2.78, MSE = 43.12, p = 0.11, partial η^2 = 0.13. As in Experiment 2, it is possible that participants prioritised the search task in the preview and HEB conditions, as these conditions were significantly faster than the FEB condition.

Table 10. Mean percentage error rates with standard error for Experiment 3.

	Set Size			
Condition	8	SE	16	SE
FEB	1.16%	0.41%	1.76%	0.77%
Preview	1.47%	0.78%	4.39%	2.57%
HEB	2.28%	0.68%	1.14%	0.56%
WM FEB	1.25%	0.40%	0.76%	0.32%
WM Preview	0.37%	0.29%	0.38%	0.29%
WM HEB	0.78%	0.49%	0.78%	0.41%

Table 11. Mean percentage working memory accuracy across condition for Experiment 3.

	Set Size	
Condition	8	16
WM FEB	72.09%	71.33%
WM Preview	63.62%	66.20%
WM HEB	67.83%	60.03%

The results suggest that despite the working memory task being a different modality to the preview task, the benefit was just as disrupted as when participants performed a task of the same modality (i.e. a visual task). That there appears to be a disruptive effect of the secondary task irrespective of the stimulus modality suggests that the initialisation phase of the preview benefit was disrupted by the working memory task, rather than the maintenance phase (Humphreys et al., 2002). However it is also possible that the demands on attention of the working memory task are sufficiently high that there are not enough resources available to allocate to the preview task (McCann & Johnston, 1992; Ruthruff et al., 1995). In their original paper on attentional load, Lavie (1995) stated that the extent to which irrelevant distractors can be processed is dependent on how much attention is required by relevant stimuli. Under conditions of high perceptual load (e.g. an increased number of task relevant stimuli), there are fewer resources leftover from the task to process distractors, thus distractor interference is reduced. However, Lavie and colleagues proposed that active attention is required to focus on task-relevant stimuli and, if insufficient attention is allocated to the load task due to a secondary task, then distractor interference can again occur, even under high load conditions. This is what was found when

participants were also required to carry out a working memory task (de Fockert, Rees, Frith & Lavie, 2001; Lavie Hirst, de Fockert & Viding, 2004): distractor interference in high load conditions increased as participants did not have the attentional resources to focus on the task relevant stimuli.

Given that working memory task load has been shown to affect the ability to attend to stimuli, it is possible that the working memory load in Experiment 3 was sufficiently demanding on participants' attentional resources that their capacity to ignore the irrelevant distractors in the preview set was affected and, consequently, there was increased distractor interference. For example, Logan (1978) found that the effect of working memory load on search tasks decreased when participants practiced the working memory task over a series of sessions in comparison to participants who were exposed to different stimuli during each session. It could be argued that the audio working memory task used in the Humphreys et al. (2002) article (a present/absent verbal monitoring task) had a lower working memory load. It may be that at a high working memory load both the initialisation and the maintenance phase of the preview are disrupted. In order to test this hypothesis, the experiment used a similar procedure to second and fourth experiments in Humphreys et al. (2002) (working memory onsets with the preview and working memory onsets 1000ms after the preview), but using the current working memory task.

Experiment 4b therefore repeated Experiment 4a but using a limited number of audio tone sequences for the working memory task which were then repeatedly used throughout the experiment. Participants were also given an extended practice period. This use of repetition and practice should enable the working memory task to become stored in long term memory and, consequently, reduce the working memory load. If working memory load does affect both the initialisation and maintenance phase of the preview then there should be equal disruption in both onset conditions in Experiment 4a, but a greater disruption to the common onset condition in Experiment 4b.

2.7. Experiment 4a

Experiment 4a replicated the common onset, auditory secondary task and the delayed auditory secondary task of Humphreys et al. (2002) but using the same audio task as in Experiment 3 (i.e. a discrimination task using a sequence of tones which temporally surround the preview search task).

2.7.1. Participants

Twenty participants (10 female) took part in exchange for £10. One participant was eliminated for having too many outlier responses, as when data was trimmed they were left with no data in one condition. Participants were between 20 and 32 years of age (Mean = 25.53 years, SD = 3.35 years) and reported having normal or corrected-to-normal vision and normal hearing. All participants were right-handed.

2.7.2. Stimuli

Stimuli were the same as those used in Experiment 3.

2.7.3. Design and procedure

The experiment had 4 conditions: A Full Element Baseline (FEB), a Half Element Baseline (HEB) a preview/working memory onset condition and a preview/working memory delay condition. The design and procedure for the FEB and HEB were the same as those used in Experiments 1-3. The procedure of the preview/working memory conditions were similar to those of the second and fourth experiments in Humphreys et al. (2002) Experiments 2 and 4. For the onset condition, participants were presented with a fixation dot for 1000ms followed by the preview items (4 or 8 female faces) for 2000ms. During the first 1000ms of the preview items being presented, the 6 audio working memory tones played, each lasting approximately 167ms so that the duration was 1000ms, in line with Humphreys et al (2002) and participants were instructed to memorise the 'tune'. The remaining 1000ms of the preview was silent. Following this, the remaining search items (houses and target male face) appeared on screen and were present until the participant made a response. Once a response had been made the screen went blank and, after a pause of 1000ms, a second

sequence of tones played which was either identical to the sequence they were asked to memorise, or similar but with one tone changed. Participants were then prompted to indicate "same" or "different" with the "s" and "d" keys respectively, as in previous experiments. The delay condition was identical to the onset condition except in the timing of the tones. Here the initial 1000ms of the preview items being presented were silent and in the following 1000ms the tones played. Thus there was a delay between the onset of the preview items and the onset of the working memory tones. Volume was kept constant between participants. The experiment lasted approximately 1 hour.

2.7.4. Results and discussion

Outliers were again eliminated using previously-stated method (4.43% of the data). Table 12 shows the mean correct RTs and SDs across set size and condition and Figure 7 shows the search slopes for each condition.

Table 12. Mean RTs and SDs across set size and condition for Experiment 4a.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	807	164.16
16	1102	262.96
Onset		
8	620	150.39
16	737	218.47
Delay		
8	635	148.72
16	718	188.26
HEB		
4	374	42.13
8	386	39.51

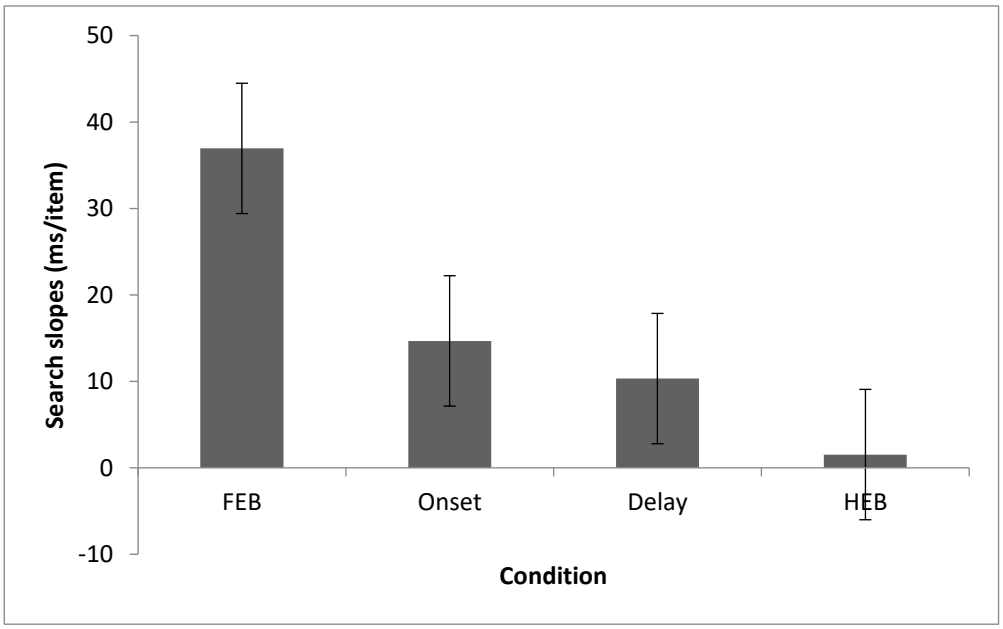

Figure 7. Search slopes for each condition for Experiment 4a. Error bars represent SEM.

Onset preview x delay preview. Of critical importance, a 2 x 2 ANOVA was conducted on the data from the two preview conditions with within participant factors of working memory timing (onset x delay) and set size (8 x 16). Whilst there was an effect of set size $F(1,18) = 48.84$, MSE = 3.96, $p < 0.01$, partial $\eta^2 = 0.73$ (observed power = 1), there was no effect of condition, $F(1,18) < 0.01$, MSE = 21.04, $p = 0.95$, partial $\eta^2 < 0.01$, and no two-way interaction, $F(1,18) = 2.48$, MSE = 2.45 $p = 0.14$, partial $\eta^2 = 0.12$. This would suggest that there was no significant difference in disruption to the preview benefit between the working memory conditions, despite the difference in onset.

Full factor ANOVA. Mean correct RTs were entered into 4 x 2 within participants ANOVA with main factors of condition (FEB, onset, delay and HEB) and set size (8 and 16). There were main effects of condition, $F(3,54) = 82.32$, $p < 0.01$, partial $\eta^2 = 0.82$, and set size, $F(1,18) = 104.91$, $p < 0.01$, partial $\eta^2 = 0.85$. The condition x set size interaction was also significant, $F(3,54) = 44.02$, $p < 0.01$, partial $\eta^2 = 0.71$. Observed power for all values was 1. The data were then divided into separate ANOVAs to examine the effects more closely.

Onset preview ANOVAs. Data for the onset working memory preview condition were entered into two 2 x 2 ANOVAs with main effects of condition (FEB x preview and HEB x preview) and set size (8 x 16). There were again main effects of condition, $F(1,18) = 42.78$,

MSE = 34.21, $p < 0.01$, partial $\eta^2 = 0.75$, and $F(1,18) = 62.28$, MSE = 27.26, $p < 0.01$, partial $\eta^2 = 0.78$, (for FEB and HEB respectively), and set size, $F(1,18) = 124.69$, MSE = 6.54, $p < 0.01$, partial $\eta^2 = 0.87$, and $F(1,18) = 45.14$, $p < 0.01$, MSE = 1.78, partial $\eta^2 = 0.72$, respectively. Both two-way interactions were significant, $F(1,18) = 27.47$, MSE = 5.45 $p < 0.01$, partial $\eta^2 = 0.63$ and $F(1,18) = 36.57$, MSE = 1.44, $p < 0.01$, partial $\eta^2 = 0.67$, indicating that the preview benefit had been disrupted by the working memory task. All observed power values were 1.

Delay preview ANOVAs. Data for the delayed onset working memory preview condition were entered into two 2 x 2 ANOVAs with main effects of condition (FEB x preview and HEB x preview) and set size (8 x 16). There were main effects of condition, $F(1,18) = 80.63$, MSE = 18.17, $p < 0.01$, partial $\eta^2 = 0.82$, and $F(1,18) = 83.62$, MSE = 20.02, $p < 0.01$, partial $\eta^2 = 0.82$ for the FEB and HEB conditions respectively, and set size, $F(1,18) = 76.48$, MSE = 8.89, $p < 0.01$, partial $\eta^2 = 0.81$, and $F(1,18) = 26.14$, MSE = 1.64, $p < 0.01$, partial $\eta^2 = 0.59$, respectively. Both two-way interactions were significant, $F(1,18) = 68.29$, MSE = 3.16, $p < 0.01$, partial $\eta^2 = 0.79$, and $F(1,18) = 14.45$, MSE = 1.63, $p < 0.01$, partial $\eta^2 = 0.45$, denoting the preview benefit had been disrupted by the working memory task. Observed power values were > 0.95.

Search errors. Mean percentage error rates can be seen in Table 13. As in previous experiments, these were low (all < 3%). When compared in a 4 x 2 ANOVA, no main effect of set size, $F(1,18) = 0.55$, MSE < 0.01, $p = 0.47$, partial $\eta^2 = 0.03$, and no significant two-way interaction, $F(3,54) = 1.35$, MSE < 0.01, $p = 0.29$, partial $\eta^2 = 0.07$, but there was a main effect of condition, $F(3,54) = 5.2$, MSE < 0.01, $p < 0.01$, partial $\eta^2 = 0.23$, (observed power = 0.91) as error rates were slightly higher in the FEB and HEB conditions. It is possible that there may have been a very small speed-accuracy trade-off in the HEB condition, but this is very unlikely in the FEB condition as RTs were slower than in the other conditions.

Working memory accuracy. Mean percentage accuracy rates for the working memory task can be seen in Table 14. Overall accuracy was 66.20%. Compared in a 2 x 2 ANOVA, there was no main effect of condition, $F(1,18) < 0.01$, MSE = 0.01, $p = 0.98$, partial $\eta^2 = 0.05$, or set size, $F(1,18) < 0.01$, MSE = 0.01, $p = 0.94$, partial $\eta^2 = 0.01$ and no significant two-way

interaction, $F(1,18) < 0.01$, MSE = 0.01, $p = 0.97$, partial $\eta^2 < 0.01$, suggesting that accuracy was consistent across condition and set size.

Table 13. Mean percentage error rates with standard error for Experiment 4a.

	Set Size			
Condition	8	SE	16	SE
FEB	2.57%	0.48%	2.91%	0.74%
Onset	0.41%	0.24%	1.56%	1.08%
Delay	0.97%	0.38%	1.55%	0.51%
HEB	2.55%	0.54%	1.48%	0.52%

Table 14. Mean percentage working memory accuracy across condition for Experiment 4a.

	Set Size	
Condition	8	16
Onset	66.12%	66.25%
Delay	65.98%	66.27%

In contrast to the aforementioned study by Humphreys et al. (2002), there appeared to be equal disruption to the preview benefit for both the common onset and delayed onset conditions, even though the working memory task was of a different modality. One explanation for this is that there was a potential effect of working memory load on both the initialisation and maintenance phase of the preview benefit. The most likely explanation of the discrepancy in results is that the attentional demand of the working memory task in the current experiment (having to listen, memorise and retain a sequence of tones) is relatively more than that of the original audio secondary task experiment where participants simply had to indicate whether a "1" was present or absent from a sequence of four spoken numbers (Humphreys et al., 2002). If this were the case, then reducing the working memory load of the task the demand on participants' attentional resources should reduce and the difference between the preview for the delayed onset and common onset conditions should reappear. To test this, Experiment 4b was conducted using repeated sequences of tones in the working memory task.

2.8. Experiment 4b

Experiment 4b examined whether decreasing the working memory load would differentially affect the efficiency of the preview benefit for the common onset and delayed onset conditions. If increased working memory load was responsible for the results of Experiment 4a then a reduced working memory load should only disrupt the initialisation phase of the preview benefit, thus replicating the results of Humphreys et al. (2002).

2.8.1. Participants

Twenty participants (9 female) took part in exchange for £10. Participants were between 19 and 31 years of age (Mean = 22.64 years, SD = 2.55 years) and reported having normal or corrected-to-normal vision and normal hearing. One participant was left-handed.

2.8.2. Stimuli

Stimuli were the same as that used in Experiments 3 – 4a.

2.8.3. Design and procedure

Experiment 4b used the same design and procedure as Experiment 4a, except for the working memory task for the working memory/preview conditions. Here, instead of being presented with a new sequence of tones to memorise on each trial, there were only four sequences of tones to learn which were repeated equally throughout the experiment, therefore each sequence was heard 20 times by the end of the test. Further, data was not recorded for the first 40 trials (or for the 10 practice trials at the beginning) as this first half was used for participants to become familiar with the sequences. Therefore, by the time the data for the working memory conditions was being recorded, participants had encountered each sequence of tones at least 22 times (including those heard in the practice trials). This was designed such that the tones were most likely being stored in long term memory, as opposed to working memory and, therefore, the working memory load was arguably decreased. Whilst this is perhaps an indirect way of manipulating working memory load (for example, as opposed to decreasing the number of tones), it was

important that the tones and the preview were kept at the same duration as in the previous study for consistency. It not only meant the results were more comparable, but also meant the timing manipulation was not altered.

2.8.4. Results and discussion

Outliers were again eliminated using the same method (6.60% of the data). Table 15 shows the mean correct RTs and SD for each condition by set size. Figure 8 shows search slopes for each condition.

Table 15. Mean RTs and SDs across set size and condition for Experiment 4b.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	760	134.84
16	994	190.74
Onset		
8	535	98.64
16	651	185.77
Delay		
8	484	98.17
16	512	118.01
HEB		
4	373	41.12
8	384	41.63

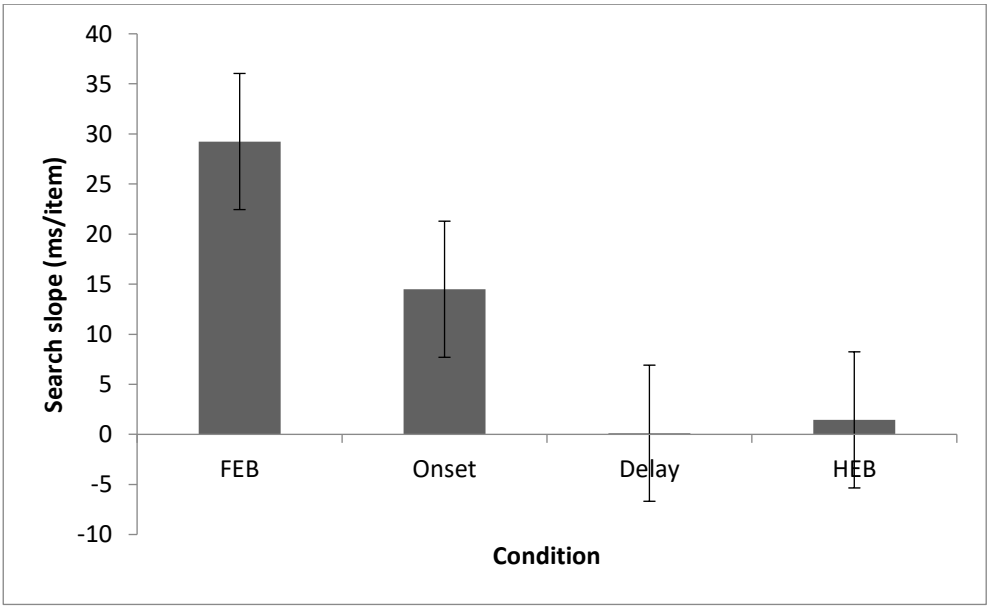

Figure 8. Search slopes across condition for Experiment 4b. Error bars represent SEM.

Delay x onset. Of critical importance here, a 2 x 2 ANOVA was conducted on the working memory/preview conditions. Here there was a main effect of set size $F(1,19) = 27.02$, $MSE = 4.75$, $p < 0.01$, partial $\eta^2 = 0.61$, but no effect of condition, $F(1,19) = 0.13$, $MSE = 8.08$, $p = 0.75$, partial $\eta^2 = 0.01$. There was, however, a two-way interaction, $F(1,19) = 8.93$, $MSE = 2.45$, $p < 0.01$, partial $\eta^2 = 0.33$. Observed power for significant values were > 0.81. The results show that RTs were more efficient in the delay condition than in the onset condition, suggesting the timing of the working memory task in relation to the preview had differentially impacted search performance. For completeness, a detailed analysis can be seen below.

Full factor ANOVA. Mean correct RTs were entered into a 4 x 2 within participants analysis of variance with factors of condition (FEB x HEB x onset x delay) and set size (8 x 16). Both main effects were significant, $F(3,57) = 122.37$, $MSE = 13.02$, $p < 0.01$, partial $\eta^2 = 0.87$, and $F(1,19) = 76.65$, $MSE = 5.21$, $p < 0.01$, partial $\eta^2 = 0.81$, for condition and set size, respectively. The condition x set size interaction was also significant $F(3,57) = 49.63$, $MSE = 1.83$, $p < 0.01$, partial $\eta^2 = 0.73$. Observed power for all values was 1. The data were then split into separate ANOVAs to gain a more detailed understanding of the effects and interactions.

Delay x FEB and HEB. Data for the delay condition and the FEB were entered into a 2 x 2 ANOVA with within factors of condition (delay x FEB) and set size (8 x 16). RTs were significantly faster in the delay condition, $F(1,19) = 142.22$, $MSE = 11.29$, $p < 0.01$, partial $\eta^2 = 0.89$, and at set size 8, $F(1,19) = 116.58$, $MSE = 3.25$, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interaction was also significant, $F(1,19) = 83.03$, $MSE = 1.97$, $p < 0.01$, partial $\eta^2 = 0.82$, showing search was more efficient in the delay condition than in the FEB condition. Observed power for all values was 1. A further 2 x 2 ANOVA comparing the delay and HEB was carried out. RTs were significantly faster in the HEB condition, $F(1,19) = 25.57$, $MSE = 7.26$, $p < 0.01$, partial $\eta^2 = 0.59$, and at set size 8, $F(1,19) = 16.22$, $MSE = 0.45$, $p < 0.01$, partial $\eta^2 = 0.52$. The two-way interaction was not significant, $F(1,19) = 2.89$, $MSE = 0.42$, $p = 0.14$, partial $\eta^2 = 0.36$, suggesting a full preview benefit was achieved with the delayed working memory task. Observed power for the main effects were both > 0.97.

Onset x FEB and HEB. Data for the onset condition and the FEB were entered into a 2 x 2 ANOVA with within factors of condition (onset x FEB) and set size (8 x 16). RTs were significantly faster in the onset condition, $F(1,19) = 92.74$, MSE = 16.54, $p < 0.01$, partial $\eta^2 = 0.84$, and at the lower set size, $F(1,19) = 76.72$, MSE = 7.58, $p < 0.01$, partial $\eta^2 = 0.81$. The condition x set size interaction was also significant, $F(1,19) = 48.35$, MSE = 1.37, $p < 0.01$, partial $\eta^2 = 0.73$, showing search was more efficient in the onset condition than in the FEB condition. Observed power for all values was 1. An additional 2 x 2 ANOVA comparing the onset condition to the HEB was also conducted. RTs were significantly faster in the HEB condition, $F(1,19) = 61.78$, MSE = 14.13, $p < 0.01$, partial $\eta^2 = 0.78$, and at set size 8, $F(1,19) = 27.45$, MSE = 2.81, $p < 0.01$, partial $\eta^2 = 0.63$. The two-way interaction was significant also, $F(1,19) = 19.47$, MSE = 2.67, $p < 0.01$, partial $\eta^2 = 0.52$, which indicates a partial preview benefit for the onset condition. Observed power across values was > 0.97.

Delay condition Experiment 4a x Delay condition Experiment 4b. Data for the delay condition from Experiment 4a and Experiment 4b were entered into a 2 x 2 ANOVA with the between factor of Experiment (4a x 4b) and the within factor of set size (8 x 16). RTs were significantly faster in Experiment 4b, $F(1,19) = 19.22$, MSE = 35.05, $p < 0.01$, partial $\eta^2 = 0.53$, and at set size 8, $F(1,19) = 37.10$, MSE = 1.59, $p < 0.01$, partial $\eta^2 = 0.69$. The two-way interaction was also significant, $F(1,19) = 5.95$, MSE = 2.56, $p = 0.02$, partial $\eta^2 = 0.26$, suggesting search was more efficient in the delay condition in Experiment 4b than in Experiment 4a. However, observed power for the interaction was only 0.63, and thus further testing is needed.

Search errors. Mean percentage error rates can be seen at Table 16. These were low (all < 3%). Compared in a 4 x 2 ANOVA with main effects of condition (FEB, HEB, delay and onset) and set size (8 and 16), neither of the main effects were significant, $F(3,57) = 2.45$, MSE = 8.01, $p = 0.08$, partial $\eta^2 = 0.12$, for condition and $F(1,18) = 0.26$, MSE = 3.37, $p = 0.62$, partial $\eta^2 = 0.01$, for set size. The two-way interaction also did not reach significance, $F(3,57) = 0.78$, MSE = 7.3, $p = 0.53$, partial $\eta^2 = 0.04$, suggesting there was no speed-accuracy trade-off in any condition.

Working memory accuracy. Mean percentage accuracy rates for the working memory task can be seen in Table 17. Overall working memory accuracy was 79.14%. Compared in a 2 x

2 ANOVA with main effects of condition (onset x delay) and set size (8 x 16), there was no main effect of either condition, $F(1,19) < 0.01$, MSE = 87.8, $p = 0.99$, partial $\eta^2 < 0.01$, or set size $F(1,19) = 0.04$, MSE = 211.57, $p = 0.62$, partial $\eta^2 < 0.01$, and the two-way interaction was also not significant, $F(1,19) = 0.25$, MSE = 78.44, $p = 0.62$, partial $\eta^2 = 0.01$, suggesting that working memory accuracy was not significantly better in either condition or either set size. A paired sample t-test comparing the overall mean percentage accuracies for Experiment 4a and Experiment 4b was significant, $t(19) = 5.63$, SEM = 2.31 $p < 0.01$, as working memory accuracy was higher in Experiment 4b. This is most likely due to the repetition of the working memory sequences, thus making the task easier.

Table 16. Mean percentage error rates with standard error for Experiment 4b.

	Set Size			
Condition	8	SE	16	SE
FEB	2.98%	1.02%	2.90%	0.56%
Onset	0.79%	0.79%	2.19%	1.12%
Delay	1.12%	0.64%	1.63%	0.87%
HEB	2.30%	0.53%	1.65%	0.41%

Table 17. Mean percentage working memory accuracy across condition for Experiment 4b.

	Set Size	
Condition	8	16
Onset	79.21%	78.88%
Delay	78.21%	79.91%

The findings replicate the findings of Humphreys et al. (2002). That is, a secondary task of different modality maximally disrupts the preview benefit when it and the preview onset simultaneously. If there is a period of viewing the preview before the secondary task begins, the items can be better inhibited. The results of the current study add to this finding by indicating the importance of the amount of working memory load caused by the secondary task. If the task is too demanding, then regardless of when the preview/secondary task onset, attention is consumed by the secondary task, leaving no attentional resources left to inhibit the preview items.

2.9. Chapter summary and discussion

This Chapter furthered the literature on the effect of secondary task on preview search, by examining how the content, modality, timing and load of the secondary affect the extent of disruption to the preview benefit. The results suggest that task content did not affect the preview benefit (Experiment 2), and that an audio dual-task disrupted the preview benefit as much as a visual dual-task (Experiment 3). However, when the dual-task load was reduced via repetition of the stimuli, the preview was worse under audio dual-task conditions when the task onset at the same time as the preview, in comparison to when there was a 1000ms delay between the preview onset and the dual-task onset.

Throughout the experiments, participants were told to prioritise the working memory task over the search task and aim to be as accurate as possible. It is therefore a possibility that had participants been otherwise instructed, or even free to carry out the experiment in whatever manner they chose, the results may have been different. However, as previously considered, prior literature suggests that instructing participants to prioritise the search task does not eliminate the disruption caused by a secondary task (Watson & Humphreys, 1997), therefore whilst the search slopes may alter slightly with preview prioritising (one would expect them to become shallower), it appears unlikely that there would be no disruption.

Lavie and colleagues (Lavie and Tsal, 1994; Lavie, 1995) showed how tasks which have a greater demand on our attentional resources result in less processing of other stimuli. It is possible that this is what is seen in Experiments 3 and 4a: the demands of the audio working memory task were sufficiently high that the ability to attend to the preview was impaired and thus the benefit suffered. However, the effect of practice in deceasing the impact of dual-task costs has been demonstrated in the literature (Strobach et al, 2012; Goh et al., 2012). Subsequently, when the task involved more learning, as in Experiment 4b, the working memory load decreased, enabling attentional resources to be allocated to the preview, thus resulting in some improvement in the processing of the preview. The current work shows that decreased memory load alone is not sufficient to allow for a preview benefit; the timing of the tasks and the goals of the participant also have an effect. For example, in Lavie and Tsal's (1994) task, participants were only required to report on

the target and could, as far as was possible, ignore the distractors. Here, however, the participants' goal was to both perform the search task and remember the working memory tune. Although the preview benefit was better in the low working memory load condition in comparison to the high load condition, it was still not a full preview benefit. It is possible that even if the number of sequences of tones were reduced until there was only one sequence to memorise the mere requirement to do the additional task could mean a full preview benefit is not achievable.

One idea proposed by Humphreys et al. (2002) was that the preview benefit was biphasic. They suggested that the preview benefit consisted of two distinct phases: an initialisation phase where the intention to ignore the current items and attend to the new items is generated; and a maintenance phase where these attentional biases are kept active. They proposed that the initialisation phase could not be achieved in the presence of a dual-task, regardless of its modality, i.e., the preview benefit would always be disrupted if a dual-task onset simultaneously with the preview. The maintenance phase, however, is modality dependent; it is only disrupted when performing a task of the same modality. The current experiments show that this is not necessarily true. When performing a dual-task with a high attentional load the maintenance phase is disrupted even when this task of a different modality.

Although the results show the preview benefit can be disrupted by a dual-task of different modality under high load conditions and the importance of dual-task timing, the true extent of the effect of timing has not been completely discovered. Although it can now be said with some confidence that, under lower load conditions, a preview benefit can be obtained when a different modality dual-task begins after viewing the preview, it is still unknown whether having a low load dual-task around the preview and search task (as in Experiment 3) would disrupt the benefit. Whilst the findings of Experiment 3 suggest the benefit would be disrupted, it is important to note that this experiment used a relatively high load working memory task. It is possible that if using a simpler and rehearsed task (as in Experiment 4b) participants would have sufficient attentional resources available to inhibit the preview items. This does, however, seem unlikely. If indeed the preview benefit is biphasic as suggested by Humphreys et al. (2002) then attention required for the

initialisation phase would most likely be already occupied with rehearsal of the working memory task.

It would be interesting to ascertain whether active rehearsal of a working memory task is as demanding of attentional resources as encoding a working memory task. One way this could be achieved would be to analyse the preview data from different intervals over the course of a dual-task study. For example, using a working memory task similar to Experiment 4b (which repeats throughout), one may expect to see differences between, say the average RT over trials one through to ten, and the average RT over trials ninety through to one hundred. By analysing data as such and comparing it to data from an unrepeated working memory task, we may begin to understand more explicitly the difference on attention between encoding and rehearsing, and the effect these differentially have on preview benefit.

Chapter 2 – The role of location inhibition in search

Search history can be used to guide attention in subsequent search trials, be it via IOR (Klein, 1988), priming (Kristjánsson, et al, 2002), contextual cueing (Chun & Jiang, 1998) or visual marking (Watson & Humphreys, 1997). This chapter examined whether keeping half the items in a FEB search in the same location would lead to an increase in search efficiency. The results indicate that fixed item locations can lead to a search equal in efficiency to a preview search, but these results could not be replicated. There is some suggestion that attention is preferentially directed to the non-fixed location and that a probe detection task may cause interference.

3.1. Introduction

The ability to prioritise certain locations over others is a key aspect of visual search. Take, for example, the task of looking for a friend in a crowded restaurant. If, upon scanning the crowd over, one has already looked in some areas and rejected them the friend is not there, it would be useful to have a mechanism which prevents one's attention from being orientated back to those locations. If one knows from prior experience, however, that the friend usually waits next to the bar, then a mechanism that biases attention to that location over others will also make my search more efficient. When the friend has been found, they are wearing a red coat over a yellow dress, whilst most people in the restaurant are in black. After visiting the bathroom and upon returning, consider that the friend may have taken their seat and removed their coat. It would now be useful to have a mechanism in place which biases one's attention away from the irrelevant black clothes to help one find the friend who is not wearing black.

Such mechanisms to guide attention in search do exist. The ability to prioritise new locations over old locations and bias attention away from previously attended locations can be seen in studies of IOR (Posner & Cohen, 1984; Klein, 1988; Klein, 2000), and preview search (Watson & Humphreys, 1997). These areas were discussed in detail in the introduction chapter and will therefore not be discussed again here. However, the effects of long-term search array priming (i.e. contextual cueing) (Chun & Jiang, 1988) and

distractor priming (Kristjánsson et al., 2002) will be discussed further here to provide further context for this chapter.

3.1.1. Priming of search arrays – contextual cueing

Contextual cueing (Chun & Jiang, 1998) is a form of implicit learning of repeated search arrays which enables participants to locate a target faster than in novel search arrays. This effect is seen despite participants having no explicit awareness that the arrays have been repeated and is not attributable to low-level feature priming (e.g. shape or colour of stimuli).

In their initial paper on contextual cueing, Chun and Jiang (1998) also examined whether contextual cueing could be due to automatic perceptual facilitation (as seen in regular priming studies) or associative learning of configurations (i.e. learning the likely locations in which target will appear). Typical priming studies tend to show that priming effects last for approximately thirty seconds, or across approximately five trials (Maljkovic & Nakayama, 1994), and facilitation can be seen after the first trial (Maljkovic & Nakayama, 1994; Kristjánsson et al., 2002). Contextual cueing, on the other hand, appears to have a longer duration across several blocks of trials and facilitation improves over the course of each block of approximately 24 trials. It therefore seems likely that the learning taking place in contextual cueing will differ in some respects from typical priming studies. Their results showed that when the target location was varied, no effect of contextual cueing was observed, despite the distractors in repeated arrays remaining in consistent locations. It can therefore be argued that contextual cueing does not necessarily arise simply from known distractor locations being inhibited, but rather from attention being biased towards particular locations in an array when the target has repeatedly appeared there previously.

Since their initial paper, the facilitatory effects of contextual cueing have been documented using a wide range of stimuli and experimental conditions (Kunar, Flusberg, Horowitz, & Wolfe, 2007; Jiménez & Vázquez, 2011; Beesley & Shanks, 2012). Although there is still debate as to what precisely is facilitated during contextual cueing (e.g. is it the facilitation of target detection, as suggested by Kunar et al. (2007), or whether is it an orienting of attention towards target location, as suggested by Chun and Jiang (1998)), the importance

of a consistent spatial relationship between the target and the distractors can be found throughout the literature (Chun & Jiang, 1998; Manginelli & Pollmann, 2009; Zellin, Conci, von Mühlenen & Müller, 2013). For example, Manginelli & Pollmann (2009) found that the facilitation of contextual cueing was reduced or abolished when the target was relocated on later trials, despite distractors remaining in the same locations. An extension of this research by Zellin et al. (2013) found that that when the target was later returned to its original position under which contextual cueing had taken place, the facilitation was reinstated, suggesting that contextual cueing results specifically from learned associations between the target and distractor locations. Indeed, earlier research (Olson & Chun, 2002; Brady & Chun, 2007) has suggested that contextual cueing facilitations can be obtained when only the target and its nearest distractors are repeated but the rest of the display is remapped. Further evidence for the inflexibility of contextual cueing has been demonstrated by Zellin, Conci, von Mühlenen and Müller (2011), who found that alternating the location of target across trails such that two configurations were required to be learnt simultaneously also prevented contextual cueing taking place.

Although there is strong evidence that contextual cueing is dependent on the consistency of its surrounding visual-spatial environment and is ill-adaptive to changes in local context, research by Conci, Sun and Müller, (2011) and Conci and Müller (2012) has shown that contextual cueing can occur (albeit more weakly) when participants were required to learn the location of two potential targets which appeared in the same context across every trial. Further research by Zellin, von Mühlenen, Müller and Conci (2014) on long-term adaptations of contextual cueing has shown that although initial change in target location results in the abolition of contextual cueing effects, subsequent learning of new contexts over a number of days will eventually result in equivalent contextual cueing effects for novel target locations, as for originally learnt target locations. These experiments suggest that contextual cueing is not as inflexible as originally thought. Whilst contextual cueing may not initially adapt well to previously unlearned target associations or occur when more than one unique global context needs to be learned, it can arise in situations where there are multiple targets to locate in a common global context (Conci et al., 2011; Conci &

Müller, 2012), and with repeated, long-term learning for novel target locations (Zellin et al. 2014).

Although prior literature has found that repeated distractor arrays offered no benefit when the target location was randomly determined, research conducted using contextual cueing and preview search (Hodsoll & Humphreys, 2005) suggest differently. The aforementioned article by Hodsoll and Humphreys (2005) consisted of contextual cueing baseline conditions with display sizes of ten items or twenty items, and preview conditions of the same size where either the search display (second set of items to appear) was repeated, or the preview display (first set of items to appear) was repeated. The authors found that under normal search conditions, contextual cueing did not take place at the higher display size, nor could contextual cueing be seen when the search display in the preview condition was repeated at the higher display size. However, when the preview items appeared in repeated locations, it enabled contextual cueing to occur at the higher display sizes, despite the target appearing in novel locations. The authors proposed that contextual cueing could occur under these conditions so long as the spatial relationship between the target and the preview items remained consistent. Their findings suggested that participants may have been able to inhibit the learned locations of previewed distractors. If this is the case, is it possible that repeated distractor displays can enable efficient search even in a FEB search condition if the distractor locations can be learned across trials?

3.1.2. Effects of distractor priming

In their original study on priming effects in conjunction search, the main finding of Kristjánsson et al. (2002) was that detection of a target was expedited when it was the same across trials, as opposed to being different on every trial. This was not, however, the only finding of interest in their study. The search task used in their experiment required participants to indicate whether a target was present or absent from the display. Not only was there an effect of priming in target present conditions, but priming could also be seen in the target absent conditions. This suggested that not only did keeping the target consistent across trials facilitate search, but also that keeping distractors consistent also facilitated search.

In order to validate this result, Geyer, Müller and Krummenacher (2006) conducted a further study where the consistency of the target and the distractors were differentially varied across present/absent search trials. Their results not only confirmed the findings in Kristjánsson et al. (2002), but showed that the effect of facilitation was greater for distractor-consistent trials than it was for target-consistent trials. This suggests that modulations to attention in both single-feature and conjunction search tasks are not strictly target-driven (as suggested in Treisman and Gelade, (1980), Wolfe et al. (1989) and Treisman and Sato, (1990)), but can also be driven by the features of distractor items. This effect can be seen both for distractor location and feature, and occurs independently of response type (i.e. present/absent) (Kristjánsson & Driver, 2008). Furthermore, negative priming effects can also be seen in search (see 'negative priming' effect for a definition of negative priming (Tipper, 1985; 1992)): when a distractor on the preceding trial is unexpectedly the target in the following trial, search times are slowed (Kristjánsson & Driver, 2008).

3.1.3. The purpose of this chapter

As discussed, the role of location inhibition in visual search is not confined solely to preview conditions. However, if location inhibition is a key factor in creating a more efficient search (such as with the preview benefit), then keeping half the distractor items fixed in the same place across trials should result in a more efficient FEB search, perhaps even akin to a preview search. To assess how much participants attended to the fixed/non-fixed distractors, two probe detection experiments were carried out, one with the probe appearing on the fixed items (Experiment 6a) and one with the probe appearing on the non-fixed items (Experiment 6b). If participants effectively ignore the repeated distractor locations and allocate attention to novel locations, probe detection should be higher in the FEB condition when next to the fixed distractor and in the fixed/preview condition when appearing next to the novel distractors. Experiment 7 repeated Experiment 6a but used a probe task on only 25% of the trials to assess whether a probe task could cause dual-task interference. If this is the case, search will again be more efficient overall in the fixed location condition than the standard FEB condition, due to less dual-task interference

disrupting the inhibition of fixed items. The results will contribute to the overall understanding of distractor location inhibition and prior learning on search efficiency, and how experience can be used in guiding attention.

3.2. Experiment 5

Experiment 5 examined the effect of location inhibition on search efficiency by keeping half of the distractor items (female faces) in the same location across trials. If the distractor locations can be effectively inhibited, search in the fixed location condition will be more efficient than search in the FEB condition, and may be as efficient as the preview condition.

3.2.1. Participants

Twenty participants (12 female) took part in exchange for £20. Participants were aged between 18 and 40 (Mean = 24.37 years, SD = 5.21 years). All reported having normal or corrected-to-normal vision. Four participants were left-handed.

3.2.2. Stimuli

The stimuli were the same as the upright faces and houses as those used Experiments 1 – 4b.

3.2.3. Design and procedure

The experiment lasted approximately one hour. The design and procedure were identical to the no working memory conditions of Experiments 2 and 3. There were five conditions: A Full Element Baseline (FEB) condition, a Fixed Conjunction (FC) condition, a Half Element Baseline (HEB), a Fixed Preview (FP) condition and a preview condition. For both preview conditions female faces appeared 1000ms before house distractors and a male target face, whilst all items onset simultaneously in the HEB, FEB and FC conditions. In both the fixed conditions, the female faces appeared in the same locations across trials (in a circle approximately 9^{o} from the screen centre) whilst the remaining distractors and the target

appeared in any location (see Figure 9). This was a departure from the contextual cueing procedures used in previous literature, in which the target always appeared in the same location relative to distractors. As the target did not appear in the same location relative to distractors in the current experiments, it is unlikely any benefit will be due to target location expectancy. Rather, any benefit would indicate distractor location inhibition. In the FEB, HEB and preview condition, all items appeared at random locations. Only the houses and the target male face appeared in the HEB. Participants completed 60 trials per condition, split evenly across set size (8 or 16) and side of target (left or right of fixation dot). Reaction times and accuracy were recorded.

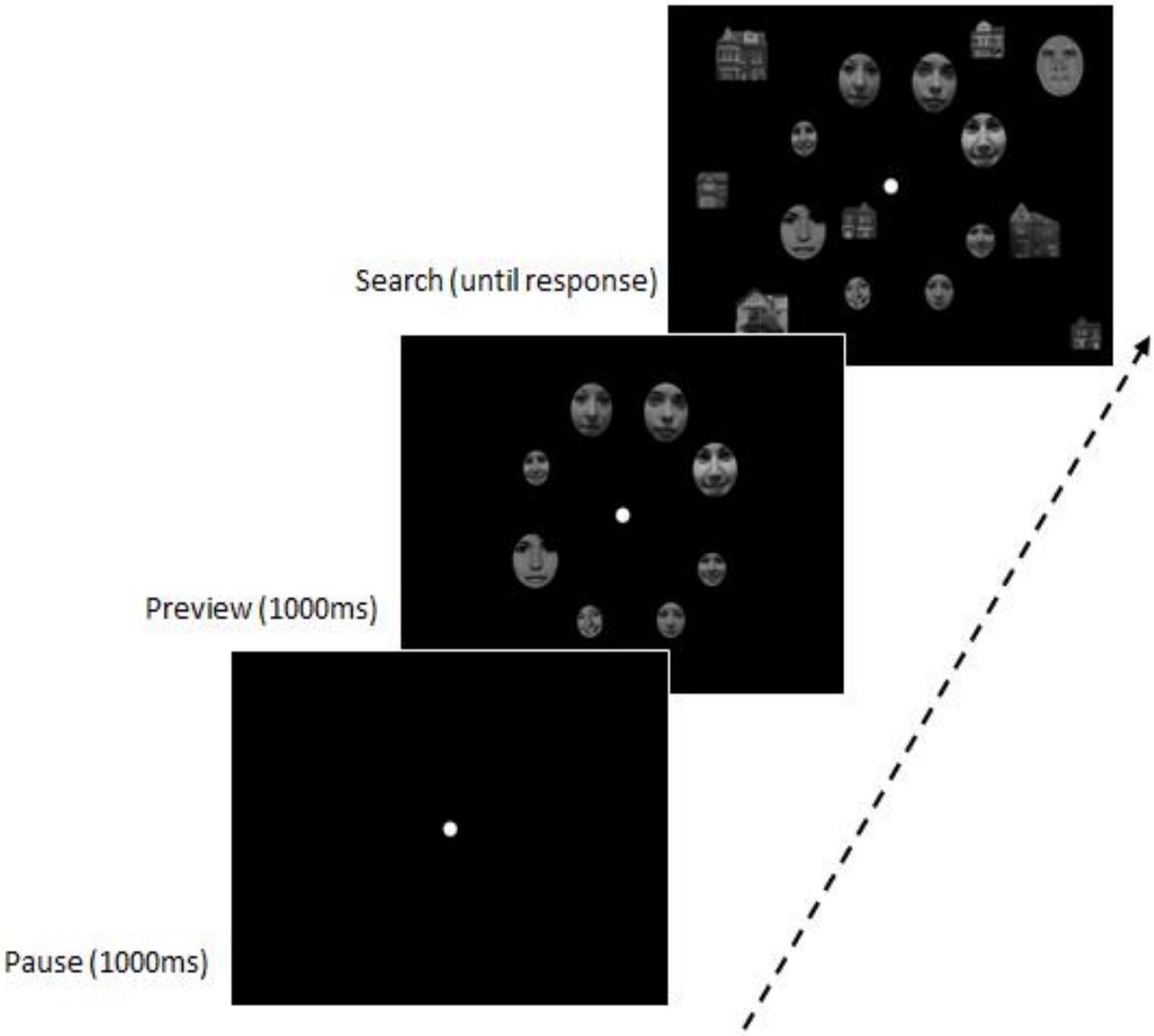

Figure 9. Example of FP condition for Experiment 5. Female faces appeared in those locations on each trial. The FC condition contained only the search display. Non-fixed conditions had female faces appearing in any location. HEB contained only male face and houses. Arrow indicates the direction of time.

3.2.4. Results and discussion

The data were trimmed for outliers using the Van Selst and Jolicoeur (1994) method (11.45% of the data). Table 18 shows the mean correct RTs and SDs across set size and condition. Figure 10 shows search slopes for each condition.

Table 18. Mean RTs and SDs across set size and condition for Experiment 5.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	839	172.81
16	1235	320.74
FC		
8	767	195.09
16	838	176.04
FP		
8	539	140.05
16	588	152.67
Preview		
8	483	84.30
16	529	99.03
HEB		
4	396	58.18
8	406	58.21

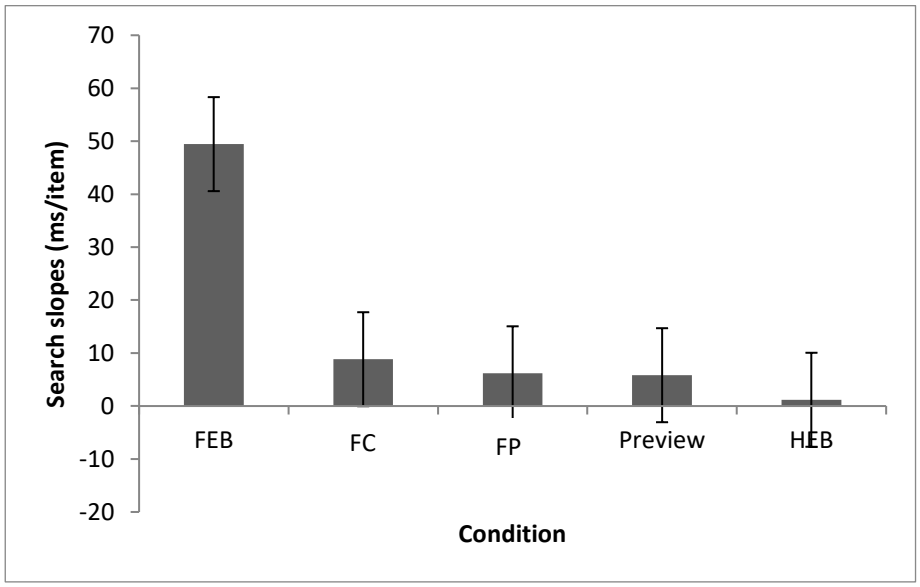

Figure 10. Search slopes across condition for Experiment 5. Error bars represent SEM.

Preview x FC. Of key interest, mean correct RTs from the preview condition and the FC condition were entered into a 2 x 2 ANOVA with main factors of condition (FC x preview) and set size (8 x 16). RTs were significantly faster in the preview condition, $F(1,19) = 74.01$, $MSE = 23.67$, $p < 0.01$, partial $\eta^2 = 0.82$, and at set size 8, $F(1,19) = 35.61$, $MSE = 1.93$, $p < 0.01$, partial $\eta^2 = 0.65$. There was not, however, a significant condition x set size interaction, $F(1,19) = 2.86$, $MSE = 1.05$, $p = 0.11$, partial $\eta^2 = 0.13$, suggesting there was no difference

in search efficiency between the FC and the preview condition. Observed power for significant values was 1.

FEB x FC. The data were entered into a 2 x 2 ANOVA with main factors of condition (FC x FEB) and set size (8 x 16). As predicted, RTs were faster in the FC than in the FEB, $F(1,19) = 33.24$, MSE = 33.32, $p < 0.01$, partial $\eta^2 = 0.64$, and at the lower set size, $F(1,19) = 119.42$, MSE = 9.14, $p < 0.01$, partial $\eta^2 = 0.86$. There was also a significant condition x set size interaction, $F(1,19) = 61.87$, MSE = 8.54, $p < 0.01$, partial $\eta^2 = 0.77$, suggesting the fixed conjunction was more efficient than the FEB. Observed power for all values was 1. For completeness, a full analysis can be seen below.

Full factor ANOVA. Mean correct RTs were entered into a 2 x 5 ANOVA with within participant factors of condition (FEB x FC x preview x FP x HEB), and set size (8 x 16). There was a main effect of both condition, $F(4,76) = 102.24$, MSE = 25.68, $p < 0.01$, partial $\eta^2 = 0.84$, and set size, $F(1,19) = 146.18$, MSE = 4.47, $p < 0.01$, partial $\eta^2 = 0.89$. The two-way interaction was also significant, $F(4,76) = 65.49$, MSE = 3.85, $p < 0.01$, partial $\eta^2 = 0.78$. Observed power in all cases was 1. The data were then divided into more specific ANOVAs to examine more finely the effects of fixing the locations of the face distractors on reaction times.

Preview x FEB and HEB. Data for the preview condition and the FEB were entered into a 2 x 2 ANOVA with main factors of condition (preview x FEB) and set size (8 x 16). RTs were significantly faster in the preview condition than the FEB condition, $F(1,19) = 128.01$, MSE = 44.01, $p < 0.01$, partial $\eta^2 = 0.87$, and set size, $F(1,19) = 115.31$, MSE = 8.48, $p < 0.01$, partial $\eta^2 = 0.86$. There was also a significant condition x set size interaction, $F(1,19) = 81.84$, MSE = 7.45, $p < 0.01$, partial $\eta^2 = 0.81$, consistent with the notion that search was more efficient in the preview condition. Observed power for all values was 1. Data for the preview condition and the HEB were entered into a 2 x 2 ANOVA with main factors of condition (preview x HEB) and set size (8 x 16). RTs were significantly faster in the HEB than the preview, $F(1,19) = 48.16$, MSE = 4.59, $p < 0.01$, partial $\eta^2 = 0.72$, and at the lower set size, $F(1,19) = 48.45$, MSE = 0.32, $p < 0.01$, partial $\eta^2 = 0.72$. The condition x set size interaction was significant, $F(1,19) = 14.89$, MSE = 0.46, $p < 0.01$, partial $\eta^2 = 0.44$, showing

search was not as efficient in the preview condition as in the HEB and thus only a partial preview benefit had occurred. Observed power across values was > 0.96.

FP x FEB and HEB. Data for the FP condition and the FEB were entered into a 2 x 2 ANOVA with main factors of condition (FP x FEB) and set size (8 x 16). RTs were slower in the FEB condition than in preview condition, $F(1,19) = 104.21$, $MSE = 43.06$, $p < 0.01$, partial $\eta^2 = 0.85$, and at set size 16, $F(1,19) = 111.67$, $MSE = 8.87$, $p < 0.01$, partial $\eta^2 = 0.86$. The condition x set size interaction was also significant, $F(1,19) = 76.12$, $MSE = 7.87$, $p < 0.01$, partial $\eta^2 = 0.83$. The results again suggest a preview benefit. Observed power was 1 in all cases. Data for the FP condition and the HEB were entered into a 2 x 2 ANOVA with main factors of condition (FP x HEB) and set size (8 x 16). There was a significant effect of condition, $F(1,19) = 41.37$, $MSE = 12.76$, $p < 0.01$, partial $\eta^2 = 0.69$, and set size, $F(1,19) = 21.41$, $MSE = 0.82$, $p < 0.01$, partial $\eta^2 = 0.53$. The two-way interaction was significant, $F(1,19) = 10.38$, $MSE = 0.78$, $p < 0.01$, partial $\eta^2 = 0.35$, showing participants were more efficient in the HEB condition and that a partial preview benefit had occurred. Observed power in all cases was > 0.86

Preview x FP. Data for the FP condition and the preview condition were entered into a 2 x 2 ANOVA with main factors of condition (FP x preview) and set size (8 x 16). RTs were slightly faster in the preview condition, $F(1,19) = 5.36$, $MSE = 12.37$, $p = 0.03$, partial $\eta^2 = 0.22$, and were faster in the lower set size, $F(1,19) = 57.21$, $MSE = 0.81$, $p < 0.01$, partial $\eta^2 = 0.75$. There was no two-way interaction, $F(1,19) = 0.03$, $MSE = 1.24$, $p = 0.86$, partial $\eta^2 < 0.01$ indicating that search was equally efficient across both preview conditions. Observed power for the effect of set size was 1, but was only 0.59 for the effect of condition.

FC x FP. Data for the FP condition and the FC condition were entered into a 2 x 2 ANOVA with main factors of condition (FP x FC) and set size (8 x 16). As with the standard preview condition, RTs were faster in the FP condition than the FC condition, $F(1,19) = 96.78$, $MSE = 11.78$, $p < 0.01$, partial $\eta^2 = 0.84$, and at set size 8, $F(1,19) = 46.83$, $MSE = 1.54$, $p < 0.01$, partial $\eta^2 = 0.71$. Again, there was no significant condition x set size interaction, $F(1,19) = 1$, $MSE = 2.25$, $p = 0.33$, partial $\eta^2 = 0.05$. Observed power for significant values was 1. The results of this ANOVA and the FC x preview ANOVA show that when half the stimuli remain

fixed in the same location in a conjunction search, search was not significantly different to search in a preview condition.

Search errors. Mean percentage error rates can be seen in Table 19. Overall error rates were low (all < 2.4%). Entered into a 5 x 2 ANOVA, the only effect to reach significance was the two-way interaction, $F(4,76) = 2.90$, $MSE = 11.71$, $p = 0.02$, partial $\eta^2 = 0.13$. However, the observed power was 0.76.

Table 19. Mean percentage error rates with standard error for Experiment 5.

	Set Size			
Condition	8	SE	16	SE
FEB	2.19%	0.66%	2.17%	0.91%
Fixed conjunction	1.91%	0.59%	2.32%	0.71%
Fixed preview	1.25%	0.54%	3.94%	1.13%
Preview	3.06%	1.25%	0.69%	0.40%
HEB	1.35%	0.45%	2.42%	0.66%

The results of this experiment show search in the FC condition was as efficient as a preview search and significantly more efficient than a standard conjunction search task. The results also suggest that participants were able to learn the locations of the fixed distractors, as in contextual cueing (Chung & Jiang, 1998)) and effectively guide their attention elsewhere. This is consistent with the idea that location inhibition is important in producing and efficient search, as in preview benefit (Watson & Humphreys, 2000; Olivers, et al, 1999).

It is interesting to note, however, that whilst Hodsoll and Humphreys (2005) reported that the spatial relationship between the target and the preview items must be kept consistent to enable contextual cueing to occur, the target location in this experiment appeared at random in relation to the fixed distractors and thus the spatial relationship was not consistent. However, Hodsoll and Humphreys (2005) used marginally higher display sizes, but their stimuli were smaller than in the present study. As a result, participants in their study had both more items to search through and more potential target locations (due to the increased available space). In contrast, the larger stimuli in the present study meant

that there was less space in which the target could appear when an amount of space was already occupied by the fixed distractors.

Given the supposed importance of location inhibition for preview search, it might have been expected that search in the fixed preview condition would be more efficient than in the standard preview condition, which is not what the results show. The fixed preview results also seem to contradict the finding of Hodsoll and Humphreys (2005) that fixing the locations of previewed items can help in finding a target. However, the experiment in the aforementioned article had 24 blocks each of which contained 12 repeated displays giving a total of 288 instances of the repeated display; the current experiment only had 60 instances of the repeated display. Whilst fewer instances of repeated displays may have been sufficient to detect a difference between the conjunction conditions, it is possible that this procedure is not sensitive enough to detect a difference between the more efficient preview conditions. Here, the equal efficiency in both preview conditions suggests that so long as participants are given sufficient time to view the preview (Watson & Humphreys, 1997) then they are able to inhibit the previewed items' locations regardless of whether those items appeared in fixed or random locations from trial-to-trial.

Whilst it is assumed that the search efficiency demonstrated in the current experiment was due to participants being able to ignore the locations of the fixed items, other theories of preview search may also explain the finding. It is possible, for example, that instead of inhibiting the location of the previewed or fixed items, participants' attention is captured by the onset of the new search items (Donk and Theeuwes, 2001; Donk and Theeuwes, 2003). Alternatively, rather than attention being captured by new items, participants may bias their attention towards the locations containing the new/non-fixed items. In order to test this theory further, two probe detection experiments were carried out to indicate how much attention was being paid to the two different distractor groups: the female faces (previewed/fixed items; Experiment 6a) and the houses (search/non-fixed items; Experiment 6b). If participants were to inhibit the locations of the previewed/fixed items, then probe detection in the FC and preview conditions should be worse than in the FEB condition in Experiment 6a. If attention were being captured by the onset of new items,

then probe detection should be better in the preview condition than in either conjunction conditions in Experiment 6b. Finally, if participants are using the preview to allocate attention to the location of the new items then probe detection should be better in the preview and FC conditions and accuracy across these two conditions should be similar in Experiment 6b.

3.3. Experiment 6a

Experiment 6a used search tasks with a probe detection task in order to see how much attention was paid to the fixed female face distractors. If, as supposed in the previous experiment, the increased search efficiency in the FC condition was due to participants inhibiting and subsequently ignoring the fixed distractors, then probe detection will be better in the conjunction condition than in the FC condition.

3.3.1. Participants

Twenty participants (12 female) took part in exchange for money £7.50. Participants were aged between 18 and 34 (Mean = 25.34 years, SD = 3.93 years). All reported having normal or corrected-to-normal vision. All participants were right-handed.

3.3.2. Stimuli

Stimuli were the same as those used in the previous experiment, but with the addition of a probe. The probe was a small grey square approximately 0.3 x 0.3^{o} in size from a normal viewing distance of 57cm.

3.3.3. Design and procedure

The experiment lasted approximately 45 minutes. There were three conditions: a FEB condition, a FC condition and a preview condition. The conditions were identical to those run in the previous experiment, except that the number of trials for each condition was increased to 160 to allow for the present/absent probe detection task. The probe was

present on 50% of the trials, divided evenly across set size. When present, the probe appeared approximately 0.1° vertically and 0.1° horizontally from either the bottom left (25% trials) or bottom right (25% of trials) corner of any female face distractor. For the preview condition, the probe appeared next to previewed distractors, but only once the remaining search items appeared. For the FC condition, the probe appeared next to one of the fixed location distractors. Only one probe was present per trial; when present, the probe appeared with the search display items and remained on screen until the search task was completed. Following the completion of the search task, a white screen appeared with the question "Did you see a probe? No (a) or Yes (l)". Participants were instructed to press the appropriate response key and to try to be as accurate as possible. The experiment then moved on to the next trial. No feedback was given for either the search task or the probe detection task.

3.3.4. Results and discussion

Search results. Data were trimmed for outliers using the aforementioned method (eliminating 4.12% of the data). Table 20 shows the mean correct RTs and SDs for each condition by set size. Figure 11a shows the search slopes for each condition and Figure 11b shows the percentage of correct responses when the probe was present across the conditions.

Table 20. Mean RTs and SDs across set size and condition for Experiment 6a.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	1309	354.80
16	1614	489.66
FC		
8	1282	350.49
16	1580	443.11
Preview		
8	835	250.37
16	987	335.32

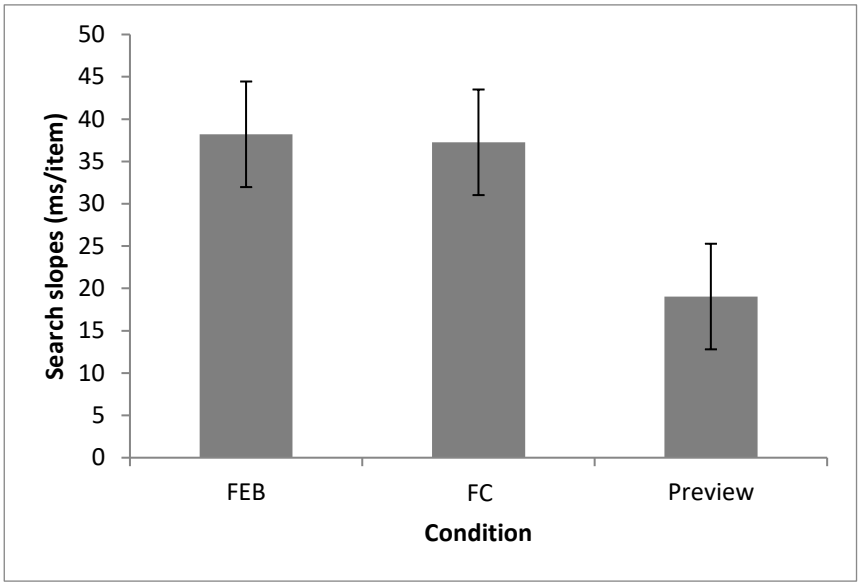

Figure 11a. Search slopes for each condition for Experiment 6a. Error bars represent SEM.

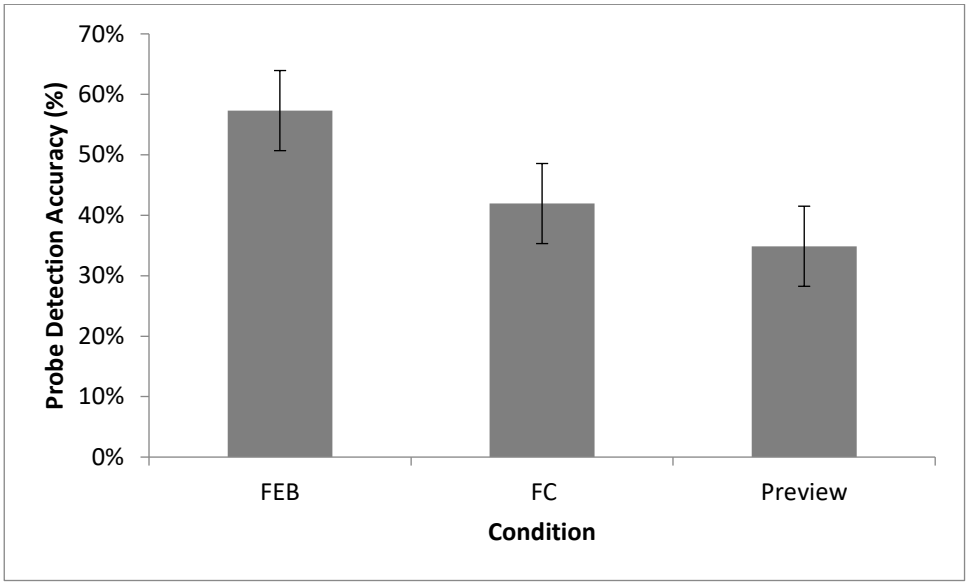

Figure 11b. Percentage of correct Probe Detection when present across condition for Experiment 6a. Error bars represent SEM.

Preview x FC. Mean correct RTs for the preview and FC condition were entered into a 2 x 2 ANOVA with main effects of condition and set size (8 x 16). The results showed RTs were faster in the preview condition, $F(1,19) = 58.43$, $MSE = 92.75$, $p < 0.01$, partial $\eta^2 = 0.75$, and at the lower set size, $F(1,19) = 78.51$, $MSE = 12.92$, $p < 0.01$, partial $\eta^2 = 0.81$. The two-way interaction was also significant, $F(1,19) = 12.67$, $MSE = 8.4$, $p < 0.01$, partial $\eta^2 = 0.44$.

Contrary to the previous experiment, the FC was not as efficient as the preview condition. Observed power for all values was > 0.92.

FEB x FC. A 2 x 2 ANOVA comparing the FEB and the FC condition showed that whilst there was a main effect of set size, $F(1,19) = 72.32$, $MSE = 25.23$, $p < 0.01$, partial $\eta^2 = 0.79$, neither the main effect of condition nor the two-way interaction was significant, $F(1,19) = 0.23$, $MSE = 80.25$, $p = 0.64$, partial $\eta^2 = 0.23$, and $F(1,19) = 0.03$, $MSE = 0.29$, $p = 0.87$, partial $\eta^2 < 0.01$, respectively, suggesting that search was not more efficient in the FC condition. Observed power for the set size effect was 1. For completeness, a detailed analysis was carried out below.

Full factor ANOVA. Mean correct RTs were entered into a 3 x 2 within participant analysis of variance with the main factors being condition (FEB x FC x preview) and set size (8 x 16). Both main effects were significant, $F(2,38) = 38.45$, $MSE = 99.52$, $p < 0.01$, partial $\eta^2 = 0.67$, and $F(1,19) = 85.42$, $MSE = 22.37$, $p < 0.01$, partial $\eta^2 = 0.82$, for condition and set size respectively. The two-way interaction was also significant, $F(2,38) = 7.22$, $MSE = 10.27$, $p < 0.01$, partial $\eta^2 = 0.28$, showing search was more efficient in some conditions than others. Observed power for all values was > 0.92.

Preview x FEB. Entered into a 2 x 2 ANOVA, RTs were significantly faster in the preview condition, $F(1,19) = 48.34$, $MSE = 125.54$, $p < 0.01$, partial $\eta^2 = 0.72$, and at set size 8, $F(1,19) = 62.84$, $MSE = 16.71$, $p < 0.01$, partial $\eta^2 = 0.77$. The condition x set size interaction was significant, $F(1,19) = 9.4$, $MSE = 12.53$, $p > 0.01$, partial $\eta^2 = 0.33$, showing, as expected, that the preview condition was more efficient than the FEB condition. Observed power for the main effects were 1, but for the interaction was 0.83.

Search errors. Mean percentage error rates can be seen in Table 21. Entered into a 3 x 2 ANOVA, the main effect of condition was not significant, but both the main effect of set size, $F(2,38) = 11.34$, $MSE = 1.84$, $p > 0.01$, partial $\eta^2 = 0.37$, and the two-way interaction, $F(2,38) = 7.78$, $MSE = 1.52$, $p > 0.01$, partial $\eta^2 = 0.29$, were significant. Observed power was > 0.89 for both significant values. The difference is due to elevated error rates at set size

16. Although not clear why this has occurred, it does not suggest that there was a speed-accuracy trade-off.

Table 21. Mean percentage error rates with standard error for Experiment 6a.

	Set Size			
Condition	8	SE	16	SE
FEB	3.31%	0.36%	4.13%	0.40%
Fixed conjunction	4.00%	0.62%	3.75%	0.23%
Preview	2.57%	0.36%	4.50%	0.22%

These results are not consistent with Experiment 5 in showing a greater search efficiency under fixed item conditions. A possible explanation for this, dual-task interference, will be addressed further in the discussion. Whilst these findings complicate interpretation of probe performance, an analysis has been carried out below for completeness.

Probe Detection Results. The percentages of trials when the probe was correctly detected for each condition were entered into paired-sample T-tests. Probe detection was significantly higher in the FEB condition than in the preview condition, $t(19) = 6.67$, $p < 0.01$, and in the FC condition $t(19) = 3.92$, $p < 0.01$. Probe detection was no more accurate in the preview over the FC condition, $t(19) = 1.94$, $p = 0.07$.

The results show that the probe was missed significantly more in the FC and preview conditions than in the FEB condition. Furthermore, probe detection across the FC and preview conditions were similar. This supports the theory that participants were inhibiting the locations of the preview/fixed items. However, in this experiment there was no search benefit in the FC condition in comparison to the FEB. It is important to note that the search slope in the preview condition was unusually high (19.04ms/item as opposed to ~3ms/item): it is possible that the probe task created dual-task interference in this experiment.

3.4. Experiment 6b

Experiment 6b also used search tasks with a probe detection task. This was to assess whether participants were allocating attention to new locations and/or if their attention is

being automatically captured by the onset of the new items. The probe therefore appeared next to the new/non-fixed house distractors as opposed to the old/fixed female face distractors. If attention is being captured by the onset of new items, then accuracy of probed detection should be greater in the preview and FC conditions than in the FEB.

3.4.1. Participants

Twenty participants (14 female) took part in exchange for money £7.50. Participants were aged between 18 and 34 (Mean = 25.38 years, SD = 4.84 years). All reported having normal or corrected-to-normal vision. All participants were right-handed.

3.4.2. Stimuli

Stimuli were the same as those used in Experiment 6a: old/fixed distractors were 4 or 8 female faces, new/non-fixed distractors were 3 or 7 houses and the target was a male face which appeared at the same time as the house distractors.

3.4.3. Design and procedure

The experiments lasted approximately 45 minutes. The experiment was identical to that of Experiment 6a, except that the probe, when present, appeared next to one of the house distractors.

3.4.4. Results and discussion

Search results. Outliers were once again eliminated using the aforementioned method (6.82% of the data). Table 22 shows the mean correct RT and SD for each condition by set size. Figure 12a shows the search slopes for each condition. Figure 12b shows the percentage of correct responses across the conditions when the probe was present.

Table 22. Mean RTs and SDs across set size and condition for Experiment 6b.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	1309	391.12
16	1673	568.12
FC		
8	1262	416.63
16	1671	576.32
Preview		
8	839	272.23
16	1008	348.38

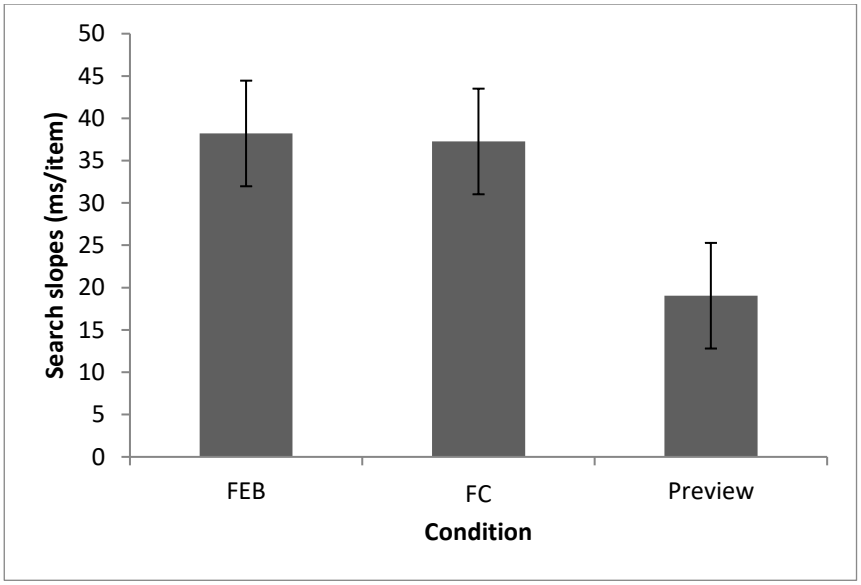

Figure 12a. Search slopes for each condition for Experiment 6b. Error bars represent SEM.

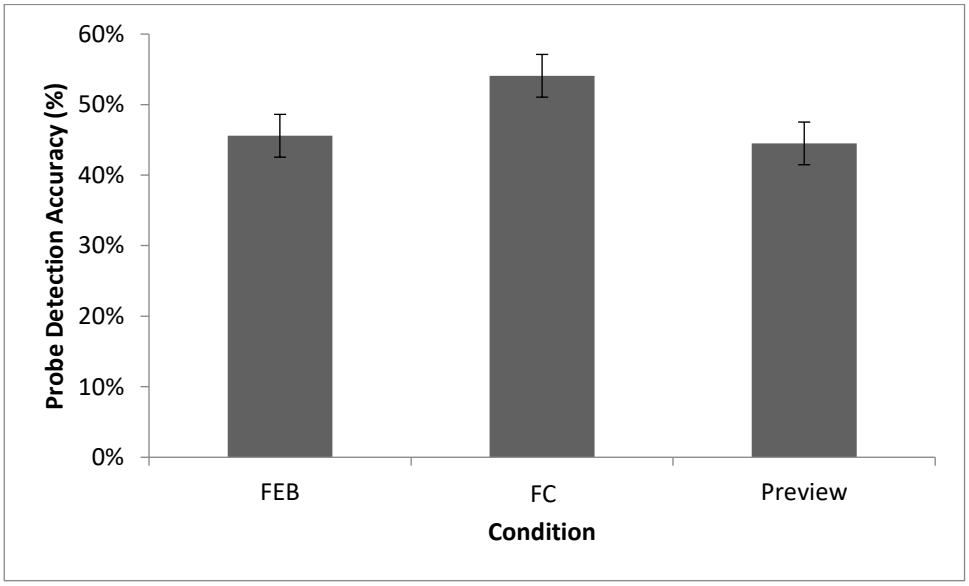

Figure 12b. Percentage of correct Probe Detection when present across condition for Experiment 6b. Error bars represent SEM.

FEB x FC. Mean correct RTs for the FEB and the FC condition were entered into a 2 x 2 ANOVA with main factors of condition (FEB x FC) and set size (8 x 16). As expected, there was a main effect of set size, $F(1,19) = 112.35$, $MSE = 31.36$, $p < 0.01$, partial $\eta^2 = 0.86$, but once again neither the main effect of condition nor the two-way interaction was significant, $F(1,19) = 0.05$, $MSE = 32.29$, $p = 0.83$, partial $\eta^2 < 0.01$, and, $F(1,19) = 1.12$, $MSE = 1.92$, $p = 0.28$, partial $\eta^2 = 0.06$, respectively, indicating again that search was not more efficient in either condition. Observed power for the set size effect was 1. For completeness, a detailed analysis has been carried out below.

Full factor ANOVA. Mean correct RTs were entered 3 x 2 within participant ANOVA with the factors being condition (FEB x FC x preview) and set size (8 x 16). As with the previous experiment, both the main effects were significant, $F(2,38) = 48.64$, $MSE = 80.54$, partial $\eta^2 = 0.72$, $p < 0.01$ and $F(1,19) = 128.23$, $MSE = 26.43$, $p < 0.01$, partial $\eta^2 = 0.87$ for condition and set size respectively. The two-way interaction was also significant, $F(2,38) = 37.36$, $MSE = 5.66$, $p < 0.01$, partial $\eta^2 = 0.66$. Observed power was 1 for all values. To indicate where the interaction was taking place the data were then split into more specific ANOVAs.

Preview x FEB. Entered into a 2 x 2 ANOVA, RTs were significantly faster in the preview condition than the FEB, $F(1,19) = 50.01$, $MSE = 113.81$, $p <0.01$, partial $\eta^2 = 0.73$, and at the smaller set size, $F(1,19) = 127.33$, $MSE = 14.21$, $p < 0.01$, partial $\eta^2 = 0.87$. The condition x set size interaction was significant, $F(1,19) = 36.91$, $MSE = 9.28$, $p < 0.01$, partial $\eta^2 = 0.66$, once again indicating that the preview condition was more efficient than the FEB condition. Observed power was 1 for all values.

Preview x FC. Entered into a 2 x 2 ANOVA, RTs were faster in the preview condition than the FC, $F(1,19) = 61.84$, $MSE = 95.55$, $p < 0.01$, partial $\eta^2 = 0.76$, and when there were fewer items, $F(1,19) = 127.67$, $MSE = 13.06$, $p < 0.01$, partial $\eta^2 = 0.87$. The two-way interaction was also significant, $F(1,19) = 49.9$, $MSE = 57.78$, $p < 0.01$, partial $\eta^2 = 0.72$, supporting the

notion that in this experiment also the fixed condition was not as efficient as the preview condition. Observed power was 1 for all values.

Search errors. Mean percentage error rates can be seen in Table 23. Overall search errors were all < 5.3%. Compared in a 3 x 2 ANOVA, the only significant effect was that of set size, $F(1,19) = 77.21$, $MSE = 5.24$, $p < 0.01$, partial $\eta^2 = 0.44$. Observed power = 0.95. Errors were significantly higher at set size 16, suggesting there was no speed-accuracy trade-off.

Table 23. Mean percentage error rates with standard error for Experiment 6b.

	Set Size			
Condition	8	SE	16	SE
FEB	3.88%	0.92%	5.75%	1.34%
Fixed conjunction	4.75%	1.04%	5.69%	0.99%
Preview	3.25%	0.55%	5.25%	0.56%

As with the previous experiment, the results do not support the findings of Experiment 5, which implied search efficiency in a FC condition to be similar to that of a preview condition. Whilst these apparently contradictory findings again detract from the validity of the probe task results, an analysis was carried out.

Probe Detection Results. The percentages of trials when the probe was correctly detected for each condition were entered into paired-sample T-tests. Probe detection was significantly lower in the preview condition than in the fixed conjunction condition, $t(19) = 3.31$, $p < 0.01$, and was also lower in the FEB condition than in the FC condition $t(19) = 3.34$, $p < 0.01$. Interestingly, probe detection was equally as accurate in the FEB and preview conditions, $t(19) = 0.61$, $p = 0.55$.

The results show that probe detection was significantly better in the FC condition than in the FEB condition and the preview condition. Probe detection was equally as accurate across the preview and FEB condition. These results are not compatible with the idea that the search benefits seen in Experiment 5 were due to onset capture; had this been the case, probe detection should have been higher in the preview condition as the houses onset at the same time as the target. The results also do not support the theory that the search benefit is due to participants generating an attentional bias towards the unoccupied

locations in the fixed/preview conditions. Had this been true, we would have expected to see greater similarity between probe detection accuracy in the preview condition and the FC condition, as attentional biases could be generated for new/non-fixed locations in both these conditions.

It is notable that the search slope in preview condition of Experiment 6b was far higher than is typically the case (at 21.08ms/item), reinforcing the notion that there was a confounding factor at play. One suggestion is that the probe task caused dual-task interference with the search task, something which is known to disrupt preview benefit (Watson & Humphreys, 1997; Olivers & Humphreys, 2002). If this were the case, it may also have caused disruption to the fixed item benefit seen in Experiment 5. To try and reduce the effects of having to perform an additional task, Experiment 7 was carried out, which replicated Experiment 6a except that the probe detection task took place on only 25% of the trials.

3.5. Experiment 7

Experiment 7 repeated Experiment 6a but with the 'weighting' that might be applied to the probe detection and search tasks altered by presenting the probe task on only a quarter of trials whilst the remaining trials contained the search task. Under the conditions used here the search task was designed to be more strongly weighted than the probe task with the intention to induce standard preview benefit.

3.5.1. Participants

Twenty participants (10 female) took part in exchange for £7.50. Participants were aged between 18 and 32 (Mean = 24.41 years, SD = 3.33 years). All reported having normal or corrected-to-normal vision. Two participants were left-handed.

3.5.2. Stimuli

The stimuli were the same as those used in Experiment 6 with the addition of a 1000Hz tone to indicate the probe detection trials.

3.5.3. Design and procedure

The experiment took approximately 45 minutes. The procedure was identical to that of Experiment 6a except that the probe detection task took place on only 40 trials (25%). Of these 40 trials, the probe was present on 20 of them and was absent on the other 20. The remaining 120 trials contained normal search tasks. As with Experiment 6a there were 3 conditions: A FEB condition, a FC condition and a preview condition.

For probe detection trials, the procedure was as the same as normal search trials up until the search items appeared (immediately after the 1000ms pause in both conjunction conditions and after the 1000ms preview display in the preview condition). Participants then heard a 1000Hz tone which indicated they were instructed to perform a probe detection task, as opposed to a regular search task. The stimuli remained on the screen for 600ms and then disappeared. The question "Did you see a probe? No (a) or Yes (l)" was subsequently displayed and remained on screen until participants responded. RTs, search accuracy and probe detection accuracy were recorded.

3.5.4. Results and discussion

Search results. Outliers were once again eliminated using the aforementioned method (9.9% of the data). Table 24 shows the mean correct RTs and SDs for each condition by set size. Figure 13a shows the search slopes across condition and Figure 13b shows the percentage of correct responses across the conditions when the probe was present.

Table 24. Mean RTs and SDs across set size and condition for Experiment 7.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	979	221.70
16	1287	329.06
FC		
8	608	159.71
16	727	216.66
Preview		
8	948	257.32
16	1181	338.95

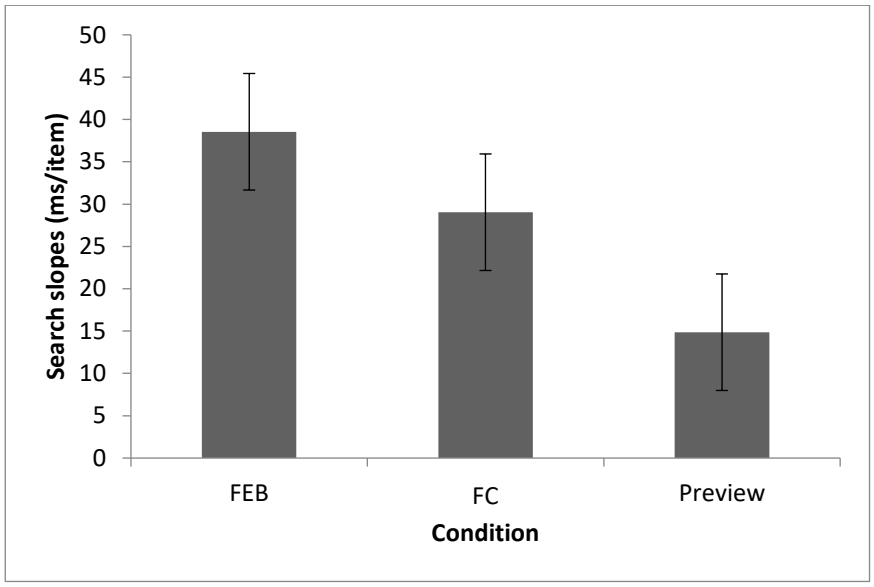

Figure 13a. Search slopes across conditions for Experiment 7. Error bars represent SEM.

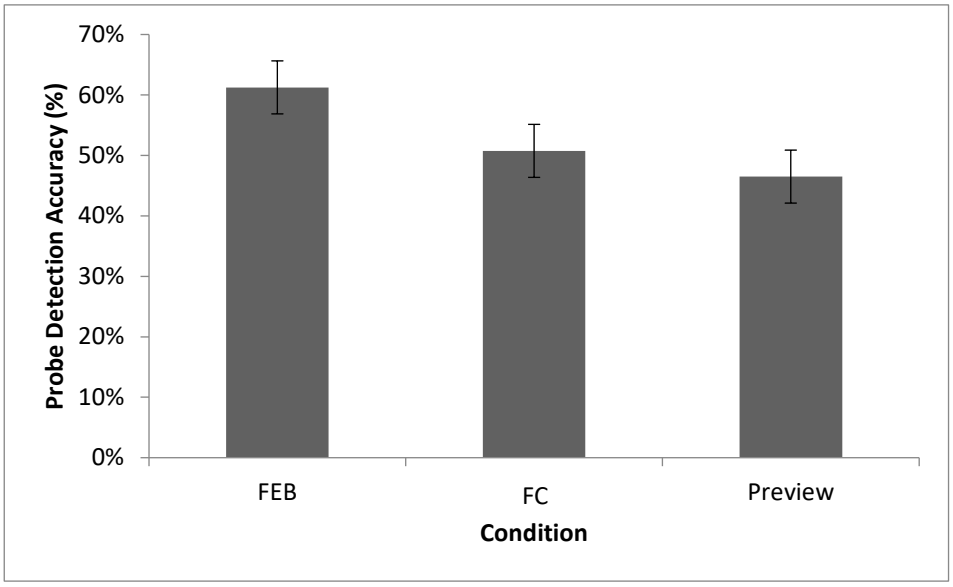

Figure 13b. Percentage of correct Probe Detection when present across condition for Experiment 7. Error bars represent SEM.

FEB x FC. Of note, a 2 x 2 within participant ANOVA on the FEB and FC conditions showed there was a main effect of set size, $F(1,19) = 108.91$, $MSE = 13.43$, $p < 0.01$, partial $\eta^2 = 0.85$, but no main effect of condition, $F(1,19) = 2.64$, $MSE = 36.42$, $p = 0.13$, partial $\eta^2 = 0.12$. However, the condition x set size interaction was significant, $F(1,19) = 16.45$, $MSE = 1.75$, $p < 0.01$, partial $\eta^2 = 0.47$, indicating again that search was more efficient in the fixed conjunction condition. Observed power was > 0.97 for significant values.

Preview x FC. A 2 x 2 ANOVA comparing the preview condition with the FC condition showed that whilst RTs were faster in the preview condition, $F(1,19) = 83.67$, $MSE = 33.78$, $p < 0.01$, partial $\eta^2 = 0.82$, and again at the lower set size, $F(1,19) = 93.56$, $MSE = 6.59$, $p < 0.01$, partial $\eta^2 = 0.83$, and that the two-way interaction was once again significant, $F(1,19) = 19.11$, $MSE = 3.36$, $p < 0.01$, partial $\eta^2 = 0.53$, indicating the FC condition was once again less efficient then the preview condition. Observed power in all cases was > 0.99. A detailed analysis has been completed below for completeness.

Full factor ANOVA. The mean correct RTs were entered into a 3 x 2 within participant ANOVA with the factors being condition (FEB x FC x preview) and set size (8 x 16). As with the previous experiment, both the main effects were significant, $F(2,38) = 51.64$, $MSE = 49.04$, $p < 0.01$, partial $\eta^2 = 0.73$, and, $F(1,19) = 122.94$, $MSE = 11.81$, $p < 0.01$, partial $\eta^2 =$

0.87. The two-way interaction was also significant, $F(2,38) = 25.89$, MSE = 3.12, $p < 0.01$, partial $\eta^2 = 0.58$. Observed power was 1 for all values.

Preview x FEB. A 2 x 2 ANOVA showed RTs were significantly faster in the preview condition than the FEB, $F(1,19) = 59.55$, MSE = 72.96, $p < 0.01$, partial $\eta^2 = 0.76$, and at the smaller set size, $F(1,19) = 128.58$, MSE = 7.11, $p < 0.01$, partial $\eta^2 = 0.87$. The condition x set size interaction was significant, $F(1,19) = 33.10$, MSE = 5.43, $p > 0.01$, partial $\eta^2 = 0.64$, indicating that the preview condition was more efficient than the FEB condition. Observed power was 1 for all values.

Search errors. Mean percentage error rates can be seen in Table 25. Entered into a 3 x 2 ANOVA, there was a main effect of condition, $F(2,38) = 11.24$, MSE = 3.09, $p > 0.01$, partial $\eta^2 = 0.37$, and set size, $F(1,19) = 33.34$, MSE = 3.36, $p > 0.01$, partial $\eta^2 = 0.64$. The two-way interaction was also significant, $F(2,38) = 6.02$, MSE = 3.55, $p > 0.01$, partial $\eta^2 = 0.24$. Search errors were higher in both set size 16 and the preview condition. Observed power was > 0.85 for all values. This suggests that the results of the preview condition may be due to a speed-accuracy trade-off. However, given that the statistical analysis here indicates the preview was more efficient than the FC and FEB conditions, and that this was consistent with previous preview literature, it seems unlikely that the speed-accuracy trade-off has had much of an impact, although further research should look to verify this assumption.

Table 25. Mean percentage error rates with standard error for Experiment 7.

	Set Size			
Condition	8	SE	16	SE
FEB	4.24%	0.51%	5.08%	0.43%
Fixed conjunction	2.71%	0.29%	4.07%	0.30%
Preview	3.42%	0.63%	7.00%	0.61%

Although these results do not fully replicate the search benefit found in Experiment 5, the difference in efficiency between the FEB and the FC condition under reduced secondary task interference do in part support the theory that participants are able to inhibit the fixed item locations (as suggested by Experiment 5). These results certainly suggest that there

was interference caused by having to complete a probe task simultaneous to completing the search task. Results of the probe task are analysed below.

Probe Detection Results. The percentages of trials when the probe was correctly detected for each condition were entered into paired-sample T-tests. Probe detection was significantly lower in the preview condition than in the FEB condition, $t(19) = 2.53$, $p < 0.05$, and in the FC condition than in the FEB condition $t(19) = 3.04$, $p < 0.01$. Probe detection was equally accurate in the FC and preview conditions, $t(19) = 0.68$, $p = 0.51$.

The probe detection results in the preview condition replicate the findings of Experiment 6a: detection accuracy was as low in the preview condition as it was in the FC condition and was significantly better in the FEB condition. These results again suggest that participants are able to ignore the locations of the previewed/fixed items and are consequently paying less attention to the female faces in these conditions. At 14.87 ms/item, search slopes were still higher in the preview condition than is usually reported in the preview search literature, suggesting that, despite the altered probabilities of the tasks in this experiment there was still some cross trial interference of the probe task on search. Despite this, the results do partially replicate the findings of Experiment 5; search was more efficient in the FC condition than the FEB condition, although not as efficient here as in the preview condition.

3.6. Chapter summary and discussion

Rejection of irrelevant items may be achieved in a number of ways in order to create a faster, more efficient search. These include segregating distractors and targets into distinct groups (Duncan & Humphreys, 1989), rejecting distractors based on a common feature (Braithwaite, et al., 2005) and inhibiting irrelevant distractor locations (Watson & Humphreys, 1997, 2000). The focus of this chapter was to see whether having half of the search distractor items in a visual search test appear in the same location from trial to trial would be more efficient than if all items appear at random locations. The results of this chapter appear to support this hypothesis.

In Experiment 5, search was found to be more efficient in a fixed conjunction condition than in a FEB condition and was, in fact, as efficient as in a preview condition. This is thought to be due to a combination of learning and subsequent inhibition of distractor location. Although contextual cueing is considered to rely on target location being kept constant in relation to distractors under repeated conditions (Chun & Jiang 1998), the results here show that despite the target appearing in random locations from trial to trial, search can be efficient. It is possible that this is due to differences in experimental design. Whilst repeated displays in Chun and Jiang's (1998) experiments were not consciously learnt, participants here knew that certain items would appear only in certain locations and, as this was true on every trial, that these items could be rejected without having to be attended to. Therefore, rather than the location of distractors guiding attention subconsciously towards a specific target location, the consciously learned location of the distractors guide attention away from those locations, allowing resources to be allocated to other, more likely target locations.

Experiments 6a and 6b used a probe task to examine whether the efficiency seen in Experiment 5 was due to preview/fixed distractor location inhibition as opposed to intentional biasing of attention towards potential new/non-fixed item locations. It could be argued that the inhibition seen here may be due to inhibition of distractor features (e.g. roundness) as opposed to inhibition of location. This would be consistent with the concept of feature maps discussed in Treisman and Gelade's (1980) FIT theory. Treisman and Gelade suggested that spatial attention can be likened to a number of maps to represent various visual features, (such as colour, shape, depth, etc.) and that search across an individual feature map takes place in parallel (as in single feature search). It is therefore possible that the fixed distractors (which had the same shape as the target) could be inhibited on the shape feature map, enabling search to proceed in a more parallel manner to the remaining round item (i.e. the target). However, feature inhibition would not explain the difference in efficiency seen between Experiments 5 and 7. If participants are able to effectively inhibit the features of the distractors then it should not matter where the distractors appear and thus no difference between the full and fixed conjunction conditions would have arisen. Further, the distractor faces were chosen at random from a

bank of images, so different female faces were used on each trial. Previous literature on the number of items which can be held in visual working memory varies across studies and arguably depends upon the complexity of the items to remember (Luck & Vogel, 1997, 2013; Alvarez & Cavanagh, 2004; Awh, Barton, & Vogel, 2007). Even if we are generous with our estimates of how many distractor items participants could remember seeing previously, it is unlikely to be as high as the 28 distractor pool from which the female faces were selected. Taken with the fact that faces are visually complex and that the size of the faces changed to make the display even more varied, it seems highly unlikely that participants were able to remember and inhibit distractor features.

Finally, Experiment 7 replicated the findings that probe detection is worse in preview/fixed conjunction conditions when it appeared next to distractor female faces than in a FEB condition. The finding that search is more efficient when items appear in the same location was also replicated again here. Results from Experiment 7 did not however show search in a fixed conjunction condition to be as efficient as in a preview condition. This could be explained by the fact that, despite there being no direct overlap, there was some task interference from the probe detection task. The effect of a secondary task on visual search efficiency has been studied using a variety of behavioural tasks (Pomplun, Reingold & Shen, 2001; Underwood, Chapman, Bowden, & Crundall, 2002; Richard et al., 2002; Woodman & Luck, 2004), particularly in relation to preview search, as discussed extensively in Chapter 1 (Olivers & Humphreys, 2002; Humphreys et al., 2002). If, as we assume, location inhibition is responsible for the trends seen in Experiments 5 and 7 and active attention is required to successfully inhibit items, the presence of a dual-task would cause search efficiency to decrease. This would explain the lack of efficiency in the fixed conjunction condition seen in Experiments 6a and 6b, and the relative lack in Experiment 7, as well as the higher than usual search slopes in the preview condition.

It is also possible that search in Experiments 6a – 7 was efficient, but that traditional methods of analysing search efficiency were not sensitive enough to detect it. For example, in the previously discussed studies on the effect of priming in visual search (Kristjánsson et al., 2002; Geyer et al., 2006) priming caused an improvement in search times but did not actually improve search efficiency. That is to say, although search was faster across

conditions depending on target/distractor repetition, the search rates (as represented by search slopes) did not alter. It was therefore argued by some that priming did not affect processes that guide attention, but instead affect processes after attention has been deployed, such as decision-making processes or response selection ("post-selectional" processes (Kunar et al., 2007)). To assess this possibility, Becker and Horstmann (2009) conducted a priming conjunction search task which recorded both RT data and eye-tracker data. Their results showed that although the search slopes did not indicate an efficient search (i.e. greater than 10ms; (McLeod et al., 1988; Nakayama & Silverman, 1986; Treisman & Sato, 1990; Wang, Kristjansson & Nakayama, 2005; Wolfe et al., 1989)), eye-tracking data indicated participants were more likely to fixate initially on the target under priming conditions than under no priming conditions, across all set sizes. This suggests that priming does guide attention, rather than affecting post-selectional processes, and that priming does affect search efficiency, although this cannot be seen using traditional methods of measuring efficiency (such as search slopes).

It would therefore be interesting to repeat Experiments 6a – 7 using an eye-tracker as well as recording typical RT data. Not only would this indicate whether search efficiency is higher than presently indicated, but would also allow the probe detection task to be replaced with eye-tracking data. This should eliminate any potential dual-task conflict, as well as indicating where participants direct their attention. Although, as previously discussed, it is unlikely that the results seen are due to inhibition of distractor features as opposed to distractor location, this could also be tested using an eye-tracker task and by varying the colour of the distractors. For example, if half the fixed distractors (female faces) and half the non-fixed distractors (houses) were blue whilst the other half remained red and the target was always red, participants should preferably direct their attention to red female faces if they are inhibiting distractor features. If, on the other hand, they are inhibiting distractor location then participants should direct their attention towards the house distractors regardless of their colour and not towards the female faces.

A further line of research could be to examine the effect of varying the ratio between fixed distractors and non-fixed distractors. In the present studies, only half the distractors items

had fixed locations so that the data could be compared to data from preview search. However, traditional location priming studies, as well as contextual cueing studies, fix the locations of all the distractors. If participants were able to learn the locations and inhibit them, search efficiency should increase as the number of fixed distractor items increases and the number of non-fixed distractor items should decrease. Future studies in this area should also increase the number of experimental trials used. The present studies used only sixty trials, whereas Chun and Jiang's (1998) contextual cueing experiments, for example, had multiple blocks of approximately twenty-four trials each. As their results showed an added search benefit for each block of trials, it is possible that sixty trials would not be sufficient to find any genuine differences in search efficiency.

Chapter 3 – The effect of anticipation on preview benefit

Feature anticipation can guide visual attention in target detection tasks (e.g. Klein, 1988), search tasks (e.g. Posner, 1980) and preview search tasks (Braithwaite, et al, 2003). The current chapter examined whether, given a choice of strategies in preview search, participants could choose to inhibit the preview items or bias their attention towards items of the cued colours, or whether the colour cue would exogenously guide attention towards like-colour items. Results indicate that attention is biased towards items of a cued colour even when this makes search less efficient (Experiment 8), but this appears to be a voluntary choice and not the result of automatic attention guidance (Experiment 9).

4.1. Introduction

The prioritisation of new items in visual search can largely be considered from two schools of thought: bottom-up attentional capture of the new items (Theeuwes, 1992, 1993, 1994, 1996; Yantis, 1993), and top-down, goal-driven allocation of attention to the new items or away from the old items (Bacon & Egeth, 1994; Folk & Remington, 1996; Folk, Remington & Wright, 1994; Yantis & Egeth, 1999). Bottom-up attentional capture is involuntary, passive and has unlimited capacity, whilst top-down attentional control is voluntary, active and resource limited (Posner & Snyder, 2004; Jonides, 1981). Within top-down attentional allocation, the literature can be further divided into two groups: inhibition of old, behaviour-irrelevant items, such as in preview search (Watson & Humphreys, 1997); and anticipatory biasing of attention towards the new items (Moore & Egeth, 1998).

4.1.1. Exogenous and endogenous cues

Early work on the effect of anticipation on visual attention was carried out by Posner (1980). In his experiments, participants had to locate a target stimuli in a circular array around a central fixation point. In one condition, the cues were exogenous (bottom-up), appearing at one of the potential target locations in the periphery (a “peripheral” cue). In another condition, the cues were endogenous (top-down), appearing as an arrow at

fixation point which indicated a potential target location. In both cases, the cue either accurately indicated the upcoming target location (valid trials), or did not indicate the target location (invalid trials). Neutral conditions did not contain a cue of any sort. The results from Posner (1980) showed that whilst both bottom-up and top-down cues facilitated response times to the target when they were valid and slowed responses when they were invalid, only exogenous cues involuntarily captured attention. For example, under conditions where the cue was invalid on the majority of trials, participants were able to ignore the endogenous cue such that target response times were similar to neutral (no cue) conditions. However, if the cue was an exogenous cue, response times to a target appearing at a different location significantly slowed RTs, suggesting that participants were not able to prevent their attention being drawn towards the peripheral cue.

Whilst exogenous cues (such as an abrupt onset) have also been reported to capture attention without intention in other studies (Jonides, 1981; Müller & Rabbitt, 1989), research by Theeuwes (1991) suggests that this is not necessarily automatic in all cases. His study used a similar procedure to that of Posner (1980), that is, a central fixation point and peripheral target/distractor locations. As in Posner's endogenous cue trials, a central arrowhead was used to cue the upcoming location of a target. However, during some trials an exogenous, peripheral cue also appeared at the same time in either the same location or a different location. Theeuwes found that whilst a peripheral cue in the same location led to increased reaction times, a peripheral cue at a different location did not hinder participants' ability to locate the target. The findings presented in Theeuwes (1991) suggest that providing there is a valid, endogenous cue, attention can remain under top-down, voluntary control and prevent attention being involuntarily captured by an exogenous cue.

Exogenous and endogenous cueing in attention are not limited solely to visual cues on visual targets, but can be seen across modalities. A series of studies (Spence & Driver, 1994, 1996, 1999; Rorden & Driver 1999; Ward, McDonald & Lin, 2000; Schmitt, Postma, & de Haan, 2000; Vroomen, Bertelson, & De Gelder, 2001), demonstrated the effect of exogenous and endogenous cues in audio/visual discrimination tasks. The findings showed

that responses to targets in a second modality were facilitated when an informative cue in a different, primary modality appeared on the same side (Spence & Driver, 1996; Spence, Pavani & Driver, 2000). ERP studies have shown that endogenous shifts in attention for a spatial task in one modality (e.g. touch, audio) can modulate ERP responses to both within modality stimuli, and also ERP responses in other modalities (e.g. visual; Eimer et al. (2002)). Findings from exogenous orienting of attention showed responses to targets presented on the same side as an exogenous cue were facilitated both within modality (i.e. both visual stimuli) or between modality (cross-modally, i.e. audio stimuli followed by visual stimuli). Interestingly, there have been conflicting findings as to cross-modal facilitation, with some studies reporting audio cues facilitating responses to visual targets, but visual cues not facilitating responses to audio targets (Spence & Driver, 1997) and other studies showing the exact opposite effect (Ward, 1994). The effects are not due simply to response priming as they occur even when the cue is not indicative of the target location or the required response (Spence & Driver, 1996; Ward et al., 2000). These differences, however, can be attributed to methodological issues (such as endogenous orienting of attention or insensitive response measures) and more advanced research methods which address such factors show that audio cues can exogenously capture visual attention, and visual cues can exogenously capture audio attention (see Spence (2001) for a review).

4.1.2. Feature biases

Within search literature there is a vast amount of evidence of the benefit of actively biasing attention towards particular features. Research has shown that varying the proportions of stimuli features in a conjunction search can enable participants to preferentially bias their attention towards the feature most useful to the search task (Zohary & Hochstein, 1989) For example, in a search for a vertical red bar among green vertical and red horizontal bars, the proportion of stimuli can be manipulated such that the number of red items is increased, or the number of vertical items is increased. In the instance of increased red items, it would be more beneficial for participants to direct their attention instead to the vertical items, as there will be less of them to search through before the participants find the target. This is what participants appeared to do; Zohary and Hochstein (1989) found

that search was least efficient when the proportions of stimuli feature were equal and became more efficient as proportions became more varied, suggesting that participants were able to intentionally scan only one target-relevant feature. It was later suggested by Bacon and Egeth (1997) that this result was likely due to the prioritisation of target features which, as the numbers of distractors of each type diverged, enabled attention to be allocated only towards features which were relevant to locating the target. Further evidence from Egeth, Virzi and Garbart (1984) showed that in a standard conjunction search, attention could be allocated specifically to distractors which shared the relevant target defining features. Results of these experiments and others of a similar nature suggest that an anticipatory bias can be created towards items with known target relevant features (Folk et al., 1992; 1993; Folk et al., 1994; Kaptein, Theeuwes & van der Heijden, 1995; Moore & Egeth, 1998).

In a recent study, Sunder and Arun (2016) examined the effect of priming either the target, a distractor or an unrelated square on search times. Of interest, they plotted their findings using the reciprocal of search time (1/reaction time) and found that priming an informative item (i.e. the target or a distractor) created a fixed increase in the salience of the item, i.e. that bottom-up attention capture of an item could be modulated by top-down knowledge. As such, priming a target item in a more complicated search display (e.g. with a greater number of items) will produce a comparatively greater benefit to the subsequent search than would occur in a more simplistic search.

4.1.3. Feature anticipation and preview search

The effect of target anticipation in preview search has been studied by Braithwaite and colleagues (Braithwaite et al., 2003), who manipulated the number of distractor items which appeared in each colour from displays where preview items were all one colour (e.g. red) and new items were all another colour (e.g. green), to displays where both preview items and new items were an equal mixture of red and green items. Their results show a greater preview benefit in the conditions where the new items all shared a common colour. The authors suggested that this was due to participants adopting an anticipatory set towards new items based on colour. Further support for the importance of anticipation in

preview search was given by Braithwaite and Humphreys (2003). Here the colour ratio of items was manipulated (as in Braithwaite et al. (2003)) and in certain conditions participants had prior knowledge of the colour of the target. Their results showed that prior knowledge of target colour led to more efficient search in both the preview condition and in the full-element baseline condition, where all items appeared simultaneously.

However, whilst their findings clearly demonstrate the benefit of creating anticipation towards the new items, there is also compelling evidence that the benefit is, in part, due to inhibition of old item features. Indeed, Braithwaite et al. (2003) found that participants were slower to locate targets which shared a colour with the majority of distractors items in the preview search. They suggested that this was due to the negative carryover of colour inhibition from the preview group. Further, results of a probe detection task by Braithwaite et al. (2005) under similar conditions showed that a probe was less likely to be accurately detected on a target which shared a feature with the inhibited preview items.

4.1.4. The purpose of this chapter

The purpose of the studies in this chapter was to investigate how prior knowledge of a target feature affects preview search when using a conjunction task and, in particular, whether or not one strategy of deploying attention is preferable to another. Results from Braithwaite and colleagues (2003, 2005) suggest that a valid colour cue would make search more efficient than in a neutral condition where no useful cue is given. However, due to the stimuli used in these studies, alphanumeric latin letters, participants were arguably only biasing their attention towards one property: the colour of the target. In this study, however, participants had a potential choice of strategies to guide search: that of top-down attentional guidance towards items of a particular colour (by use of a valid colour cue) or top-down location inhibition of the preview items. With this in mind, it is possible that rather than inhibiting the locations of the previewed items and utilising a parallel search strategy once the search items appear, participants could instead simply choose to bias their attention towards items of the cued colour and which are face-shaped, even though this ultimately results in a serial search.

Experiment 8 consisted of a preview search that briefly presented a cue of a target feature (its colour) before any of the display items appeared in order to test whether this would affect search efficiency. If participants preferentially use a search guidance strategy based on the cue, attention could be deployed to each face of that colour, resulting in a less efficient search than seen in standard preview conditions. Experiment 9 repeated Experiment 8 but varied the accuracy of the colour cue from 100% valid (predicts the colour on every trial) to no cue given at all to examine whether participants had voluntary control over whether their attention was guided by the colour cue, or whether the cue automatically guided their attention towards items of that colour. The results are discussed in relation to optimal search strategy.

4.2. Experiment 8

Experiment 8 examined the effect of target colour cue on preview benefit by using a valid colour cue on every trial. If participants are able to ignore the colour cue, search should follow the pattern of a standard preview search, i.e. with shallow search slopes across both the neutral and cue conditions. However, if the cue guides attentions automatically, participants may search through the distractor female faces of the cue colour, resulting in a more serial (and thus less efficient) search.

4.2.1. Participants

Twenty participants (10 female) took part in exchange for £10. Participants were aged between 19 and 30 (Mean = 22.83 years, SD = 4.01 years). All reported having normal or corrected-to-normal vision. All participants were right-handed.

4.2.2. Stimuli

Stimuli were the upright faces and houses used in chapters 1 and 2. Half of the stimuli were put through a red colour filter (RGB 255,0,0) and half were put through a blue colour filter (RGB 0,0,255). As with chapters 1 and 2, half the stimuli were smaller than the other half (4 x 4^{o} and 3 x 3^{o} at a normal viewing distance of 57cm) to add visual complexity.

4.2.3. Design and procedure

A custom computer program written in ePrime (Psychology Software Tools, Inc.) was used to generate displays and record responses. The program was run on a PC connected to a 24" LCD monitor running at 60Hz. Participants performed a search task to find a red male face (target) amid distractors and asked to indicate whether the target was to the left or right of a white fixation dot in the middle of the screen. If the target was to the left of the fixation dot, participants were instructed to press the "z" key. If the target was to the right of the fixation dot, participants were instructed to press the "m" key. Across all trials participants were given a practice trial before the experiment proper. Participants completed 80 trials in each condition, split evenly between set size and target colour. The target was present in all trials and participants' reactions times (RTs) and accuracy were recorded.

Participants completed six conditions: three neutral conditions and three cue conditions. These consisted of a half element baseline (HEB) condition, a preview condition and a full element baseline (FEB) condition. All conditions began with the appearance of a fixation dot (1000ms). In the HEB condition participants had to find the target male among 3 or 7 red house distractors. In the preview conditions an initial display of either 4 or 8 female face distractors appeared for 1000ms before the remaining 3 or 7 houses and the target appeared. In the FEB condition participants had to find the target among 4 or 8 female face distractors and 3 or 7 house distractors (for total set sizes of 8 or 16 items; see Figure 14).

In the cue conditions, the fixation dot which appeared before the search items briefly (500ms) changed colour to either red (50% of the trials) or blue (remaining 50 % of the trials). This indicated the colour of the target male face on 100% of the trials. In the neutral condition, the fixation dot changed to an irrelevant colour (either green or yellow) so participants had no indication of what the target colour would be. This was designed to eliminate the potential confound of the luminance change brought on by the change in colour capturing attention. The experiment lasted approximately one hour.

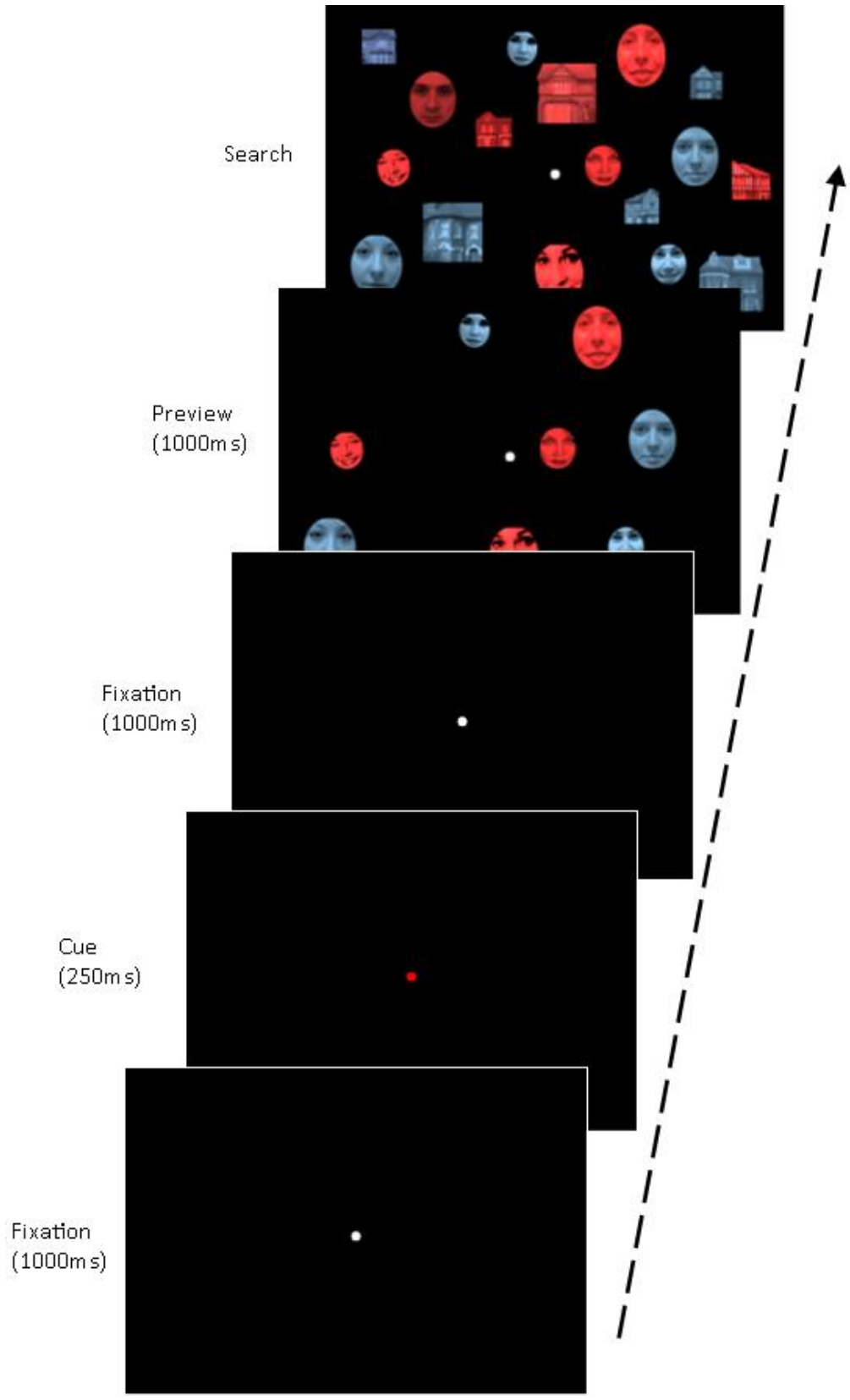

Figure 14. Typical trial in the preview condition, higher set size, for Experiment 8. FEB consists of only the search display and HEB consists of the search display with no female faces. Arrow indicates direction of time.

4.2.4. Results and discussion

Data were trimmed for outliers using the Van Selst and Jolicoeur (1994) method (6.2% of the data eliminated). Table 26 shows the mean correct RTs and SDs across condition by set size. Figure 15 shows the search slopes across conditions.

Table 26. Mean RTs and SDs across set size and condition for Experiment 8.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB Cue		
8	713	107.70
16	942	133.24
FEB Neutral		
8	824	145.61
16	1033	176.13
Preview Cue		
8	480	101.12
16	569	162.10
Preview Neutral		
8	436	257.30
16	480	338.95
HEB Cue		
4	360	28.46
8	372	31.56
HEB Neutral		
4	381	50.16
8	395	52.88

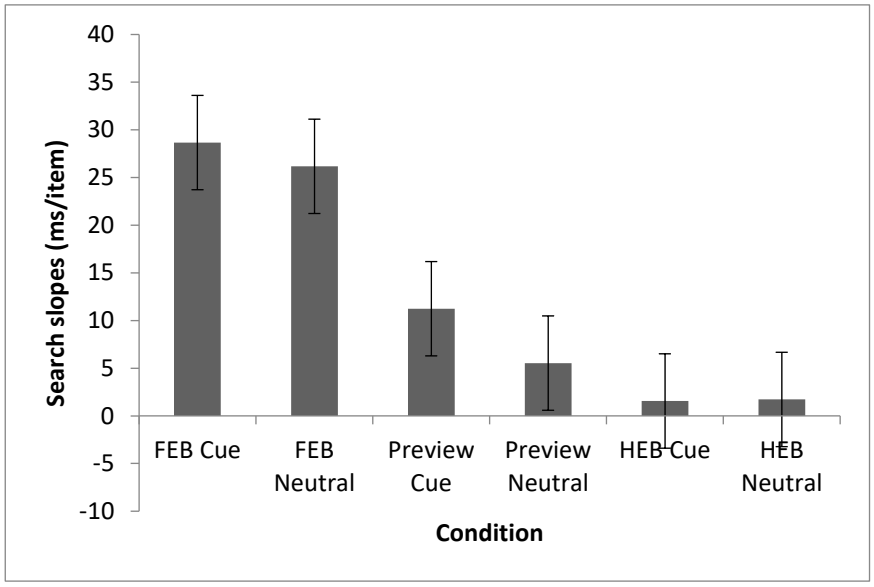

Figure 15. Search slopes across conditions for Experiment 8. Error bars represent SEM.

Preview cue x preview neutral. Of significance to this experiment, the data for both the cued preview condition and the neutral preview condition were entered into a 2 x 2 ANOVA with main effects of cue (cue x neutral) and set size (8 x 16). Both main effects were significant, $F(1,19) = 8.24$, MSE = 10.65, $p = 0.01$, partial $\eta^2 = 0.3$, and $F(1,19) = 40.43$, MSE = 22.3, $p < 0.01$, partial $\eta^2 = 0.68$, for cue and set size respectively. The two-way interaction was also significant, $F(1,19) = 9.56$, MSE = 1.08, $p < 0.01$, partial $\eta^2 = 0.34$. Search was more efficient in the neutral preview condition than it was in the cue preview condition. Observed power for the set size effect and the interaction were both > 0.84. However, the observed power for the effect of cue was only 0.78.

Full factor ANOVA. Mean correct RTs were entered into a 2 x 3 x 2 ANOVA with within participant factors of cue (cue x neutral), condition (FEB x preview x HEB) and set size (8 x 16). There was no overall main effect of cue, $F(1,19) = 1.44$, MSE = 15.29, $p = 0.25$, partial $\eta^2 = 0.07$, but both main effects of condition and set size were significant, $F(2,38) = 347.42$, MSE = 15.87, $p < 0.01$, partial $\eta^2 = 0.95$, and, $F(1,19) = 222.67$, MSE = 2.69, $p < 0.01$ respectively. As expected, the condition x set size interaction was significant, $F(2,38) = 200.78$, MSE = 1.14, $p < 0.01$, partial $\eta^2 = 0.91$, showing search was most efficient in the HEB and least efficient in the FEB. Despite there being no effect of cue overall, the cue x condition interaction was significant, $F(2,38) = 23.45$, MSE = 2.98, $p < 0.01$, partial $\eta^2 = 0.55$,

as was the cue x set size interaction, $F(1,19) = 7.12$, $MSE = 0.95$, $p < 0.05$, partial $\eta^2 = 0.2.48$, suggesting the cue differentially affected the different conditions. The three-way interaction was not significant, $F(2,38) = 2.63$, $MSE = 1.08$, $p = 0.09$, partial $\eta^2 = 0.12$. Observed power was 1 for all significant values, with the exception of the cue x condition interaction, which was 0.72. The data were then split into separate ANOVAs for a more detailed analysis.

Cue conditions ANOVA. Data for the cued preview and the cued FEB were entered into a 2 x 2 ANOVA. The preview condition was faster than the FEB, $F(1,19) = 185.11, 9.91$, $p < 0.01$, partial $\eta^2 = 0.91$, and, the set size effect was also significant, $F(1,19) = 254.32$, $MSE = 3.37$, $p < 0.01$, partial $\eta^2 = 0.89$. The two-way interaction was significant, $F(1,19) = 53.65$, $MSE = 1.81$, $p < 0.01$, partial $\eta^2 = 0.74$, suggesting the preview condition was more efficient than the FEB condition. Observed power was 1 for all values. A 2 x 2 ANOVA on the cued preview and cued HEB condition showed RTs were faster in the HEB than in the preview condition, $F(1,19) = 37.91$, $MSE = 13.25$, $p < 0.01$, partial $\eta^2 = 0.67$, and at set size 8, $F(1,19) = 35.93$, $MSE = 1.49$, $p < 0.01$, partial $\eta^2 = 0.65$. The set size x condition interaction was significant, $F(1,19) = 26.56$, $MSE = 1.13$, $p < 0.01$, partial $\eta^2 = 0.58$, showing that the preview condition was not as efficient as the HEB and therefore only a partial preview benefit occurred. Observed power was 1 for all values.

Neutral conditions ANOVA. A 2 x 2 ANOVA comparing the preview condition with the FEB condition showed RTs were significantly faster in the preview condition FEB, $F(1,19) = 383.73$, $MSE = 11.54$, $p < 0.01$, partial $\eta^2 = 0.95$, and at set size 8, $F(1,19) = 206.04$, $MSE = 1.56$, $p < 0.01$, partial $\eta^2 = 0.92$. The condition x set size interaction was also significant, $F(1,19) = 109.83$, $MSE = 1.24$, $p < 0.01$, partial $\eta^2 = 0.85$, showing participants were more efficient in the preview condition than in the FEB condition. Observed power was 1 for all values. A further 2 x 2 ANOVA comparing the preview condition with the HEB showed RTs in the HEB condition were faster than in the preview condition, $F(1,19) = 31.82$, $MSE = 3.08$, $p < 0.01$, partial $\eta^2 = 0.63$, and at the lower set size, $F(1,19) = 32.96$, $MSE = 0.51$, $p < 0.01$, partial $\eta^2 = 0.43$. The two-way interaction was significant, $F(1,19) = 14.23$, $MSE = 0.33$, $p < 0.01$, partial $\eta^2 = 0.95$. Once again, the preview condition was not as efficient as the HEB

condition, which would suggest a full preview benefit was not achieved. Observed power was > 0.95 for all values.

Search errors. Mean percentage error rates can be seen in Table 27. Entered into a 2 x 3 x 2 ANOVA with main effects of cue (cue x neutral), condition (FEB, preview, HEB) and set size (8 x 16), the main effects were all significant, $F(2,38) = 7.21$, $MSE = 6.61$, $p < 0.01$, partial $\eta^2 = 0.28$ for condition and, $F(1,19) = 5.06$, $MSE = 9.97$, $p = 0.04$, partial $\eta^2 = 0.21$, for cue and, $F(1,19) = 14.04$, $MSE = 2.78$, $p < 0.01$, partial $\eta^2 = 0.43$, for set size. The only significant interaction was the cue x set size interaction, $F(1,19) = 6.54$, $MSE = 5.19$, $p = 0.02$, partial $\eta^2 = 0.26$. However, whilst the condition and set size effects had observed powers > 0.92, the remaining effects and interactions all had observed power values of > 0.68 The results, however, do indicate that error rates were higher at set size 16, for the FEB and in the neutral conditions. With the exception of the neutral conditions, no speed-accuracy trade-off is implied as set size 16 and the FEB conditions were the slowest in terms of search RTs. Further, as noted, the effect of cue only just reached significance, therefore for the purpose of this thesis the effect need not be examined further.

Table 27. Mean percentage error rates with standard error for Experiment 8.

	Set Size			
Condition	8	SE	16	SE
FEB Cue	0.83%	0.48%	3.50%	0.74%
FEB Neutral	3.67%	1.16%	3.33%	0.73%
Preview Cue	0.50%	0.27%	1.67%	0.27%
Preview Neutral	1.50%	0.57%	1.83%	0.57%
HEB Cue	0.83%	0.41%	1.67%	0.41%
HEB Neutral	2.00%	0.78%	2.17%	0.61%

The results of Experiment 8 suggests that the mere presence of the colour cue interfered with the preview benefit in both conditions but, as the analysis above shows, significantly more so when the cue was valid. Surprisingly, it appears that when an accurate target colour cue is used in a preview condition, search is less efficient than in a preview condition where no meaningful colour cue is used. This suggests that when given a choice,

participants will favour an anticipatory search strategy as opposed to an inhibitory one, even when this results in a less efficient search. The reason for the less efficient search slope in the preview cue condition may be that instead of inhibiting the preview items in parallel and performing a single-feature search on the new items, participants instead perform a serial search on the new items, biasing their attention towards the cued target colour. However, it is also possible that participant's attention was directed towards the cued-colour items involuntarily. In their study on priming in conjunction search, Kristjánsson et al. (2002) had a condition where the target would change from trial to trial (the "switch" condition). Despite the knowledge that the target would never be the same as on the preceding trial, participants were significantly slower in locating target in this condition than in the condition where the target was consistent from trial to trial. This finding suggests that it was not under participants' voluntary control to direct their attention towards these items, but rather that the items automatically captured participants' attention.

The results also appear to contradict previous literature on anticipation and preview search (Braithwaite et al., 2003; Braithwaite & Humphreys, 2003). In previous literature, segmenting the items in the review search by colour and varying the ratio of coloured items such that the colour of the target could be anticipated resulted in a more efficient search. However, as there were less features to anticipate in Braithwaite and colleagues' experiments, it is possible that participants adopted a mixed strategy to their search, which entailed both inhibiting the previewed items and creating an anticipatory bias towards the known target colour. If this were the case, the participants' search times should change in relation to what task related resources are available. In order to establish whether the deployment of attention was in fact under participants' voluntary control, and to test the theory that participants adjust their strategy based on whether they can use anticipation or inhibition, Experiment 9 repeated Experiment 8, altering the ratio of valid to invalid cues and comparing them to a standard preview condition.

4.3. Experiment 9

Experiment 9 examined the effect of manipulating the validity of the target colour cue on preview benefit. If the results of Experiment 8 arose because participants' attention was guided automatically to distractor items of the cue colour, then the results of Experiment 9 will be the same as those of Experiment 8, i.e. less efficient search in the cue condition, regardless of whether the cue is likely to be useful or not. However, if participants are choosing to deploy their attention to items of the cue colour as opposed to inhibiting preview items, search should be more efficient as the usefulness of the colour cue decreases.

4.3.1. Participants

Twenty participants (10 female) took part in exchange for £10. Participants were aged between 19 and 30 (Mean = 22.78 years, SD = 4.23 years). All reported having normal or corrected-to-normal vision. Three participants were left-handed.

4.3.2. Stimuli

Stimuli were the same as those used in Experiment 8.

4.3.3. Design and procedure

The experiment lasted approximately one hour. Design and procedure was identical to that of Experiment 8 for the neutral FEB condition, the neutral HEB condition, the neutral preview condition and the cued preview condition (for this experiment, preview 100% condition). The remaining conditions were all preview conditions and, therefore, followed the same procedure as the cued preview condition of Experiment 8. However, the validity of the cue was manipulated across two conditions so that in one condition it was only accurate on 80% of trials (preview 80%), and in the other condition on 20% of the trials (preview 20%). Participants were instructed before each condition as to the rate of cue validity so that they knew beforehand whether the cue was likely to be valid or not. Participants completed 80 trials in each condition, split evenly between set size and target colour.

4.3.4. Results and discussion

Data were trimmed for outliers using the aforementioned method (eliminating 9.00% of the data). Table 28 shows the mean correct RTs and SDs for each condition by set size. Figure 16 shows the search slopes across conditions.

Table 28. Mean RTs and SDs across set size and condition for Experiment 9.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
FEB		
8	1000	208.80
16	1350	266.48
Preview 100%		
8	537	52.02
16	700	51.69
Preview 80%		
8	530	93.71
16	668	129.43
Preview 20%		
8	497	142.48
16	553	262.74
Preview Neutral		
8	468	128.35
16	534	142.09
HEB		
4	383	130.01
8	402	195.20

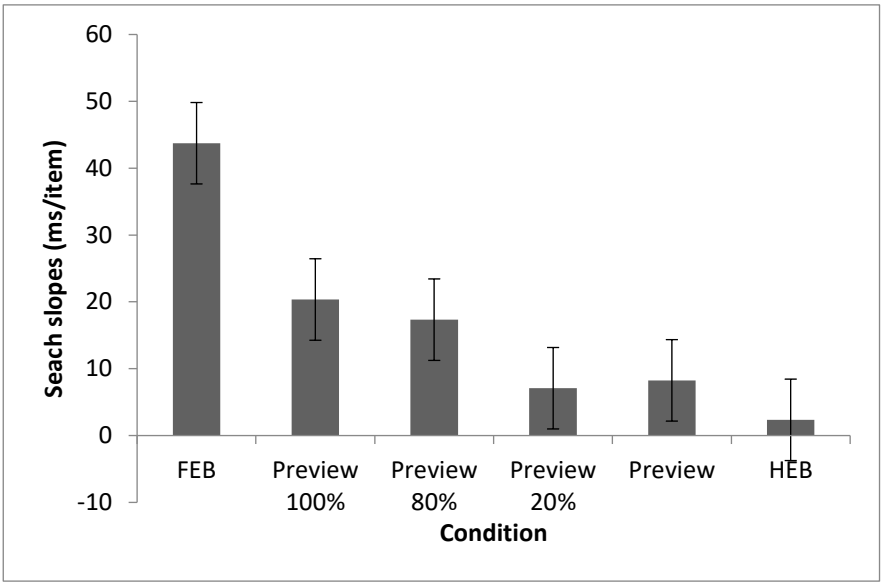

Figure 16. Search slopes across conditions for Experiment 9. Error bars represent SEM.

Preview 20% x preview neutral. Mean correct data for the neutral preview and the 20% valid preview conditions were entered into a 2 x 2 ANOVA. There was a main effect of condition, $F(1,19) = 5.89$, $MSE = 1.99$, $p < 0.05$, partial $\eta^2 = 0.24$, and set size, $F(1,19) = 43.33$, $MSE = 1.74$, $p < 0.01$, partial $\eta^2 = 0.74$; search was marginally faster in the neutral preview condition and was faster at set size 8. The condition x set size interaction was not significant, $F(1,19) = 0.79$, $MSE = 0.56$, $p = 0.39$, partial $\eta^2 = 0.04$, which suggests that search was equally efficient across both preview conditions. Observed power for the set size effect was 1, but the observed power for the effect of condition was only 0.64. For the remainder of the analysis, these results were collapsed together.

Preview 80% x preview 100%. The data for preview 80% and preview 100% conditions were entered into a 2 x 2 ANOVA. As predicted, there was a main effect of set size, $F(1,19) = 32.42$, $MSE = 14.16$, $p < 0.01$, partial $\eta^2 = 0.08$. However, the main effect of condition was not significant, $F(1,19) = 1.67$, $MSE = 4.54$, $p = 0.21$, partial $\eta^2 = 0.63$, and neither was the two-way interaction, $F(1,19) = 0.94$, $MSE = 3.11$, $p = 0.35$, partial $\eta^2 = 0.05$. This shows that neither condition was significantly more efficient than the other. Observed power for the effect of set size was 1. For the remainder of the analyses these two conditions were collapsed together.

High validity previews x low validity previews. The collapsed data for the preview neutral and preview 20% conditions, and the collapsed data for the preview 80% and preview 100%

conditions were entered into a 2 x 2 ANOVA. The main effect of condition was significant, $F(1,19) = 8.56$, MSE = 21.28, $p < 0.01$, partial $\eta^2 = 0.31$, as was the main effect of set size, $F(1,19) = 50.44$, MSE = 4.46, $p < 0.01$, partial $\eta^2 = 0.73$. The interaction was also significant, $F(1,19) = 11.63$, MSE = 3.46, $p < 0.01$, partial $\eta^2 = 0.38$, showing search was more efficient in the invalid preview conditions than the valid preview conditions. Observed power was > 0.9, except for the effect of condition, which was 0.79.

High validity previews x FEB. The collapsed data for preview 80% and preview 100% conditions and the FEB were entered into a 2 x 2 ANOVA with main effects of condition (high validity previews x FEB) and set size (8 x 16). Both of the main effects were significant, $F(1,19) = 84.04$, MSE = 76.43, $p < 0.01$, partial $\eta^2 = 0.82$, and $F(1,19) = 344.39$ MSE = 3.64, $p < 0.01$, partial $\eta^2 = 0.95$, for condition and set size respectively. The two-way interaction was also significant, $F(1,19) = 21.64$, $p < 0.01$, partial $\eta^2 = 0.53$. Although the high validity preview conditions were not as efficient as the low validity preview conditions, they were still more efficient then the FEB. There was, at least, a partial preview benefit.

Low validity previews x HEB. The collapsed data for preview neutral and preview 20% conditions and the HEB were entered into a 2 x 2 ANOVA with main effects of condition (low validity previews x HEB) and set size (8 x 16). Both main effects were significant, $F(1,19) = 39.78$, MSE = 7.34, $p < 0.01$, partial $\eta^2 = 0.68$, and $F(1,19) = 44.52$, MSE = 0.72, $p < 0.01$, partial $\eta^2 = 0.74$, for condition and set size respectively. The two-way interaction was also significant, $F(1,19) = 33.71$, MSE = 0.28, $p < 0.01$, partial $\eta^2 = 0.64$. Despite the low validity preview conditions being more efficient than the high validity preview conditions, they were not as efficient as the HEB. It was not, therefore a full preview benefit.

Search errors. Mean percentage error rates can be seen in Table 29. Entered into a 6 x 2 ANOVA with factors of condition and set size, none of the effects of interactions reached significance, suggesting there was no speed-accuracy trade-off.

Table 29. Mean percentage error rates with standard error for Experiment 9.

	Set Size			
Condition	8	SE	16	SE
FEB	2.00%	0.66%	3.67%	1.02 %
Preview 100%	2.00%	0.57%	1.67%	0.31%
Preview 80%	0.67%	0.27%	1.67%	0.27%
Preview 20%	0.67%	0.31%	2.33%	0.69%
Preview Neutral	1.33%	0.86%	2.67%	0.66%
HEB	2.67%	0.57%	2.50%	0.63%

The results of Experiment 9 replicated the results of Experiment 8 and, in addition, showed that as the proportion of valid target colour cues increased, the preview benefit decreased. The results are consistent with the idea that participants intentionally made use of an attentional biasing strategy as opposed to an inhibitory strategy which, it would seem in terms of preview benefit, is the more efficient option. This also eliminates the possibility that the cue primed participants' attention involuntarily such that items of the cued colour automatically captured participants' attention. When the use of this attention biasing strategy becomes unhelpful in guiding attention, participants resort to using an inhibitory strategy.

Although previous studies concerning preview benefit and both anticipation and inhibition of items (Braithwaite et al. 2003; Braithwaite & Humphreys, 2003) have shown that both these forms of top-down attentional control play an active part in the production of the preview benefit, the author is unaware of previous literature concerning which is used more readily by participants and why this might be. One explanation for participants utilising a less efficient search strategy is that it requires more attentional resources to inhibit items than it does to set up an anticipatory set for them. Indeed, recent work by Theeuwes (2013) suggested that feature-based attention could arguably be exogenous in nature, rather than endogenous, implying fewer resources would be required to anticipate a target feature than inhibit a distractor feature. This could be tested further by carrying out experiments similar to those by Braithwaite and colleagues (2003, 2005) and introducing an attention-demanding dual-task (Al-Aidroos, et al, 2012; Allen et al., 2008; Humphreys et al., 2002). By comparing the effect of the dual-task on anticipation and

inhibition separately, it may be possible to tell which method of attentional control was impacted most by depleted resources. This would, in turn, indicate whether either method requires more resources than the other and thus is more demanding on participants.

4.4. Chapter summary and discussion

The purpose of the current studies was to ascertain whether a valid target-feature cue would affect a preview search and whether this effect diminishes as the cue becomes less useful. The results indicate that, somewhat contrary to previous literature, a valid target-feature cue resulted in less efficient preview search than in a preview condition where there was no such cue. Furthermore, by orthogonally manipulating the proportion of valid colour cues within a block of trials, preview benefit become increasingly efficient as the cue validity decreased. It is not clear what exactly caused this effect, although the most likely explanation is that under normal preview conditions, participants will utilise an inhibition strategy (Watson & Humphreys, 1997) but will adopt an anticipatory strategy where possible, even when this results in a serial, less efficient search. It may be that anticipating item features uses less attentional resources than inhibiting items. Certainly, the involuntary orienting of attention seen in priming studies (Kristjánsson et al., 2002) does not require active attention, whereas dual-task studies suggest that preview inhibition does. However, in this instance, participants' attention orienting appeared to be under their voluntary control, therefore further studies will need to be conducted in order to support this theory.

The principle concern with the current studies is that it appears to be contradictory to previous studies carried out by Braithwaite et al. (2003) and Braithwaite and Humphreys (2003). Not only do the results in the experiments presented here suggest that foreknowledge of a target feature hindered search in the preview condition, but also that there was no benefit of this foreknowledge in the FEB condition. There are a couple of key differences in methodology between the present studies and those of Braithwaite and colleagues (2003) which may be causing this difference in findings. The first key difference was the way in which foreknowledge of the colour was given. In the current studies the target was cued before each individual trial whilst Braithwaite et al. (2003) kept the target

colour constant throughout the "foreknowledge" block of trials and informed participants of the target colour at the beginning of the block. As the results in Chapter 1 showed, secondary tasks can have adverse effects on preview benefit and this disruption can be seen when carrying out even a simple, probe detection task (as suggested in Chapter 2). Although observing the colour cue cannot be thought to be an attention demanding secondary task, it is possible that the abrupt onset of the colour change of the probe dot exogenously captures attention and, much like in the PRP studies reported by Telford (1932), attention does not have sufficient time to disengage from this before the onset of the preview a mere 250ms later. It is possible that lengthening the interval between the onset of the cue and the onset of the preview or, as in Braithwaite et al. (2003), taking advantage of participants' long-term learning might eliminate this confound.

The second key difference is that throughout the foreknowledge block of trials the target for Braithwaite et al. (2003) was kept constant. It was possible for the target to either be a letter "Z" or a letter "N" (letters which share rotational symmetry) and the target was always the same colour and the same size as the trial before. The current studies, on the other hand, had slightly more variation in the target features: although the target was always the same male face, it could be red or blue and could also be either big or small, thus a greater number of feature combinations were possible from trial to trial. Previous literature examining the effects of target consistency have shown that repetition of target colour and other properties can give rise to speeded responses (Huang, Holcombe & Pashler, 2004; Kristjánsson et al., 2002) and that this may be done in a bottom-up manner (Theeuwes, 2013). It is therefore possible that the stimuli and procedure used in the case of Braithwaite et al. (2003) were sufficient to cause a priming effect, enabling participants to respond to the target more efficiently, whilst a colour cue using the fixation dot may be been sufficiently different from the target so that attention was not automatically biased.

One question not answered here is whether an inhibitory and an anticipatory search strategy can be used together, or whether the two are mutually exclusive. If, for example, participants were not using inhibition at all and were searching only through items which were, say, blue, we might expect to see two things: firstly, there should be no difference between the cued preview condition and the cued FEB condition. This was not what was

observed here, suggesting perhaps that participants restricted their search to a more limited number of cue-colour items under preview conditions. Secondly, if participants search through only cue-colour items in the cued preview and cued FEB conditions, but all items in the neutral FEB condition, we might expect to see FEB to cued preview/cued FEB search slopes of approximately 2:1. Although slopes approach this ratio for FEB to cued preview, the same is not true for the FEB to cued FEB slopes, which did not significantly differ from each other.

Research by Barrett et al. (2016) examining the interaction of top-down and bottom-up attention mechanisms in preview search suggests that preview benefit occurs most strongly where both attentional capture by stimuli onset of and top-down inhibition based on target knowledge take place. This suggests that not only can the two mechanisms interact, but that they do interact, and in fact their interaction provides the optimal conditions for preview benefit to occur. Whilst this may appear to contradict the findings of the present studies, it is important to note that Barrett et al. (2016) manipulated the onsets of preview and search items in order to facilitate attentional guidance, whereas here we have used a valid cue in order to prime participants to target features. Although it would be difficult to draw conclusions on the different ways these two mechanisms differentially impact preview search without a direct comparison, the present study does suggest that the two mechanisms do operate in different ways. For example, the onset of new items represents a more bottom-up, attentional capture mechanism, whereas target cueing represent a more top-down, attentional guidance mechanism which is deployed under the participants' own volition.

Perhaps, then, it is that under normal search conditions participants prioritise the target shape, e.g. a face, but under cued conditions participants' attention is directed to all shapes of the cued colour. This would explain the lack of difference between the FEB conditions; under both conditions, participants would be searching through approximately half the items. As the colour cue is in the centre of the display and endogenously guides rather than exogenously attracts attention, the cue could be described as a central, symbolic cue (Posner, 1980). Posner reported that whilst attention capture by a peripheral cue (appearing at a potential target location) could not be suppressed, attention to a centrally

cued location could be suppressed under circumstances when that cue is uninformative. Thus, as the colour cue became less informative (as in Experiment 9) participants were able to ignore the cue and resort instead to an inhibitory preview strategy. Further, research by Spence and Driver (1994, 1996) has demonstrated that facilitation can occur cross-modally, i.e. peripheral audio clues facilitate responses to visual, as well as audio targets. One would therefore expect such a cue to cause similar disruption to that of the visual cue. If such a cue were symbolic (i.e. a higher pitched tone represented red) then under conditions such as Experiment 9 where the cue becomes less informative, the same pattern of results should emerge as with a visual cue (i.e. participants rely on inhibition rather than feature guidance). However, if the cue were a peripheral cue, indicating, say, the side of the screen the target could appear on, search under preview conditions could be expected to be akin to the HEB (providing the audio cue was valid) as participants need only focus on inhibiting the previewed items on the cued side of the screen. Perhaps of more interest, a valid, peripheral audio cue in a full conjunction condition might be expected to halve the average search slope, as participants could deploy their attention only to the items on the cued side. Conversely, an invalid cue should be more difficult for participants to ignore under preview or full conjunction conditions, thus search would be less efficient than when using an invalid symbolic cue.

A further method which could be employed to examine whether participants are searching through all cue-colour items or merely having their attention drawn to cue-colour items would be to use an eye-tracker. This would indicate where exactly during the preview and the search participants are looking and whether or not they are attending the items they should have inhibited (preview items) which are the same colour as the target, or whether the colour cue primes their attention such that their focus is captured by the new items of the target colour.

The results of this Chapter and of Chapter 2 lend further knowledge to the roles of anticipation and inhibition in search tasks. Thus far in preview literature, work appears to have largely focussed on the inhibition of previewed items, be this via location (Olivers et al., 1999) or distractor feature (Kunar et al., 2003b). In other studies, such as Braithwaite et al. (2003) it is difficult to segregate these two factors. Whilst it may be that colour

carryover inhibition is responsible for the benefit seen their studies, it is equally possible that anticipation of the target colour is what is driving the results. Further studies using more varied distractors and a well-defined, consistent target would be useful to provide an understanding into the role of anticipation which can be separated from the effects of inhibition.

Chapter 4 – How rotation affects attendance to faces

Research has shown faces, especially emotional faces, are attended to more readily than other, non-face objects (Öhman, 2002), but most research in this area used only faces that look directly at us. Research using faces in different orientation suggests we respond to such faces differently (Vuilleumier & Pourtois, 2007; Bruce, et al, 1987). This chapter examines the effect of rotating a face into profile view on the ability to process identity and emotion. Results show faster responses to fearful faces, but not when they are rotated by 90^{o} (Experiments 10a and 10b) and that responses are slower across rotation when performing an identity match/mismatch task, although rotation effects an emotion match/mismatch task less (Experiment 11a and 11b). Results from experiments examining the effect of emotion in a preview search using rotated faces suggest search was more efficient with fully rotated faces, but remain inconclusive (Experiment 12).

5.1. Introduction

5.1.1. The importance of faces

Human faces are of significant social importance to us. We can gain a multitude of information from faces, including gender, age and identity to emotional state, direction of attention and predictions of likely behaviour. Consequently, attention is more readily orientated to faces than to other visual stimuli (Mack, Pappas, Silverman & Gay, 2002; Theeuwes & Van der Stigchel, 2006). This engagement of attention is, at least initially, exogenous (Bindemann et al., 2007), relatively difficult to disengage from (Bindemann et al., 2005) and can be seen in normal, infant and patient populations (Morton & Johnson, 1991; Vuileumier, 2000). Evidence from neuropsychological and neuroimagining studies (e.g. fMRI) suggests that there are specific regions in the brain (such as the fusiform gyrus) which are responsible for processing faces (Wada & Yamamoto, 2001; Damasio, Tranel & Damasio 1990; Desimone, 1991; Perrett et al., 1992), and Event Related Potential (ERP) studies show that faces are responded to more rapidly than other objects (Bentin et al., 1996; Jeffreys, 1989; Pegna, Khateb, Michel & Landis, 2004). It would appear, then, that

faces cause a specific reaction in visual processing more generally and the allocation of attention more particularly.

5.1.2. The effects of emotion

Whilst faces themselves capture and hold attention better than other items, there are subcategories within faces which engage attention more effectively than other faces. For example, there is evidence that attractive faces can capture attention more than unattractive faces (van Hooff, Crawford & Van Vugt, 2011; Anderson et al., 2010), familiar faces are processed more rapidly than unfamiliar faces (Tong & Nakayama, 1999) and, of interest here, faces with a negative expression (e.g. angry or fearful) are more rapidly attended to than faces with neutral or positive expressions (Öhman, 2002; Vuilleumier, 2002). Research using probe detection tasks (Pourtois, Grandjean, Sander & Vuilleumier, 2004) has shown that probes are detected more easily and their features may be discriminated faster and more accurately when they appear at a location which recently contained a negative face as opposed to a neutral face, particularly in individuals with high anxiety (Fox, Russo, Bowles & Dutton, 2001). Moreover, evidence from invalid cue trials has shown that participants are significantly slower at locating a target when the invalid cue is a negatively valenced face, rather than a happy or neutral face (Fox, Russo & Dutton, 2002). This suggests that not only is attention specifically guided toward negative stimuli, but it may also be harder to disengage attention from negative face stimuli.

Negatively valanced (specifically fearful) faces may also be processed without awareness. Imaging studies by Whalen and colleagues (Whalen et al., 1998; Whalen et al., 2004) showed greater amygdala activation when participants were presented with backwards masked fearful faces compared to backwards masked neutral faces, even though participants could not report having seen the faces. Studies of patients with unilateral neglect also show that there can be equal amygdala activation to fearful faces which are presented in a patient's contralesional (and therefore neglected) visual field as when the same stimuli are consciously perceived (Vuilleumier Henson, Driver & Dolan, 2002; Morris DeGelder, Weiskrantz & Dolan, 2001).

Despite all the evidence on the unique effect of faces (and especially negatively valanced faces) on attention, research using visual search tasks with face stimuli is surprisingly mixed. Search for a face among inverted or scrambled faces is not efficient enough to be said to immediately grab the attention, or "pop-out" (Brown, Huey, & Findlay, 1997; Kuehn & Jolicoeur, 1994). Although research by Hansen and Hansen (1988) found that negative (angry) faces pop-out, their results have been attributed to low-level visual factors rather than emotion (Purcell, Stewart, & Skov, 1996). That said, search is often found to be more efficient when searching for an angry face among neutral or positive faces than when searching for a neutral or positive face among angry faces (Fox et al., 2000; Öhman, Lundqvist & Esteves, 2001; Blagrove & Watson, 2010) and evidence from target-absent trials suggests that it is easier to reject a crowd of neutral or positive faces than a crowd of angry faces (Hansen & Hansen, 1988; Hampton et al., 1989). Although experiments using preview search (Blagrove & Watson, 2010) report no effect of face valance at standard preview durations (1000ms), the preview benefit was less efficient at 250ms when the preview consisted of negative faces as opposed to positive faces. These results support the notion that it is more difficult (at least initially) to ignore negative faces.

5.1.3. The effect of facial orientation

The majority of the above research studies have used face stimuli in only one three-dimensional rotation. That is, the faces used have all been squarely facing the participant, not rotated to either the left or the right. This seems to be an oversight which detracts from the overall ecological validity of the experiments as in real life we come across faces in many depth orientations, from looking straight at us to looking entirely to either the left or the right. Is the way in which we process faces different when the faces are not looking directly at us? If so, what impact might that have on previous findings? Research using macaque monkeys has shown that there are cells in the superior temporal sulcus (STS) which show an increase in response to faces in a "straight on" orientation over other objects. Activity in these cells declined as the face was gradually rotated to the side until by 90^{o} (with a face in profile to either left or right) the response preference was almost completely eliminated (Perrett, Mistlin & Chitty, 1987). Research has shown that other cells

respond more optimally to the rotated faces, suggesting that there are specific cells in the visual cortex which are triggered by faces in specific rotations (Perrett et al., 1985).

Further research into depth orientation suggests that in some cases rotating a face may not always be disadvantageous. As Perrett et al. (1989) point out, a face rotated 45° in profile will lead to a decreased response from cells tuned specifically to 0° or 90° rotation, but as it is leads to a response from both these cells, the aggregate may be an overall increased response. This may convey a processing advantage under some conditions. This idea has been supported by Bruce et al. (1987), who found that participants were faster to match two sequentially presented unfamiliar faces as the same person when the face was rotated 45° as opposed to when the face was presented straight on. They also reported that responses to faces rotated 90° were slower than faces rotated 0 or 45°.

5.1.4. The purpose of this chapter

Given these findings, it would be pertinent to suppose that people may respond to experimental tasks using faces differently if the faces changed in their depth rotation. The purpose of the studies in this chapter was to establish whether this was the case in basic emotion detection tasks, matching/mismatching tasks and a series of search tasks (including preview search). Experiment 10 examined the effect of rotation and emotion in a simple detection task, with responses to fearful faces expected to elicit faster responses than neutral faces, and at 0o or 45o than at 90o. A similar pattern of results were expected for Experiment 11, which examined facial rotation and emotion on a forced choice match/mismatch task in order to see the effect rotation has on our ability to derive information from features once they have been spatially rotated. Having examined the effects of depth rotation when faces were at fixation and fully attended, Experiment 12 studied whether these effects have an impact on visual search. Given that people were faster to make judgements on faces rotated by 90o, it was predicted that these faces would be more easily processed and rejected under search conditions. To test this, a preview paradigm was used where the preview items varied by both emotion and rotation. Results are discussed in relation to previous literature, possible reasons why we may not have seen an effect of emotion and future research.

5.2. Experiment 10a

Experiment 10a examined the effect of face depth rotation on expression detection. Prior literature suggests when the face is presented straight-on, reactions to the fearful faces will be faster than to the neutral faces (Öhman, 2002; Vuilleumier, 2002). If there is an advantage to processing faces rotated 45° (Bruce et al., 1987), then responses to a fearful face in this condition could be even faster than at 0°. Further if minimal information can be extracted from faces at 90°, then response should be slowest in this condition for both neutral and fearful faces.

5.2.1. Participants

Twenty participants (12 female) took part in exchange for money (£5). Participants were aged between 19 and 33 (Mean = 24.63 years, SD = 4.16 years). All reported having normal or corrected-to-normal vision. One participant was left-handed.

5.2.2. Stimuli

The stimuli employed were 40 monochrome images of faces (including shoulders) (20 female) taken from the Karolinska Directed Emotional Faces (KDEF) of human facial expressions of emotion (Lundqvist, Flykt & Öhman, 1998), which were obtained from the Karolinska Institute upon request. The stimuli were purposefully developed for medical and psychological research, using actors to simulate the emotions. Each face was displayed at 5 different angles: fully in profile to the left and right (90°), half rotated to the left and right (45°) and straight on (0°), and each face was taken with 2 different expressions: neutral and fearful. The stimuli subtended approximately 7.5 x 16° from a normal viewing distance of 57cm and were presented in the middle of the screen.

5.2.3. Design and procedure

A custom-written computer program was used to generate displays and record responses. The program was run on a PC connected to a 24” monitor running at 60Hz. Participants

were presented with a series of 240 images of faces which consisted of 80 faces straight on (rotated 0°), 80 half rotated into profile (rotated 45°, 40 to the left and 40 to the right) and 80 rotated fully into profile (rotated 90°, 40 to the left and 40 to the right). Half the stimuli had a neutral expression and half had a fearful expression.

The trials began by a fixation cross appearing in the centre of the screen. The fixation cross measured 2 x 3° from a normal viewing distance. The fixation cross remained for 1000ms after which the test stimuli was presented. Participants performed 2 conditions: a neutral condition and a fearful condition. In the fearful condition participants were instructed to press the space key as fast as possible when they saw a face with a fearful expression. If the face showed a neutral expression, participants were instructed to do nothing at all and after 2000ms the stimulus disappeared and the experiment proceeded to the next trial automatically (see Figure 17). The reverse was true for the neutral condition. Participants' reaction times (RTs) and accuracy were recorded. The experiment lasted approximately half an hour.

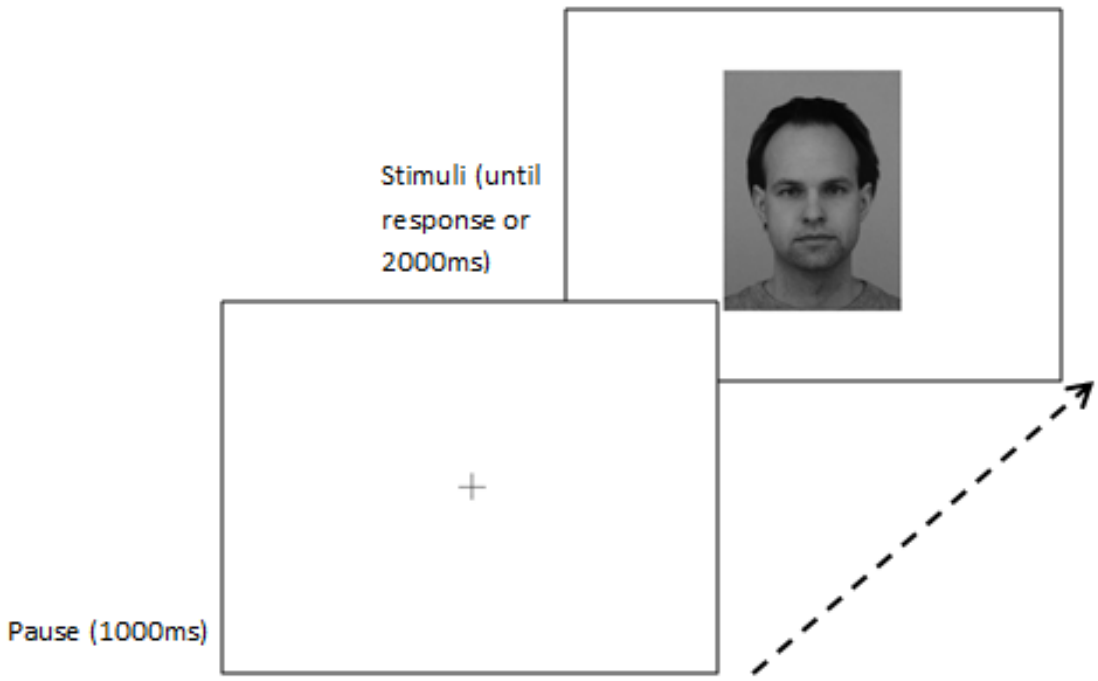

Figure 17. Example of the procedure for Experiment 10a. The arrow indicates the direction of time.

5.2.4. Results and discussion

Data were trimmed for outliers using the Van Selst and Jolicoeur (1994) method (6.4% of the data were removed). Table 30 shows the mean corrected RT and SDs for each condition. Figure 18 shows the mean correct RTs across the different rotations for each condition.

Table 30. Mean RTs and SDs condition and rotation for Experiment 10a.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
Fear		
0°	608	97.72
45°	679	99.25
90°	609	111.30
Neutral		
0°	657	102.96
45°	689	98.95
90°	605	96.12

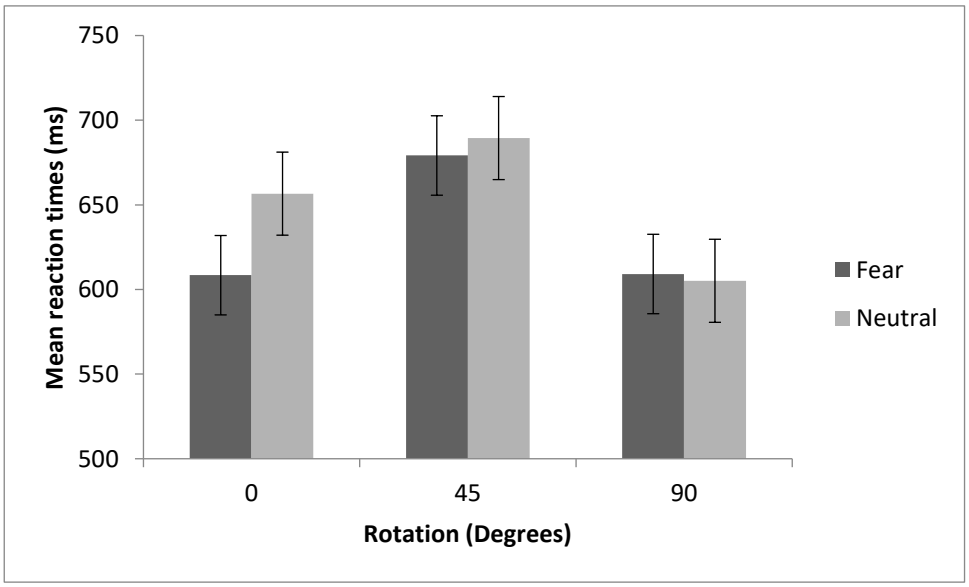

Figure 18. Mean RTs across rotation for each condition for Experiment 10a. Error bars represent SEM.

Mean RTs were entered into a 2 x 3 ANOVA with within participant factors of condition (fear x neutral) and rotation (0° x 45° x 90°). There was no main effect of condition, $F(1,19) = 0.81$, $MSE = 14.32$, $p = 0.37$, partial $\eta^2 = 0.02$, but there was a main effect of rotation, $F(2,38) = 154.94$, $MSE = 2.58$, $p < 0.01$, partial $\eta^2 = 0.76$, and a significant two-way

interaction, F(1,19) = 4.67, MSE = 1.34 $p < 0.01$, partial $\eta^2 = 0.12$. The observed power for all significant values was < 0.83.

Effect of expression. The data were entered into 3 paired sample t-tests (0° neutral x 0° fear, 45° neutral x 45° fear and 90° neutral x 90° fear) to compare the main effect of expression. At 0° rotation, RTs were significantly faster in the fear condition than in the neutral condition, t(19) = 2.94, $p < 0.01$. At 45° and 90° there was no difference between conditions, t(19) = 0.65, p = 0.52 and t(19) = 0.22, p = 0.83 respectively.

Effect of Rotation: Fear condition. The data were entered into 3 paired sample t-tests (0° fear x 45° fear, 45° fear x 90° fear and 0° fear x 90° fear) to compare the main effect of rotation for the fearful faces. RTs were significantly faster at 0° than at 45°, t(19) = 8.43, $p < 0.01$, and at 90° than at 45°, t(19) = 6.41, $p < 0.01$. There was no significant difference in RTs at 0° and 90°, t(19) = 0.09, p = 0.93.

Effect of Rotation: Neutral condition. The data were entered into 3 paired sample t-tests (0° neutral x 45° neutral, 45° neutral x 90° neutral and 0° neutral x 90° neutral) to compare the main effect of rotation on the neutral faces. RTs were significantly faster at 0° than at 45°, t(19) = 3.56, $p < 0.01$, at 90° than at 45°, t(19) = 8.56, $p < 0.01$, and at 90° than at 0°, t(19) = 7.62, < 0.01.

Errors. Mean error percentages can be seen in Table 31. Entered into a 3 x 2 ANOVA the only effect to reach significance was the main effect of rotation F(2,38) = 13.6, MSE = 8.6, $p < 0.01$, partial $\eta^2 = 0.42$.

Table 31. Mean percentage error rates with standard error for Experiment 10a.

	Rotation (degrees)					
Condition	0	SE	45	SE	90	SE
Fear	4.44%	1.15%	6.81%	1.29%	3.75%	0.86%
Neutral	3.56%	0.66%	6.81%	1.05%	3.69%	0.69%

The results of Experiment 10a support the previous literature in the sense that RTs were significantly faster to a fearful face than a neutral face at 0° depth rotation (Öhman, 2002;

Vuilleumier, 2002; Pourtois et al., 2004). However, once the face was rotated the effect of expression is abolished; there was no difference in RTs to a fearful face compared to a neutral face at either the 45° or the 90° rotation. Interestingly, participants performed worse at 45° than at either 0° or 90° across both conditions. Whilst this appears to contradict research on the so-called "3/4 view advantage" (Bruce et al., 1987) the reason for the slowing of RTs here may be due to the same factors which were advantageous in Bruce et al.'s (1987) studies: the authors proposed that the advantage was due to the fact that at a 3/4 (or 45°) view, people are presented with more information about the face and its features. While this is beneficial in learning and recognising a previously unfamiliar face, the comparatively larger amount of visual information available at 45° to 0° and 90° may be slowing participants here due to the greater number of visual features to process.

5.3. Experiment 10b

Experiment 10b repeated Experiment 10a but with the faces inverted to eliminate potential low level visual feature confounds. It is possible that the difference in RTs between the fear and neutral condition at 0° is not caused by the actual expression but by a difference in low level visual features. For example, a face with a fearful expression tends to have wide eyes, raised eyebrows and perhaps an open mouth whilst a neutral expression will not. To eliminate this potential confound, Experiment 10b was carried out using the same procedure and stimuli except that all the faces were geometrically inverted. Research has shown that the way in which people process faces is different when the faces are inverted (Farah et al., 1998; Leder & Bruce, 2000; Itier & Taylor, 2002), specifically the way in which the brain responds to a fearful expression is different with an inverted face (Vuilleumier & Pourtois, 2007), therefore if the difference between the fearful and neutral faces at 0° is thought to be due to the expression rather than low level visual features, then inverted faces should eliminate this difference.

5.3.1. Participants

Twenty participants (14 female) took part in exchange for money (£5). Participants were aged between 19 and 34 (Mean = 23.45 years, SD = 4.02 years). All reported having normal or corrected-to-normal vision. Two participants were left-handed.

5.3.2. Stimuli

The stimuli were the same as those used in Experiment 10a except all of the images of faces were inverted.

5.3.3. Design and procedure

The experiment lasted approximately half an hour. Design and procedure were identical to that of Experiment 10a (see Figure 19).

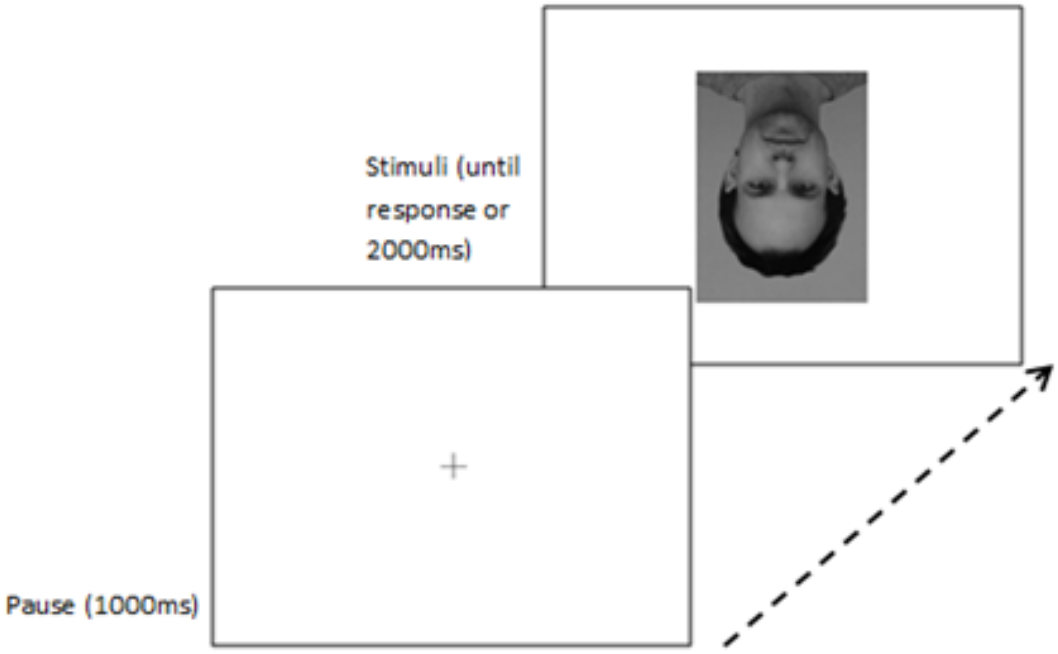

Figure 19. Example of the procedure for Experiment 10b. The arrow indicates the direction of time.

5.3.4. Results and discussion

Data were trimmed for outliers using the aforementioned method (6.4% of the data). Table 32 shows the mean correct RTs and SDs for each condition and rotation. Figure 20 shows mean correct RTs across degrees for each condition.

Table 32. Mean RTs and SDs condition and rotation for Experiment 10b.

	Measure	
Condition/Set Size	Mean RT (ms)	SD
Fear		
0°	737	233.45
45°	878	276.32
90°	683	187.95
Neutral		
0°	752	200.88
45°	857	219.30
90°	718	204.21

Mean RTs were entered into a 2 x 3 ANOVA with within participant factors of condition (fear x neutral) and rotation (0° x 45° x 90°). There was a main effect of condition, $F(1,19) = 12.14$, MSE = 20.55, $p < 0.01$, partial $\eta^2 = 0.39$, and a main effect of rotation, $F(2,38) = 4.78$, MSE = 5.82, $p < 0.01$, partial $\eta^2 = 0.2$, and a significant two-way interaction, $F(1,19) = 74.63$, MSE = 5.62, $p < 0.01$, partial $\eta^2 = 0.8$. The observed power was > 0.99 for all significant values, with the exception of the rotation effect which was 0.55.

Effect of expression. The data were entered into 3 paired sample t-tests (0° neutral x 0° fear, 45° neutral x 45° fear and 90° neutral x 90° fear). Across all three levels of depth rotation (0°, 45°, 90°) RTs were not affected by the expression of the faces, $t(19) = 0.48$, $p = 0.64$ at 0°; $t(19) = 0.74$, $p = 0.47$ at 45°; and $t(19) = 1.30$, $p = 0.22$ at 90°. This suggests that the results found in Experiment 10a were not due simply to differences in low level visual features (such as an open mouth or raised eyebrow), as otherwise it is likely that the difference in expression seen at 0° in Experiment 10a would be replicated here.

Effect of Rotation: Fear condition. The data were entered into 3 paired sample t-tests (0° fear x 45° fear, 45° fear x 90° fear and 0° fear x 90° fear) to compare the main effect of rotation for the fearful faces. RTs were significantly faster at 0° than at 45°, $t(19) = 11.23$,

$p < 0.01$, and at 90° than at 45°, $t(19) = 15.31$, $p < 0.01$. RTs were also significantly faster at 90° than at 0°, $t(19) = 4.39$, $p < 0.01$, showing an overall advantage at 90°.

Effect of Rotation: Neutral condition. The data were entered into 3 paired sample t-tests (0° neutral x 45° neutral, 45° neutral x 90° neutral and 0° neutral x 90° neutral) to compare the main effect of rotation on the neutral faces. RTs were significantly faster at 0° than at 45°, $t(19) = 6.67$, $p < 0.01$, at 90° than at 45°, $t(19) = 9.63$, $p < 0.01$, and at 90° than at 0°, $t(19) = 2.67$, < 0.01, again showing an advantage at 90°.

Errors. Mean error percentages can be seen in Table 33. Entered into a 3 x 2 ANOVA there was a main effect of condition, $F(2,38) = 14.22$, $MSE = 18.76$, $p < 0.01$, partial $\eta^2 = 0.42$ but not rotation, $F(1,19) = 0.34$, $MSE = 7.93$, $p = 0.57$, partial $\eta^2 = 0.02$. The two-way interaction was also significant, $F(2,38) = 17.51$, $MSE = 12.58$, $p < 0.01$, partial $\eta^2 = 0.47$. Observed power for significant values were 1. Errors are significantly higher in the fear condition and particularly at 45°. This is interesting as it suggests that participants were having greater trouble processing the expression at half rotation when the faces are inverted. Given the supposed benefit of facial information at 45°, this result appears somewhat incongruous.

Table 33. Mean percentage error rates with standard error for Experiment 10b.

	Rotation (degrees)					
Condition	0	SE	45	SE	90	SE
Fear	8.56%	1.35%	13.13%	1.70%	5.50%	0.97%
Neutral	6.31%	0.72%	9.75%	1.15%	5.25%	0.89%

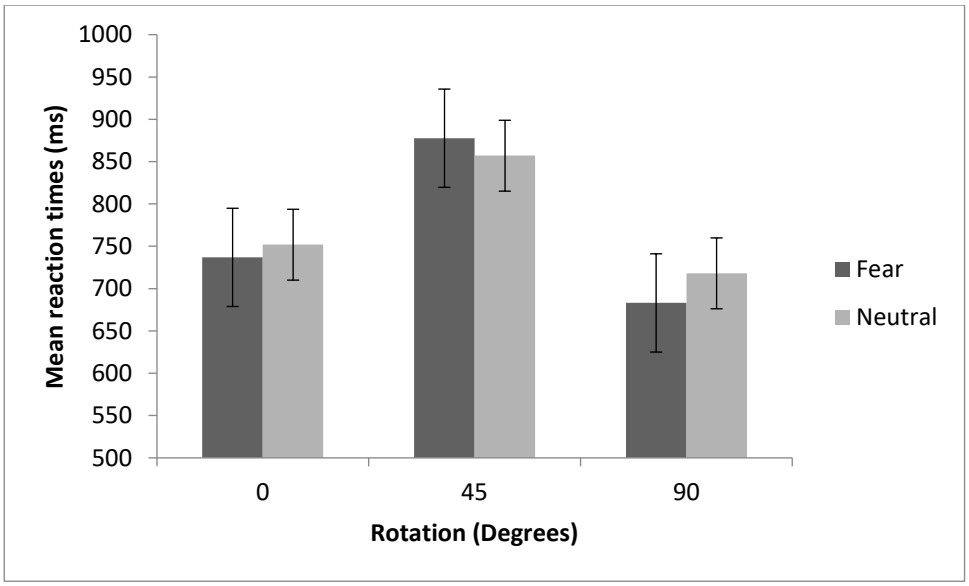

Figure 20. Mean RTs across rotation for each condition for Experiment 10b. Error bars represent SEM.

The results from Experiment 10b show that the faster response times in the fearful condition over the neutral condition at 0° seen in Experiment 10a is not replicated when the faces are inverted. This suggests that the results found in Experiment 10a are not due differences in low level visual features as, if this were the case, the data trends would be expected to be the same.

An interesting trend which did emerge in Experiment 10b was the advantage for 90° stimuli. This may be due to the fact that faces at 90° as less visually complex than faces at 0° or 45°. In fact, the only facial features of note when a face is in 90° profile are an ear, an eye, the nose and half of the mouth. It is perhaps because of this that Perrett et al. (1987) found cells responding to faces stopped firing above chance levels by the time the face was rotated into 90°. As such, it is possible that participants were mostly responding to simple, low level features such as an open mouth when the faces are rotated. As with Experiment 1a, the disadvantage found at 45° is not due simply to the adjustment to the RTs; analysis on the raw data revealed the same trends.

Experiments 10a and 10b showed that trends found in a simple expression detection task differ when faces are rotated in depth and this is not due to low level visual differences.

Experiment 11a examined the effect of depth rotation on a match/mismatch task of identity and expression.

5.4. Experiment 11a

Experiments 11a and 11b examined the classification of expression. There is considerable work indicating that the processing of facial expression can be separated from the processing of facial identity (Haxby et al., 2001). Experiment 11 sets out to assess if the effects of depth rotation had a similar impact on the processing of facial identity and expression. To do this, and to use a common task, a face matching procedure was adopted. Participants received two consecutively presented faces and had to indicate whether they had the same identity or expression.

5.4.1. Participants

Twenty participants (12 female) took part in exchange for money (£7.50). Participants were aged between 19 and 41 (Mean = 25.19 years, SD = 5.33 years). All reported having normal or corrected-to-normal vision. One participant was left-handed.

5.4.2. Stimuli

The stimuli were the same as those used in Experiment 10a.

5.4.3. Design and procedure

A custom written computer program was used to generate displays and record responses. The program was run on a PC connected to a 24" monitor running at 60 Hz. There were two conditions: an identity match condition and an expression match condition. Each condition consisted of 240 trials of two images, half of which were matched and the other half mismatched (see Figures 21a and 21b for an example of the Experimental procedure).

Each trial began with a fixation cross (same as in Experiments 10a and 10b) for 1000ms. Following this an image of a face appeared briefly (500ms) and participants were asked to memorise the face's identity (identity condition) or expression (fearful/neutral, expression condition). These faces were always presented straight on (0^o rotation). Once the stimuli had disappeared there was another 1000ms pause after which a test face appeared. The test face was either straight on (rotated 0^o, on 80 trials), half rotated into profile (rotated 45^o, on 80 trials of which 40 were to the left and 40 were to the right) or rotated fully into profile (rotated 90^o, on 80 trials of which 40 were to the left and 40 were to the right). Participants were instructed to indicate whether the second stimulus was a match or not to the previously shown face by pressing the "z" key if they matched and the "m" key if they did not match.

For the identity condition, the faces were a match if they were the same person and were a mismatch if they were two different people. The images were pre-matched across gender, hair colour and hair style to eliminate low level visual clues. For the expression condition, the two images were always of the same person and were a match if they displayed the same expression (both faces neutral or both faces fearful) and were a mismatch if they displayed two different expressions (neutral followed by fearful or fearful followed by neutral). In both conditions the test image remained on the screen until participants responded with a key press and then immediately proceeded to the next trial. Half the participants completed the identity condition first and the remaining half completed the expression condition first. Participants' reaction times and accuracy were recorded. The experiment lasted approximately 45 minutes.

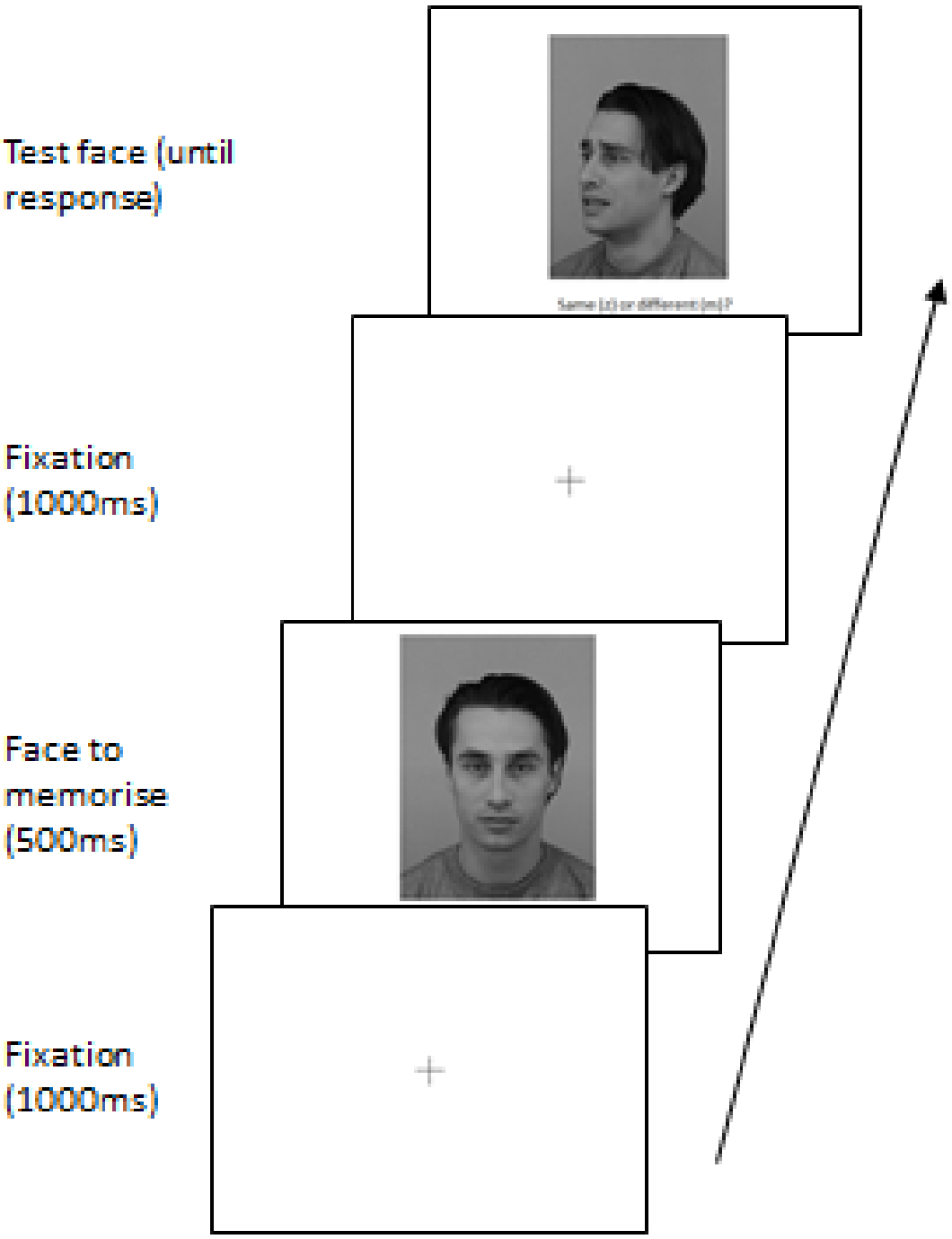

Figure 21a. Example mismatch trial for the expression condition of Experiment 11a.

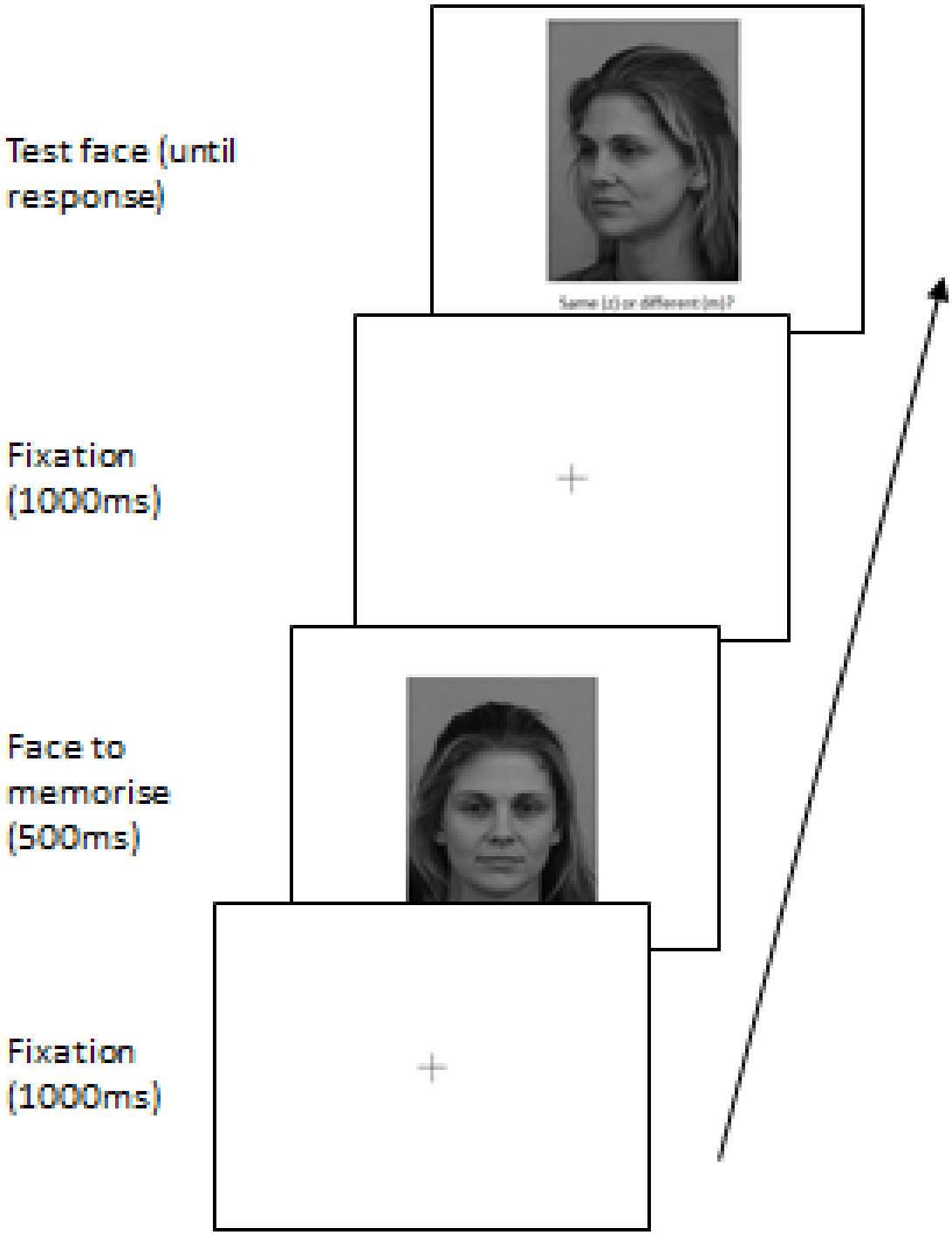

Figure 21b. Example match trial for the identity condition of Experiment 11a.

5.4.4. Results and discussion

Data were trimmed for outliers using the aforementioned method (removing 7.6% of the data). Table 34 shows the mean correct reaction times across condition and rotation.

Figure 22 shows mean correct RTs across degrees of rotation for each condition and depending on whether the faces were a match or mismatch.

Table 34. Mean RTs and SDs condition and rotation for Experiment 11a.

	Measure	
Condition/Rotation	Mean RT (ms)	SD
Identity match		
0°	600	92.79
45°	697	100.71
90°	733	112.19
Identity mismatch		
0°	684	65.90
45°	715	68.19
90°	792	73.90
Expression match		
0°	710	145.47
45°	826	187.96
90°	889	185.01
Expression mismatch		
0°	817	169.09
45°	822	147.65
90°	890	166.40

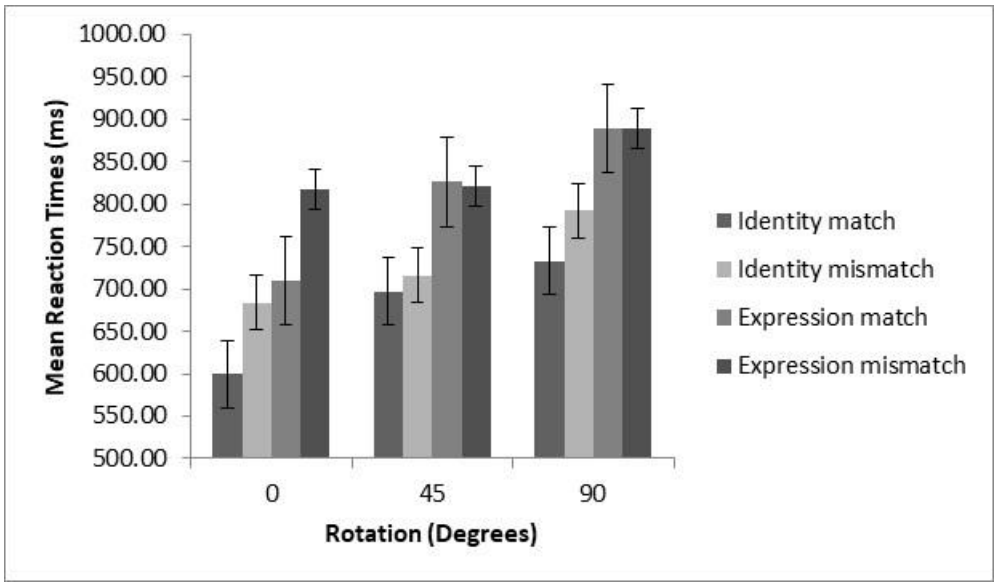

Figure 22. Mean RTs across rotation for each condition and task type for Experiment 11a. Error bars represent SEM.

Full ANOVA. Mean RTs were entered into a 2 x 2 x 3 ANOVA with within participant factors of condition (expression x identity), task type (match x mismatch) and rotation (0^o x 45^o x 90^o). There was a main effect of condition, $F(1,19) = 25.04$, MSE = 35.89, $p < 0.01$, partial $\eta^2 = 0.57$; a main effect of rotation, $F(2,38) = 127.55$, MSE = 2.39, $p < 0.01$, partial $\eta^2 = 0.87$; and a main effect of task type, $F(1,19) = 16.22$, MSE = 7.24 $p < 0.01$, partial $\eta^2 = 0.46$. RTs were faster in the expression condition than the identity condition, at 0^o rotation than at 45^o and 90^o (here 45^o was advantageous to 90^o) and when the faces matched as opposed to when they did not match. The condition x rotation interaction was not significant, $F(2,38) = 0.31$, MSE = 1.26, $p = 0.74$, partial $\eta^2 = 0.02$, and neither was the condition x task type interaction $F(1,19) = 1.45$, MSE = 3.61, $p = 0.23$, partial $\eta^2 = 0.07$, but the task type x rotation interaction was significant, $F(1,19) = 22.34$, MSE = 5.72 $p < 0.01$, partial $\eta^2 = 0.54$. This suggests mismatch trials were equally poor across both conditions and rotating faces slowed RTs proportionally across the two conditions, but it was significantly harder to detect a mismatch as the faces rotated away from the participant. The three-way interaction was also of significance, $F(2,38) = 5.73$, MSE = 1.42, $p < 0.01$, partial $\eta^2 = 0.23$. Observed power was > 0.84 for all significant values.

Effect of condition. The data were entered into a series of paired sample t-tests to compare the effect of task type across expression and rotation. In the face matching condition, RTs were significantly faster in the expression condition than the identity condition at 0^o, $t(19) = 4.23$, $p < 0.01$; at 45^o, $t(19) = 5.53$, $p < 0.01$; and at 90^o, $t(19) = 5.33$, $p < 0.01$. When faces did not match the trends were the same, with RTs significantly faster in the expression condition at 0^o, $t(19) = 4.45$, $p < 0.01$; at 45^o, $t(19) = 4.21$, $p < 0.01$; and at 90^o, $t(19) = 3.51$, $p < 0.01$.

Effect of Rotation: Expression condition. The data were entered into a series of paired sample t-tests to compare the main effects of rotation and task type for the expression condition. In the expression matching condition, RTs were significantly faster at 0^o than at 45^o, $t(19) = 7.90$, $p < 0.01$; at 0^o than at 90^o, $t(19) = 9.32$, $p < 0.01$ and at 45^o than at 90^o, $t(19) = 3.78$, $p < 0.01$. When the expressions did not match, RTs were equal across 0^o and 45^o, $t(19) = 0.42$, $p = 0.68$, but were slower at 90^o than at either 0^o or 45^o, $t(19) = 5.45$, $p < 0.01$ and $t(19) = 4.92$, $p < 0.01$ respectively.

Effect of Rotation: Identity condition. The data were entered into a series of paired sample t-tests to compare the main effects of rotation and task type for the identity condition. When the faces matched, RTs were significantly faster at 0° than at 45°, $t(19) = 8.78$, $p < 0.01$; at 0° than at 90°, $t(19) = 9.74$, $p < 0.01$; and at 45° than at 90°, $t(19) = 2.91$, < 0.01, showing RTs got progressively slower as the faces were rotated into profile. When the faces did not match, the trends were the same, $t(19) = 3.56$, $p < 0.01$ for 0° x 45°; $t(19) = 7.89$, $p < 0.01$ for 45° x 90°; and $t(19) = 11.67$, $p < 0.01$ for 0° x 90°.

Errors. Mean error percentages can be seen in Table 35. Entered into a 3 x 2 ANOVA. For the purpose of being concise, all effects and interactions were significant, all f-values > 3.3, all MSE < 3.01, all p-values < 0.01, all partial $\eta^2 > 0.15$, with the exception of the three-way interaction $F(2,38) = 2.1$, MSE = 0.92, $p = 0.13$, partial $\eta^2 = 0.1$. Observed power was > 0.95 for all significant values, with the exception of the condition x rotation interaction (0.72) and the task type x rotation interaction (0.59). Errors were significantly higher in the identity task at 90° across both the match and mismatch task and at 90° for the expression mismatch task. As rotation increased, accuracy decreased across the identity condition, consistent with the reaction time data, and further decreased at 90° to mismatch expressions, again consistent with search performance.

Table 35. Mean percentage error rates with standard error for Experiment 11a.

	Rotation (degrees)					
Condition	0	SE	45	SE	90	SE
Identity match	6.25%	1.21%	12.75%	2.08%	21.25%	3.09%
Identity mismatch	4.25%	1.04%	12.75%	2.11%	18.63%	2.89%
Expression match	7.75%	1.77%	7.00%	1.20%	8.87%	1.24%
Expression mismatch	3.75%	0.92%	9.13%	1.80%	13.63%	2.30%

The results of the both the identity task and the expression task show that as rotation increased, RTs increased in a similar manner, both when the faces did match and when they did not match, with one exception: RTs were equal when determining a mismatch of expression at 45° as at 0°. This could perhaps have been due to low level feature responses, e.g. raised eyebrows may be equally as easy to detect or not at 45° as at 0° as they are more visible than at 90°. However, this does not explain why the same trend is not seen

for expression matching. Perhaps, then, the task itself was not clear enough, for the following reasons: as the expression mismatch used the same person's face but with a different expression, it may be that the delay in response was due to participants having to supress a match response when they could clearly identify them as the same face. If responding to identity was more difficult when faces were inverted, then this trend should disappear when faces are inverted.

5.5. Experiment 11b

Experiment 11b repeated Experiment 11a with the faces inverted to eliminate low level feature confounds. As with Experiment 10a, it is possible that participants were relying on low level visual features in the expression condition rather than reacting to the expression itself. In order to determine whether or not this is the case, Experiment 11b repeated Experiment 11a but using inverted faces.

5.5.1. Participants

Twenty participants (14 female) took part in exchange for money (£7.50). Participants were aged between 19 and 41 (Mean = 24.64 years, SD = 5.79 years). All reported having normal or corrected-to-normal vision. All participants were right-handed.

5.5.2. Stimuli

The stimuli were the same as those used in Experiments 11a with the exception that they were geometrically inverted.

5.5.3. Design and procedure

The experiment lasted approximately 45 minutes. Design and procedure were identical to those of Experiment 11a (see Figure 23).

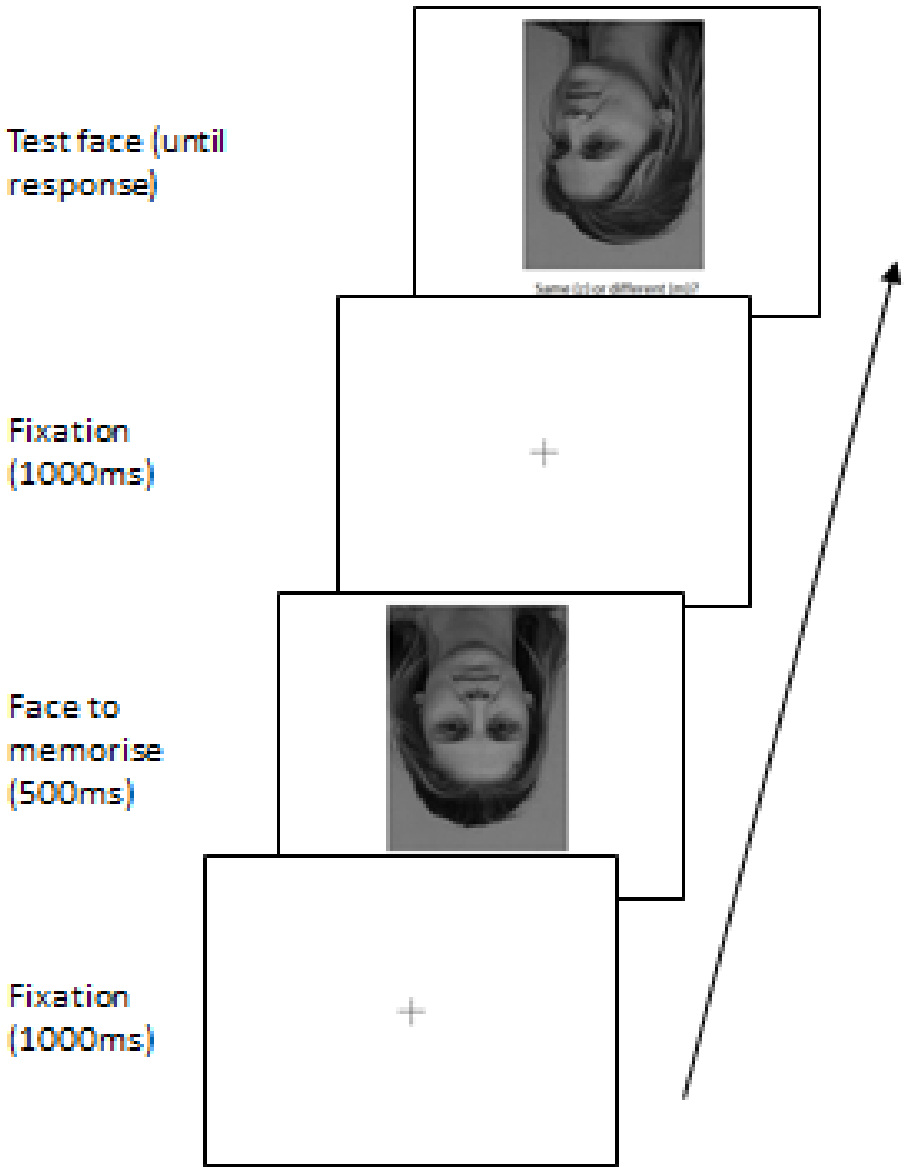

Figure 23. Example match trial for the identity condition of Experiment 11b.

5.5.4. Results and discussion

Data were trimmed for outliers using the aforementioned method (6.6% of the data were removed). Table 36 shows the mean correct RTs and SD across condition and rotation. Figure 24 shows the mean correct RTs across degrees of rotation for each condition and depending on whether the faces were a match or mismatch.

Table 36. Mean RTs and SDs condition and rotation for Experiment 11b.

	Measure	
Condition/Rotation	Mean RT (ms)	SD
Identity match		
0º	709	168.32
45º	907	193.27
90º	955	218.10
Identity mismatch		
0º	893	178.79
45º	956	204.93
90º	1014	197.29
Expression match		
0º	826	183.57
45º	1000	229.35
90º	1088	232.47
Expression mismatch		
0º	923	185.60
45º	932	151.55
90º	1190	244.73

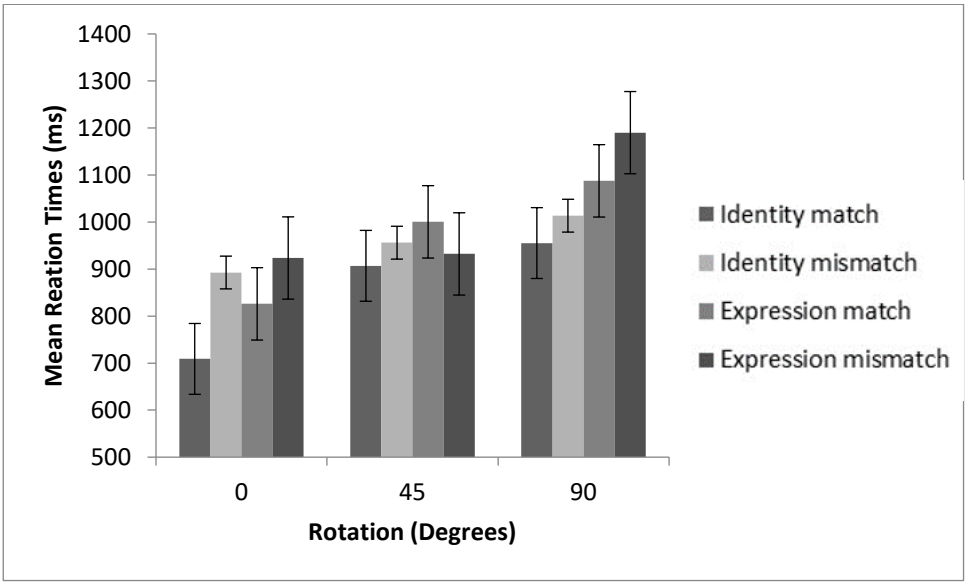

Figure 24. Mean RTs across depth rotation for each condition and task type for Experiment 11b. Error bars represent SEM.

Mean correct RTs were entered into a 2 x 2 x 3 ANOVA with within participant factors of condition (expression x identity), task type (match x mismatch) and rotation (0º x 45º x 90º). For the sake of being concise, all effects and interactions were significant, all f-values > 3.6, all MSE < 110.7, all p-values < 0.4, all partial η^2 < 0.16.

Effect of condition: The data were entered into a series of paired sample t-tests to compare the effect of task type across expression and rotation. When faces matched, RTs were significantly faster in the expression condition, at 0^o, $t(19) = 3.65$, $p < 0.01$; at 45^o, $t(19) = 2.43$, $p < 0.01$; and at 90^o $t(19) = 3.89$, $p < 0.01$ respectively. When faces did not match, however, the only significant difference was at 90^o, $t(19) = 5.01$, $p < 0.01$. Neither condition was faster at 0^o, $t(19) = 0.90$, $p = 0.32$, or at 45^o, $t(19) = 0.73$, $p = 0.51$.

Effect of Rotation: Expression condition. The data were entered into a series of paired sample t-tests to compare the main effects of rotation and task type for the expression condition. When faces had the same expression, RTs became significantly longer as the face was rotated through 45^o, $t(19) = 7.42$, $p < 0.01$, and 90^o, $t(19) = 11.03$, $p < 0.01$ in comparison to 0^o and were significantly slower at 90^o than at 45^o, $t(19) = 4.10$, $p < 0.01$. When the faces had different expressions, RTs were significantly faster at 0^o than at 90^o, $t(19) = 8.52$, $p < 0.01$, and at 45^o than at 90^o, $t(19) = 8.89$, $p < 0.01$. However, RTs were equal at 45^o as at 0^o, $t(19) = 0.57$, $p = 0.57$.

Effect of Rotation: Identity condition. The data were entered into a series of paired sample t-tests to compare the main effects of rotation and task type for the identity condition. When faces matched, RTs became significantly longer at 45^o than at 0^o, $t(19) = 9.68$, $p < 0.01$, and at 90^o than at 0^o, $t(19) = 8.24$, $p < 0.01$, and at 90^o than at 45^o, $t(19) = 2.62$, $p = 0.01$. When the faces were different, all three t-tests were significant, showing RTs significantly slowed as the face rotated, all t-values > 2.3, all p-values < 0.05.

Errors. Mean error percentages can be seen in Table 37. The data were entered into a 3 x 2 x2 ANOVA. For the purpose of being concise, all effects and interactions were significant, all f-values > 3.33, all MSE < 11.62, all p-values < 0.05, all partial $\eta^2 > 0.14$. Observed power was > 0.94 for all significant values, with the exception of the condition x rotation interaction (0.55) and the three-way interaction (0.59)). As in Experiment 11a, as rotation increased, accuracy decreased across the both conditions, but more so in the identity condition, again consistent with the reaction time data.

Table 37. Mean percentage error rates with standard error for Experiment 11b.

	Rotation (degrees)					
Condition	0	SE	45	SE	90	SE
Identity match	6.12%	1.42%	19.25%	3.57%	20.50%	3.33%
Identity mismatch	26.38%	3.72%	34.00%	4.31%	52.00%	3.78%
Expression match	5.25%	1.19%	10.13%	1.52%	14.63%	2.28%
Expression mismatch	11.38%	2.13%	13.13%	2.35%	20.25%	3.17%

The results show that as rotation increased, RTs increased for both the expression task and the identity task. This contrasted results found using upright faces in Experiment 11a, where RTs for the expression task showed little effect of rotation. The monotonic increase in RTs for expression processing indicates that it was harder to derive both familiar expression as well as facial identity with inverted faces. This is consistent with previous literature which shows a reduction in accuracy for judging a face's expression when it is inverted (McKelvie, 1995). Furthermore, the slowing of RTs when responding to inverted faces suggests the results in Experiment 11a cannot be attributed to simply to low level feature processing. If this were the case, we would expect to see similar results across the two experiments.

In addition, participants were very slow to make mismatch decisions in the identity task in comparison to Experiment 11a. This slowness was particularly prominent as the rotation increased. This is consistent with participants laboriously checking facial features before responding that the faces had different identities. The data also suggest that the prior evidence in Experiment 11a (a more robust response to expression judgements as faces rotated) were partly due to the presence of configural feature relations, present in upright rather than inverted faces.

Thus far, this research has focussed solely on the effect of expression and rotation on capturing attention and making judgements. The results show that whilst identity judgements worsen as configural information is decreased, expression judgements and responses were consistent across rotation (with the exception of when faces are 45^{o} or inverted). However, these findings do not tell us whether rotation of faces has an effect on guiding attention. Experiment 12 examined this by using visual search tasks where distractors consisted of rotated and emotional faces.

5.6. Experiment 12

Experiment 12 examined the effect of distractor depth rotation and expression on search tasks. Previous literature using emotionally valenced stimuli in a search task suggest that it is generally easier to disregard distractors if they are positively valenced or neutral, as opposed to negatively valenced (Hansen & Hansen, 1988; Hampton et al., 1989). Watson and Blagrove (2010) did not find an effect of preview distractor emotion, however, though it should be noted that their experiment used schematic faces as opposed to real ones. Given this, Experiment 12 employed a preview paradigm to establish whether human, emotionally valenced, previewed distractors faces are more readily rejected when they were rotated in comparison to when they are straight on.

5.6.1. Participants

Forty participants took part in exchange for money £7.50, of which twenty (13 females) completed the preview conditions and twenty (11 females) completed the baseline search tasks. Participants were aged between 20 and 34 (Mean = 25.54 years, SD = 3.89 years). All reported having normal or corrected-to-normal vision. Five of the participants were left-handed.

5.6.2. Stimuli

The stimuli consisted of faces and houses. The faces were the 0° and 90° rotated faces used in Experiments 10 and 11, resized to approximately 4° x 5° from a normal viewing distance of 57cm. The house stimuli were the same as those used in chapters 1-3, also sized 4° x 5° and processed through a greyscale colour filter.

5.6.3. Design and procedure

A custom-written computer program was used to generate displays and record responses. The program was run on a PC connected to a 24” monitor running at 60Hz. In total there were 10 conditions (for examples, see Figure 25a and b):

1. A preview search where previewed distractors faces were male faces, neutral and rotated 0°. The search distractors appearing at the same time as the target were greyscale houses and the target was a female face, also neutral and rotated 0°.
2. A preview search where previewed distractors faces were male faces, neutral and rotated 90°. The search distractors were houses and the target was a female face, also neutral and rotated 90°.
3. A preview search where previewed distractors faces were fearful and rotated 0°. The search distractors were houses and the target was a neutral face, rotated 0°. All faces in this condition were 50% likely to be a male face, with an even split of male and female faces on each trial.
4. A preview search where distractors faces were fearful and rotated 90°. The search distractors were houses and the target was a neutral face, rotated 90°. All faces in this condition were 50% likely to be a male face, with an even split of male and female faces on each trial.
5. A full element baseline with house distractors, a neutral female target and neutral male distractor faces. All faces were rotated 0°.
6. A full element baseline with house distractors, a neutral female face target and neutral male distractors. All faces were rotated 90°.
7. A full element baseline with house distractors, a neutral target face and fearful distractor faces. All faces were rotated 0°.
8. A full element baseline with house distractors and a neutral target face and fearful distractors faces. All faces were rotated 90°.
9. A half element baseline with a target neutral face rotated 0° and house distractors.
10. A half element baseline with a target neutral face rotated 90° and house distractors.

The different variables can therefore be summarised as follows: condition (preview x FEB x HEB), set size (8 x 16), rotation (0° x 90°) and expression (neutral x fear). In the HEB as there were no faces other than the target and the target was kept neutral across all conditions and rotations, the expression manipulation did not apply to these conditions.

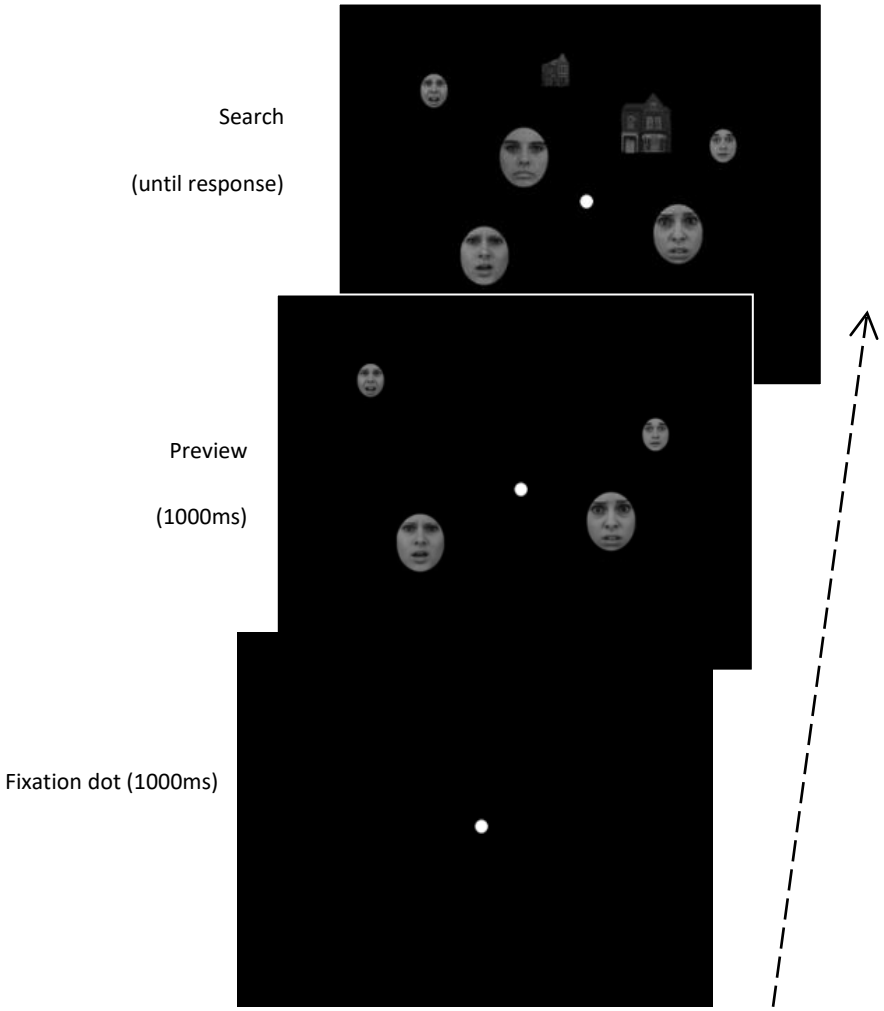

Figure 25a. Example of the procedure for Fear 0° preview condition (condition 3 of the above list) of Experiment 12. The full element baseline conditions were identical but all items appeared simultaneously. The half element baseline conditions contained only the target face and the houses. The arrow indicates the direction of time.

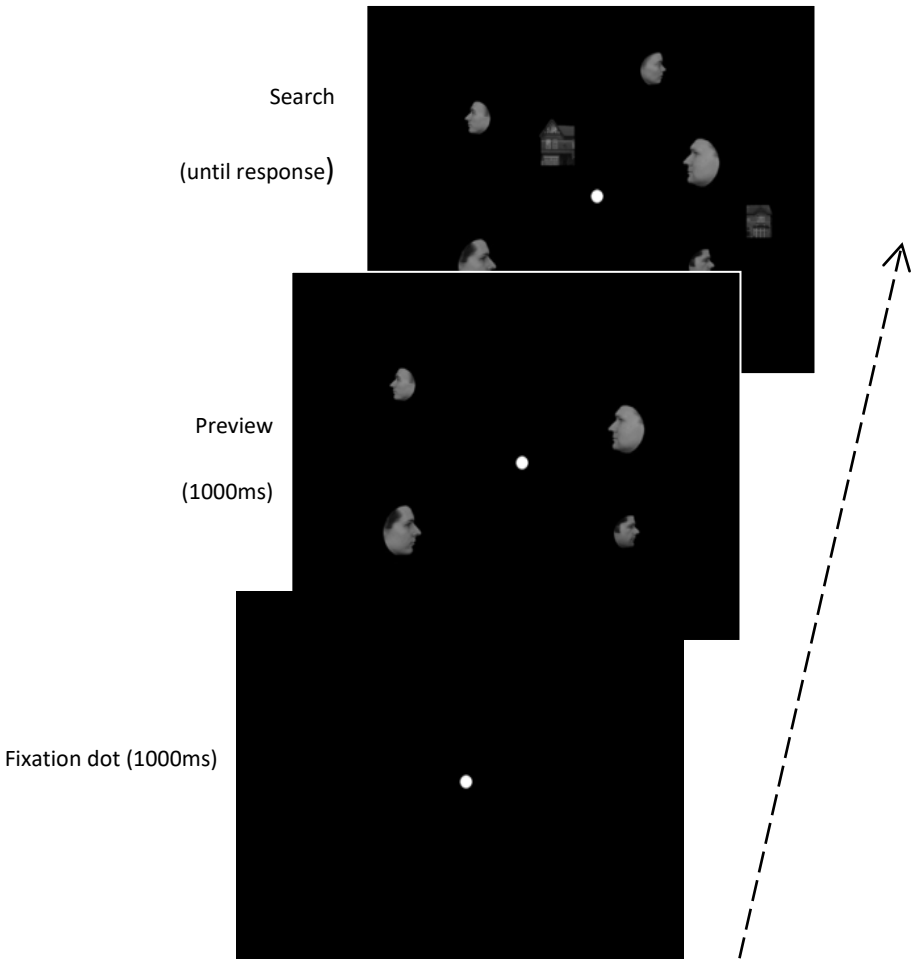

Figure 25b. Example of the procedure for Neutral 90° preview condition (condition 2 of the above list) of Experiment 12. The full element baseline conditions were identical but all items appeared simultaneously. The half element baseline conditions contained only the target face and the houses. The arrow indicates the direction of time.

In each condition, participants were instructed to search for a neutral female face. This was the same face from trial to trial and was either rotated 0° (in conditions with 0° rotated distractors) or 90° (in conditions with 90° rotated distractors). Upon finding the target face, participants had to indicate whether it was to the left or right of the fixation dot in the

middle of the screen. If the face was on the left, participants were instructed to press the "z" key and if the face was on the right, participants were instructed to press the "m" key.

Each condition began with the presentation of a fixation dot for 1000ms. In the baseline conditions, this was followed by the stimuli being presented until participants' response. In the preview conditions, half the stimuli were presented (the faces) for 1000ms after which the house stimuli and the target face appeared. This continued for 80 trials (plus 10 practice trials before the experiment proper). The study lasted approximately 45 minutes. Participants completed either the preview conditions or the baseline conditions and their accuracy and reaction times were recorded.

5.6.4. Results and discussion

Data were trimmed for outliers using the aforementioned method (7.8% of the data were removed). Table 38 shows the mean correct reaction times across conditions. Figure 26 shows the search slopes for each condition.

Table 38. Mean RTs and SDs condition and set size for Experiment 12.

	Measure	
Condition/Set size	Mean RT (ms)	SD
FEB Fear 0°		
8	1250	183.19
16	1785	343.88
FEB Fear 90°		
8	1241	246.56
16	1707	385.76
FEB Neutral 0°		
8	1196	265.56
16	1817	441.39
FEB Neutral 90°		
8	1166	247.26
16	1666	396.49
Preview Fear 0°		
8	566	171.54
16	615	185.08
Preview Fear 90°		
8	613	192.89
16	652	215.15
Preview Neutral 0°		
8	541	151.42

16	576	147.46
Preview Neutral 90^o		
8	533	119.51
16	592	143.18
HEB 0^o		
8	398	48.29
16	397	61.65
HEB 90^o		
8	417	70.15
16	410	68.70

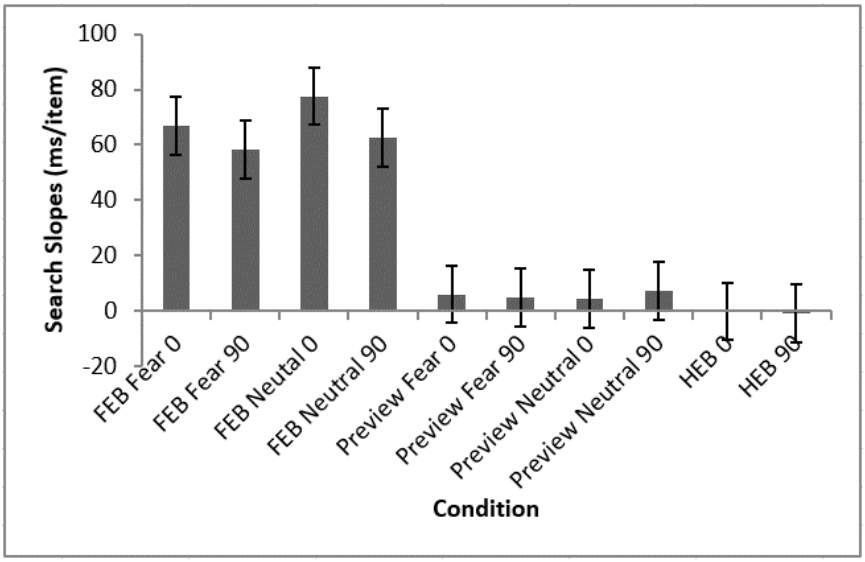

Figure 26. Search slopes across condition for Experiment 12. Error bars represent SEM.

Of importance, a 2 x 2 x 2 ANOVA with main effects of expression (fear x neutral), rotation (0^o x 90^o) and set size (8 x 16) was carried out. This shows a main effect of set size, F(1,19), MSE = 11.56, = 75.4, $p < 0.01$, partial $\eta^2 < 0.87$ but no other main effects or interactions were significant, all f-values < 3.5, all MSEs < 84.29, all p-values > 0.08, all partials $\eta^2 < 0.16$. This would suggest that neither the expression nor the rotation of the faces had any adverse or beneficial effect on search efficiency.

Full conditions. The full baseline conditions were entered into a 2 x 2 x 2 ANOVA with main effects of expression (fear x neutral), rotation (0^o x 90^o) and set size (8 x 16). There was a main effect of set size, F(1,19) = 268.44, MSE = 34.24, $p < 0.01$, partial $\eta^2 < 0.78$ and the rotation x set size interaction was significant; there was a greater effect of set size when

faces were not rotated in comparison to when they were, $F(1,19) = 4.89$, $MSE = 4.72$, $p < 0.05$, partial $\eta^2 < 0.22$, No other main effects or interactions were significant, all f-values < 1.30, all MSE < 59.33, all p-values > 0.1, all partial $\eta^2 < 0.15$.

Half conditions. The half baseline conditions were entered into a 2 x 2 ANOVA with main effects of rotation (0^o x 90^o) and set size (8 x 16). RTs were faster at 0^o than at 90^o, $F(1,19) = 7.32$, $MSE = 0.87$, $p < 0.01$, partial $\eta^2 = 0.62$. There was no main effect of set size, $F(1,19) = 1.36$, $MSE = 24.04$, $p = 0.27$, partial $\eta^2 = 0.12$, nor was the two-way interaction significant, $F(1,19) = 0.83$, $MSE = 49.65$, $p = 0.37$, partial $\eta^2 = 0.14$.

The results show that there is little effect of either rotation or expression of face distractors when performing a search task. As expected, search slopes in the half element baseline were low, as a face singleton is salient among house distractors (Triesman & Gelade, 1980) and this efficiency did not vary as a function of rotation; the face was equally as salient at 90^o as it is at 0^o. Search was also efficient in the preview condition, in terms of slope function, with all four conditions being of equal efficiency. Although the preview conditions did not vary as a function of rotation, the full element baselines showed a greater effect of set size seen when the faces were not rotated as opposed to when they were rotated through 90^o. It is not clear why this is the case, especially as it is contradictory to the finding in the HEB that a non-rotated face is reacted to faster than a rotated one.

One possible reason for this difference is that different strategies were being used to carry out the different kinds of task. For example, in a HEB condition participants were able to direct their attention to just the face shaped items, without having to check whether the face contained the defined target features (as it is the only face in the display). As aforementioned then, a sense of "roundness" associated with non-rotated faces would be more distinct in comparison to houses than the contours of a face in profile. However, in a full search condition, each item must be laboriously checked to ensure it is not the target. As there are a greater number of facial features available when a face is not rotated, it may be more difficult for participants to disengage their attention from these distractors (Bindemann et al., 2005), whilst rotated faces provide relatively fewer facial features. These differences in search are not due to variations in the expression of the faces as these

were constant across rotation for both conditions. It suggests that the experimental design was unfortunately not reliable, perhaps due to the number of interacting factors.

The difference in trend between expression recognition and identification is possibly due to the amount of detail needed to make a judgement. For example, it is widely accepted that faces are processed holistically (Farah et al., 1998; Rossion, 2008) which may be crucial in making on identity judgement. On the other hand, expression recognition (especially in a matching task) may be judged on individual features, such as a raised eyebrow or open mouth and therefore the holistic representation of the face may not be needed. The lack of holistic detail available at 90^{o}, therefore, would be less detrimental to the expression condition than to the identity condition.

However, it is also possible that the experiment paradigm was not sensitive enough to detect differences between the expression conditions. If, as suggested by Öhman (2002), Vuilleumier (2002) and Pourtois et al. (2004), negative faces are processed faster than neutral faces, it may be that the fearful faces are processed and subsequently inhibited within the duration of a standard preview (1000ms). This would explain the findings of Watson and Blagrove (2010) who found a detriment to the preview benefit with negatively valenced faces only when the preview was shortened to 250ms. It would be interesting to see whether the results of the current experiment would be any different if a shorter preview duration was adopted.

Overall, it would appear that whilst the complexity of the visual array and the amount of facial information available can have an effect on search and this effect varies depending on the type of search task being performed (preview vs. full condition), there is no evidence to suggest that fearful faces are more difficult to inhibit than neutral faces. This may be due to the design of the experiment; Watson and Blagrove (2010), for example, did not find an effect of negatively valenced faces at standard preview time (1000ms), but did find an effect when the preview was shorter (250ms). This may be due to facilitated processing of emotional faces (Schupp et al., 2004) causing participants to effectively process and then inhibit the fearful faces within the 1000ms of the preview. At shorter preview times, however, participants may have still been processing the negative faces and thus inhibition had not yet occurred. It would be interesting in future work for this to be addressed by

including a preview condition akin to those of this experiment with varied preview times. This will not only show whether negative faces are difficult to ignore under certain conditions, but will also give insight into the timing needed for people to detect, processing and then inhibit negatively valenced faces.

5.7. Chapter summary and discussion

Human faces are of significant importance in our everyday lives, giving information about relationships, inner feelings and responses to the external environment. It is little wonder then that there has been so much research dedicated to how we attend to faces, from behavioural evidence for capturing attention in a more robust manner than other objects in the environment (Langton, Law, Burton & Schweinberger, 2008; Theeuwes & van der Stigchel, 2006; Ro, Russell, & Lavie, 2001) and being processed faster than other objects (Ro, Friggel & Lavie, 2007), to physiological evidence showing specific neural regions dedicated to the processing of faces (Farah, 1996; De Renzi et al., 1994). However, the vast majority of literature related to the attentional role of faces use stimuli in their procedures which face the participant "straight on". Whilst this allows for greater control and uniformity of stimuli used and therefore eliminates many potential visual confounds, it arguably detracts from the ecological validity of the findings. In a natural environment, for example, we regularly see faces from a variety of different angles and viewpoints and still need to be able to infer their correct identity or the meaning of the configural information. The question therefore arises: are the findings of previous literature still valid when the angle of the face has changed? The purpose of these studies therefore was to test if the findings of previous literature examining the attentional properties of faces could be replicated using faces that were more varied (and thus more ecologically valid). Here, faces that had been rotated in depth (i.e. in profile) were examined to see how these differed to results where faces were viewed straight on.

Experiment 10 examined simple responses to faces of either a neutral or fearful expression across three levels of depth rotation: 0^{o} (face straight on), 45^{o} (face partly turned either to the left or the right) and 90^{o} (face in profile either to the left or the right). Whilst the findings support the notion that negative faces are responded to more rapidly than neutral

faces (Öhman, 2002; Vuilleumier, 2002; Pourtois et al., 2004), the finding did not appear to support the suggestion that faces rotated at 45° may be advantageous (Bruce et al., 1987; Perrett, et al., 1989). Indeed, the results showed a disadvantage in responding to faces at 45°. We do not, however, consider this contradictory to the previous literature; the increased number of visual features present at 45° may have caused the delay in response.

Experiment 11 examined the effect of rotation on expression recognition and identification using a match/mismatch task. Here, although 45° was no longer the most disadvantageous when it came to identification, it was not advantageous as Bruce et al. (1987) found. In fact, identification was faster at 0° than it was at 45°. This may have simply been due to differences in experimental design. For example, the 3/4 advantage described by Bruce, et al. (1987) was found when both the initial face and the test face were rotated by 45°, whereas here the initial face was never rotated. There was no effect of rotation on expression identification; reactions were equally as fast at 0° as they were at 90° and this difference in effect of rotation between expression and identity could be attributed to the greater need for a holistic representation when identifying a face, in comparison to recognising the expression of a face. The similarity in reaction times across rotation for the expression condition is, however, eliminated when the faces are inverted, suggesting an increased difficulty in ascribing emotion to facial details when the face is both upside-down and rotated through 90°. This theory is somewhat supported by the pronounced increase in reaction times when making a match in the identity task; individual features have to be checked rather than relying on the holistic representation of the face.

Experiment 12 examined the effect of rotation on attention guidance using a series of preview search tasks. Based on previous literature (Hansen & Hansen 1988; Hampton et al., 1989; Blagrove & Watson, 2010) it was initially expected that a preview of fearful faces would cause a delay in reaction times as negatively valenced faces are more difficult to ignore than positively valenced or neutral faces, and this trend should be similar across rotation (based on the findings of the previous experiments). The results were in fact largely inconclusive: initial analyses showed no effect of either expression or rotation of the preview items. When the order of condition was taken into consideration, reaction

times were faster when the faces were not rotated. Although it is not completely understood why this was so, it was possibly due to the increased visual complexity of the rotated faces. An alternative explanation is that the experiment was not sensitive enough to detect the differences and perhaps using a shorter preview may allow for this (Watson & Blagrove, 2010).

Overall, the results of this chapter suggest that as an emotional face rotates, sped up responses seen in studies where the face is straight on diminish. However, it is not clear from the present study whether this is due to the emotion seeming subjectively less intense to observers when rotated, or whether participants simply do not recognise the emotion as easily when the face is rotated. Although the stimuli used in the present studies had been validated (i.e. participants of Lundqvist, Flykt & Öhman (1998) reported that the face was fearful), this does not give any indication as to how strongly the emotion is conveyed. There could, for example, be a large difference between faces which are perceived as slightly apprehensive to faces which appear utterly terrified. Further research should aim to obtain faces which have been validated not only in respect of the emotion itself, but also of its level of intensity to eliminate this potential confound. It would also be interesting to examine brain activity whilst viewing the faces using fMRI. If the effect of facial rotation is that emotions are subjectively less intense, activity in the amygdala should be lower in response to a rotated face relative to a straight on face. However, if it is simply that it is more difficult to recognise, activity in the amygdala may not significantly differ from baseline conditions of neutral faces.

Although the results of Experiment 12 were not as informative as we had hoped, there are further lines of research which can be taken using the rotated face paradigm. One possibility is to tie it in with research on gaze-cueing of attention. Research has shown that direction of gaze can be used to orient attention (Friesen & Kingstone, 1998) both when a face is in a normal orientation and when it is rotated clockwise/anticlockwise (Bayliss, di Pellegrino & Tipper 2004). Further, brain regions which respond to the orientation of the face are the same regions which respond to direction of gaze (Puce et al., 1998; Hoffman & Haxby, 2000; Hooker et al., 2003) and, moreover, these two factors interact with head rotation affecting people's judgement of where gaze is directed (Langton, Watt & Bruce,

2000). It would be beneficial to carry out visual cueing or visual search tasks which examine the interaction of depth rotation and gaze direction on attention orientation.

A further potential line of research lies in the relationship between attendance of negatively valenced faces and anxiety. Previous literature suggests that people with high anxiety show an attentional bias towards threatening faces, both consciously and subconsciously and across a number of different experimental paradigms (MacLeod, Matthews & Tata, 1986; LeDoux, 1996; Williams, Watts, MacLeod & Matthews, 1988; Mogg & Bradley, 2002). High anxiety individuals may also find it harder to disengage their attention from negative faces (Fox et al., 2001, 2002), and these trends are reported for both clinical and nonclinical populations (Bar-Haim et al., 2007). It would be beneficial to see if rotated threatening face stimuli produces as robust a response in anxious participants as when the face is not rotated. It would also be interesting to see if there is any interaction between anxiety and rotation of the face. If a face rotated into profile is perceived as less threatening, then responses should decline until they are aligned with non-anxious individuals, whereas responses will remain high if a rotated face is perceived as equally threatening.

Discussion

6.1. Summary of Chapters

Chapter 1 suggested that the extent to which preview benefit is disrupted by a secondary task of a different modality (i.e. a primary visual search task and a secondary audio task) depends not only on the timing of the secondary task onset (after or with preview onset) but, perhaps, on the load of the task. This work extends the findings of Humphreys et al. (2002) and shows how preview theory and load theory can interact. Lavie, Rees and De Fockert (2001) showed that high working memory load resulted in greater interference from an incongruent distractor during a secondary naming task. According to Watson and Humphreys (1997), among others, items in the preview need to be attended in order to be inhibited. As a result, the higher working memory load in a secondary task, the greater the distractor interference under preview conditions as preview items cannot be sufficiently attended to in order to be inhibited.

Results from Chapter 2 provide some evidence for the role of location inhibition in conjunction search. Initial results from Experiment 5 showed search under conditions where half the items (the usual preview items) appeared in the same location from trial to trial was as efficient in the conjunction condition as in the preview condition. Although subsequent experiments failed to replicate this result, evidence from the secondary probe detection tasks suggested that participants were attending less to the fixed distractors and more to the novel distractors, again supporting the idea that the known distractor locations are being ignored.

Results from Chapter 3 gave somewhat surprising results of the consequence of cueing an attribute of the target (its colour). Whilst previous literature has shown valid cues (Posner, 1980) or target colour anticipation (Braithwaite et al., 2003) to be beneficial in locating a target, the results here show that in comparison to preview conditions where there was no useful colour cue, preview searches which did have a valid cue were less efficient.

Results from Chapter 4, although inconclusive, suggest that the way in which we respond to faces that have been rotated through to profile may be different to how we respond to faces looking straight at us. Results from Experiments 10 – 11 show we are worse at processing rotated faces than straight on faces. Experiment 12 did not show any marked effect of emotion and only a very marginal effect of rotation on a preview visual search task.

6.2. Further Discussion

In everyday life, we need attention to filter information that is helpful to our goals, and ignore information that is irrelevant. As vision is our most dominant sense, understanding how we attend to the visual world, how we ignore irrelevant stimuli, even whether we can ignore some stimuli and how our visual attention is divided between multiple tasks, is of great interest and importance. One method of studying visual attention has been using visual search tasks (Treisman & Gelade, 1980; Duncan & Humphreys, 1989; Wolfe et al., 1989; Maljkovic & Nakayama, 1994; 1996; Chun & Jiang, 1998; Kristjánsson et al., 2002) and, within visual search, preview search has been used to demonstrate how visual attention might be guided (Watson & Humphreys, 1997).

Early literature on preview search appears to be dichotomised into two schools of thought: those who suggested the benefit was due to location inhibition (Watson & Humphreys, 1997; 1998; Olivers et al., 1999; Humphreys et al., 2004) and those that regarded the benefit as a result of the abrupt onset of new items capturing attention (Donk and Theeues, 2001). However, in the years that followed a variety of other factors have been shown to contribute to the preview benefit, including feature inhibition (Kunar et al., 2003b) and feature anticipation (Braithwaite et al., 2003; Braithwaite & Humphreys, 2003), as well as the need for sufficient attentional resources (Humphreys et al., 2002; Olivers & Humphreys, 2002; Allen et al., 2008). More recently, the need for both top-down and bottom-up mechanisms has been demonstrated (Osugi & Murakami, 2017) as well as how different memory systems used in generating the preview benefit can compete for resources when their goals are not cohesive (Yamauchi et al. 2017). The results from this thesis expand on how these different mechanisms for generating a preview benefit may

interact, and how preview mechanisms may interact with other mechanisms of selective attention.

6.2.1. Attention as a limited capacity processor

At its inception, attention literature sought to establish whether the mechanisms of attention worked to disregard irrelevant information, i.e. filter theory (Broadbent, 1952, 1953, 1958) or processed all inputs to some extent and then selectively focused attention on the most task-relevant input, i.e. resource theory (Lavie & Tsal, 1994; Lavie, 1995). In fact, both theories are meritorious and can be considered compatible, with resource theory functioning on a continuum upon which the "filter" of filter theory operates depending on the task demands.

The results of Chapter 1 appear to support a hybrid of resource and multi-channel filter theories of attention (Lavie, 1995; Kahneman, 1970; McLeod, 1977). When participants were required to perform a sufficiently challenging secondary task, the preview benefit was disrupted regardless of the secondary task modality. This occurred even when the secondary task and the preview did not temporally overlap (Experiments 1b – 3) indicating the importance of participants being able to attend exclusively to the preview (if they are already rehearing the working memory task, their attention is otherwise occupied and a full preview benefit cannot occur). Experiment 4, however, showed that once the attentional demands of a between-modality task were lowered, search became more efficient when there was no temporal overlap of tasks, compared to when there was. That is, as the attention demands of the task decreased, the inputs from the separate modality tasks could then be dealt with more efficiently.

The findings of Chapter 1 also suggest that active attention is required to attend to the preview in order for inhibition to occur, supporting the results obtained in prior preview benefit studies (Watson & Humphreys, 1997; Humphreys et al., 2002). More specifically, findings from preview and dual-task studies indicate that attention needs to be focused entirely on the preview (i.e. no secondary task) for at least some period of time (Kunar, Shapiro & Humphreys, 2006). In Chapter 1, disruption to the preview benefit occurred in every secondary task condition, with the exception of the delayed onset condition in

Experiment 4b. This finding is again interesting in respect of the part played by the attentional requirements of inhibition in preview search. Separately, a between modality secondary task or a delay in the onset of the secondary task do not suffice to allow preview benefit to occur. It is the combination of these with the attentional demands of the secondary task that appear to affect whether or not a full preview benefit arises.

Recently, Osugi and Marakami (2017) discussed the possibility that visual attention utilises two distinct memory systems that have different levels of capacity: a high-capacity memory system that tracks changes in display items and a low-capacity memory system that stores information about items, such as their colour or location, and inhibits task-irrelevant features. The high-capacity system can track a greater number of items, but is more vulnerable and therefore susceptible to intereference or disruption from secondary tasks. The low-capacity system, on the other hand, can only maintain information about a fewer number of items, but is harider and less liabile to disruption from distracting information than the high-capacity system. According to Osugi and Marakami (2017), preview search requires both systems in order to obtain a maximum benefit. Although under some conditions a partial or even full preview benefit can occur in the absence of one of these mechanisms, preview efficiency tends to worsen if one of these mechanisms is disrupted and neither mechanism alone can explain the vast range of results obtained from preview search. The results of Chapter 1 support the theory proposed by Osugi and Marakami (2017). The presence of a secondary task would have disrupted the more vulnerable high-capacity memory system tracking asynchronies between the old and the new items, therefore any benefit would have to arise from the second, low-capacity system used to mark the locations of old items. As the number of previewed items in Chapter 1 exceeded this capacity of approximately 4 items (Al-Aidroos et al., 2012), only a partial benefit at best could be expected. This is in line with the results obtained.

6.2.2. Top down attentional guidance – inhibition

Top-down guidance as a result of inhibition has been prevalent throughout visual attention literature, from the inhibition of rejected locations as in IOR (Posner & Cohen, 1984; Posner, et al., 1985; Klein, 1988, 2000), to the inhibition of particular objects (Tipper, et al,

1991; Müller & Mühlenen, 2000), and the inhibition of item feature such as colour (Gibson & Jiang, 2001; Olivers & Humphreys, 2003; Braithwaite, et al., 2003, 2005). How inhibition arises has also been a subject of interest. How, for example, do we decide which items or locations we should ignore? Is it as a result of a particular event, such as a cue (Klein, 1988, 2000) or due to learning based on search history, be it explicit (Watson & Humphreys, 1997) or implicit (Chun & Jiang, 1998)?

The results of Chapter 2 indirectly lend support to the location inhibition theory of preview benefit (Watson & Humphreys, 1997, 1998 & 2000). As search efficiency in the fixed location condition were, at least, initially comparable to search in the preview conditions, it would appear that in both conditions participants are searching only through the remaining, novel distractors. Here, the argument that the preview benefit is due to exogenous orienting of attention to the search items by their sudden onset (Donk & Thueewes, 2001) cannot explain why search would be more efficient in the conjunction condition where all items appear simultaneously. Rather, the results suggest that the repetition of half of the display allowed participants to learn to ignore those locations in preference of other locations which would be more likely to contain the target (similar to the mechanism supposed to contribute to the preview benefit (Watson & Humphreys, 1997)).

The learning and inhibition of irrelevant item locations seen in Chapter 2 provides an addition to the literature on contextual cueing. Chun and Jiang (1998) originally reported no benefit to search efficiency under contextual cueing conditions if the target was not kept consistent in relation to distractors on repeated displays. In Chapter 2, the target location was allocated at random. Nevertheless, repeating distractor displays resulted in a reaction time benefit. Perhaps this difference is merely a result of experimental design; rather than learning the entire display and the spatial relationships between the target and nearby distractors, participants here only had to learn to ignore a fixed number of locations that were consistent across trials. By contrast, in Chun and Jiang (1998), there are multiple distractor/target configurations which are repeated per block (i.e. 12 different displays per block), so that the average distractor and target locations are unpredictable across the 12 displays. Further, in Chun and Jiang's studies, all items in the repeated trials were in

repeated locations, as opposed to just half the items. Whatever the cause for the difference in results obtained by Chun and Jiang and the current thesis, the implication from Chapter 2 that some form of learning based on context is taking place remains.

6.2.3. Top down attentional guidance – anticipation

Research on top-down attentional guidance focusses on the role of target and distractor features in guiding search. Whilst Treisman and Gelade (1980) showed that search for an item defined by a conjunction of features shared by distractors results in an inefficient search, subsequent literature suggests that if instructed to search through only a specific subset (e.g. only the blue items in a search for a blue "H" among green Hs and blue As), participants are able to direct their attention preferentially to that subset, resulting in a more efficient search for both conjunction and triple conjunction targets (Egeth et al., 1984; Friedman-Hill & Wolfe, 1995; Nordfang & Wolfe, 2014). However, Nordfang and Wolfe (2014) do point out that in order for these searches to be efficient, the target would need to have a feature that, within the subset of items they are instructed to guide their attention to, is unique (akin to the heterogeneity principle discussed by Duncan and Humphreys (1989)).

Given that prior literature shows a decrease in search times when participants are told to focus on particular features, it would be anticipated that the use of a valid colour cue in Chapter 3 would guide participants' attention to items of only those colours and thus make search more efficient in these conditions. However, it is important to note that the target did not possess a unique feature within the colour subset – that is, the target was not the only face-shaped item in that subset as half of the distractor faces were also that colour. This would explain why there was very little difference between the cued and the neutral conditions for the FEB and HEB in experiment 8: whilst participants could search through the cued colour in the cued condition, they could have just as easily adopted the strategy of search through only face-shaped items in the neutral conditions, resulting in similar search efficiencies.

The result of interest in this experiment was the preview condition. In the neutral preview condition, participants could rely on top-down guidance based on inhibition. In the cued

condition, participants arguably had a choice of strategies, i.e. to continue to use guidance based on prior search history, or guidance based on visual features. Here, it would appear, participants opted to deploy their attention to items of the cued colour rather than to the new items in the display. The resulting search slopes would suggest that top-down guidance based on visual feature is a less efficient search strategy than guidance based on prior search history.

Chapter 3 also examined the effect of anticipation in preview search. In contrast to the findings of Braithwaite and Humphreys (2003), the studies here showed that a valid cue did not facilitate preview search, but instead appeared to hinder it. One possible explanation for this was that the colour cue primed participants for red items, e.g., and thus their attention was automatically oriented to red preview stimuli as opposed to the target. This is not likely for two reasons. Firstly, the time required to disengage attention from a location to which one has automatically orientated is approximately ~300ms, (Klein, 1988). As the preview was 1000ms long, participants should have been able to disengage their attention from the irrelevant preview items and instead attend to the new search items. Secondly, the results from Experiment 9 suggest that participants were able to adopt a search strategy depending on the context of the task (e.g. whether the cue is useful or not, in this instance), although why a less efficient search strategy is adopted in favour of a more efficient one remains unclear.

6.2.4. Pre-attentive and attentive processing in visual search

In the case of visual attention, for instance, some information can be processed pre-attentively (placing minimal demand on attention resources or capacity), whilst other information is processed attentively (placing higher demand on attention resources). The distinction between what constitutes pre-attentive and attentive processing has largely influenced the literature on visual search. Theorists suggest that in visual search, attention is guided by information processed pre-attentively (e.g. local feature contrasts such as shape, colour or orientation), modulated by attentional sets or behavioural goals (for a review on visual search theories see Chan and Hayward (2013)). If attention can be guided on the basis of pre-attentive inputs, the search is often speeded and efficient, whilst

searches which require attention to be deployed to individual items before a target response can be made are less efficient and slower. This concept was demonstrated by Treisman and Gelade's (1980) article on FIT, which showed search to a singleton target, defined by pre-attentive characteristics such as colour or shape, was independent of the number of distractor items. Conversely, a target which shared its features with the surrounding distractor items and was only defined by a combination of features required attention to be deployed to each individual search item, resulting in search slopes which were dependent on the number of search items.

According to Treisman and Gelade (1980) then, attention must be directed to each individual location in a conjunction search display in order to combine item features and accept/reject them as distractors. It then follows that if a high working memory load uses up the attentional resources needed to attend to search items, then search under these conditions should be less efficient. Consequently, as pre-attentive processing does not require active attention then search efficiency in a single feature condition should not be altered by the introduction of a secondary task. Whilst this point is not discussed in Chapter 1, the results from Experiment 2 appear to confirm the latter, with virtually no difference in search slopes between the HEB when there was no secondary task (1.40ms/item) compared to when there was (1.96ms/item). The findings from the FEB conditions are less conclusive. Although there was no effect of working memory task, the set size working memory task interaction was significant, suggesting that search was less efficient when there was a working memory task.

Although less efficient conjunction search is in line with Treisman and Gelade's (1980) FIT, other examples of dual-task conjunction searches do not support this view. A series of working memory dual-task experiments by Logan (1978) failed to show an effect of high working memory load on search. Further, Woodman, Vogel and Luck (2001) showed that whilst high working memory load does increase search times, its effect is constant across set size and does not increase as more items are added. However, the search task in both of these experiments was to locate a specific target (or one of two targets) among distractors and did not require combining of features as a conjunction search does, therefore it is difficult to generalise the results in this way.

6.2.5. Attention, faces and the effect of rotation

In a recent article on the factors affecting search efficiency, Wolfe and Horowitz (2017) outlined a number of potential targets that could capture attention in a bottom-up manner (e.g. a colour singleton, a moving target amid stationary distractors, to name a couple). One item discussed in Wolfe and Horowitz (2017) was that of faces. Results from the HEB conditions of Experiments 1-9 showed that a target face not defined by a unique colour does pop-out from a display of distractor houses. Whether this is due to the fact that the target is a face or otherwise due to the uniqueness of the shape of the face in comparison to the houses, however, is not clear, therefore it would be difficult to say definitively from this whether a face alone can capture attention.

Wolfe and Horowitz (2017) also highlight some of the controversies surrounding negatively valanced faces, as although search for an angry face produces a more efficient search slope than that of a neutral face, such searches are still typically far more inefficient than even conjunction searches (~64ms/item as oppose to ~30ms/item; as reported in Gerritsen et al. (2008)). In contrast, previous literature (Fox et al., 2001) suggests that we respond quicker and more accurately when the target looks angry or afraid. Results from Experiment 10 appear to support the latter, with reactions to faces being faster to an angry face than to a neutral face. However, this is only true for faces which are not rotated, with faces rotated by 45^{o} and 90^{o} showing no difference in reaction times to angry than neutral faces.

The impact of face rotation on emotion and target detection remains unclear from the results presented here. Whilst results from Experiment 12 did not show any marked effect of emotion and only a very marginal effect of rotation on search efficiency, it is possible this is due to shortcomings in the experimental design rather than a genuine lack of effect. Perhaps, initially, a simpler guided attention task might be a sensible place to begin such research, e.g. do participants detect a target faster if it is cued by a face that is rotated so that it is looking in the target's direction? Previous studies using both schematic and real faces have shown that when eyeballs are directed in a specific direction, reaction times to targets located in that direction are faster (Friesen & Kingstone, 1988; Driver et al., 1999), and gaze from a fearful face is prioritised over gaze cues from other, non-fearful faces

(Carlson & Aday, 2018) but could this be replicated if it was the entire face which was turned as opposed to just the eyes? Would it be even faster if the face had a fearful expression? The results of Chapter 4 suggest that we are slower to react to negative emotions when a face is rotated, therefore there should be no benefit in responding to a target that appears in the direction of a fearful face. Whilst from a survival perspective it would be beneficial to be able to react to negative expressions just as quickly when someone is not facing us as when they are, results from Chapter 4 suggest that this is not the case.

6.2.6. Visual search experiments and ecological validity

The results of the thesis, particularly those of Chapter 4, highlight the potential issue of ecological validity in attention research. Whilst simplistic, highly controlled tasks have been essential for providing an initial understanding of attention and how it interacts with various aspects of the perceptible world is, in reality, far more complex. We often search for loosely defined targets among a multitude of visual, audio and other distractors, some of which move, some of which do not maintain a consistent luminance, and some of which are oriented in unfamiliar ways. Our visual attention system does have limitations: (e.g. inattention blindness (Hyman et al., 2010)). Nevertheless, we are generally able to cope well and achieve behavioural goals, despite the complexity of reality. There is a need, therefore, to develop attention research so that this gap between the experimental laboratory and the world outside is reduced. For example, Kunar and Watson (2011) developed what they called a multi-element asynchronous dynamic (or "MAD") visual display paradigm, which includes large displays of moving, blinking items. Under these search conditions, a preview benefit does not occur (Kunar, Thomas & Watson, 2017). If a MAD search can be considered a more realistic search, then is previous search on preview benefit, although insightful, actually applicable to everyday life? On the other hand, Chen and Zalinsky (2006) conducted a preview search using photorealistic stimuli of everyday objects. Their results suggest that a preview benefit can occur with objects which are more visually complex than standard laboratory visual stimuli. It is possible that whether or not preview benefit will occur in "realistic" searches depends on how exactly realistic is defined and controlled.

Other research examining how more dynamic visual displays would impact preview benefit was conducted by Jiang et al. (2002) when they assessed the impact of background changes on a preview search task. In the real world, the visual environment is constantly subject to background changes, such as increases in luminance as the sun appears from behind a cloud, or movement when a group of people walk through our field of vision. It seems unlikely that such shifts in background activity should impact our ability to maintain our attention on our current goals. Their research found that whilst a change in the luminance of search objects reduced the preview benefit, a similar change of luminance in the background did not disrupt the search performance, suggesting that the preview benefit can survive irrelevant background changes.

Further research examining preview benefit under more dynamic conditions by Osugi and Murakami (2015, 2017) found that the type of changes in background noise impacted whether the preview benefit was disrupted. For example, a change in background noise from dynamic to static coinciding with the onset of the search items did not disrupt the preview benefit, but a change from static to dynamic did. Further, a single transient background change coinciding with the onset of the search items did not disrupt the preview benefit, but two or more transient background changes did. These results show that whilst the preview benefit can survive some background changes (Jiang et al., 2002), the number and direction (e.g. static to dynamic or vice versa) of the background changes differentially impact the benefit. In their 2017 paper, Osugi and Murakami (2017) suggest that it is the intensity of the change that effects whether or not the benefit is impacted, For example, less intense changes as might be expected to be found regularly in the real world (e.g. small luminance changes or a single background change) do not disrupt the preview, whereas larger, more drastic changes do. This conclusion is consistent with the idea that preview benefit can occur under more naturalistic conditions.

6.3. Areas for further research

6.3.1. Secondary task difficulty

The role of secondary task difficulty in preview search was demonstrated in Experiment 4 of Chapter 1, with prior results from Humphreys et al. (2002) only being replicated when the task was easier. Difficulty in this case is inferred from the average difference in working memory accuracy, but previous studies (Lavie et al., 2001) have inferred difficulty by the amount of target interference, reflected in average reaction times. Whilst such methods are by no means inappropriate, the aggregation of data means that individual differences in task aptitude may be missed. For example, the difficulty of memorising repeated tunes in Experiment 5 might vary greatly between individuals (say, depending on their history of musical training). Future research could measure individual differences in secondary task performance and compare these to the amount of interference on search to provide insight into the relationship between individual effort on a secondary task and the impact this has on search efficiency.

Another area for potential study would be to examine the interaction of timing and working memory load on preview search using a visual working memory task. Although previous studies (Humphreys et al., 2002; McLeod, 1977) suggest two tasks of the same modality have greater interference on each other, it would be of interest to see whether visual working memory load could ever be sufficiently low to allow for full processing of preview items. Results from Experiments 6a – 7 of this thesis, for example, suggest that even a very simple visual distraction, such as the addition of a probe detection task, is sufficient to disrupt search efficiency. It may be, then, that maintaining a visuo-spatial representation of preview items in working memory requires uninterrupted visual attention and any visual activity not related to the preview items, no matter how undemanding, is enough to disrupt this representation, at least to some extent. This would extend the current findings on preview benefit and its interaction with secondary task modality.

6.3.2. Inhibition and learning in search

Top-down attentional guidance was examined extensively over the course of Chapters 2 and 3. Chapter 2 examined the role of inhibition and learning, based on search history, whilst Chapter 3 examined the role of anticipation. Whilst Chapter 2 provides indirect support for an inhibition strategy in respect of preview search as oppose to abrupt onset, further research examining the interaction between contextual cueing and preview could be profitable. For example, previous work on preview search by Jiang, Chun and Marks (2002) showed that the preview benefit was disrupted when the onset of new items coincided with changes in the old items. If location inhibition is at least partly responsible for preview benefit, then a more gradual change from distractor to target (as opposed to an abrupt onset which automatically captures attention) should show an increase in search times compared to when the target appears at a new location.

The results of Chapter 2 contradict the findings of Chun and Jiang (1998) in that learning and an increase in search efficiency was seen even when the spatial relationship between the target and the distractors in repeated display did not remain constant. As previously discussed, the reason for this could be due to experimental design differences, but it would be of interest to carry out a study with a greater number of trials which varies the proportion of fixed to non-fixed distractors to see if this results in a linear increase in search times the greater the number of repeated items. Further, varying where the repeated items are located in comparison to the target would also be an interesting addition to the literature on contextual cueing. For example, would repeating a cluster of items in closer proximity to the target produce a faster search than repeating an array of items that are spread throughout the display and of varying distances to the target?

6.3.3. Colour cues and search strategy

Despite predictions that a valid target colour cue would serve to guide attention toward the target and result in a more, or even equally, efficient search as a standard preview condition, Chapter 3 instead showed search to be less efficient with a colour cue. Not only this, but participants appear to be able to voluntarily choose whether or not they ignore

the colour cue and opt for an inhibition search strategy, or use the colour cue and opt for a guidance strategy, despite the latter being less efficient.

The reason underlying the decision to adopt a search strategy which is, in fact, not as efficient as other possible search strategies is not yet clear. It is possible that the reason for this is simply that it requires participants to use less attentional resources. In order to achieve a preview benefit it is assumed that participants inhibit the previewed items, which requires attention. On the other hand, merely directing attention to items of a predefined colour, regardless of whether some of those items have been visible for a full second and are known not to contain the target, would require fewer resources. This would not, however, explain the difference in efficiency between the cued preview and the cued full conjunction condition. It is therefore more likely that participants adopt a hybrid of strategies: inhibiting the preview items, but directing their attention toward distractors in the search display that share the target colour. Further research examining the relationship between anticipatory and inhibitory strategies and how they can be additive or reductive in preview search should be conducted, perhaps by varying the validity of location cues.

How a predictive central cue guides attention has been studied for a number of years. Posner (1980) used an arrow appearing in the middle of the visual display to cue a potential target location, which was either predictive (indicated the actual target location) or nonpredictive (indicated a random, non-target location). The findings showed search to be more efficient when the central cue was predictive. Additionally, research by Tipples (2002) demonstrated that symbolic cues (such as arrows) can cause automatic, exogenous orienting of attention (albeit under different experimental conditions, i.e. two arrows located slightly to the left and right of fixation). Further, Pratt and Hommel (2003) showed that the colour of a central arrow cue facilitated response times to targets of that colour, even in conditions where target colour was not the critical (target defining) feature, suggesting that whilst participants could choose not to attend to the colour of a cue, its presence still had an effect on the direction of their attention. The results of Tipples (2002) and Pratt and Hommel (2003) would suggest that even if the cue in Experiment 8 was not accurate in indicating target colour, participants' deployment of attention would still be influenced by it.

However, more recently Ristic and Kingstone (2006) used central arrow cues and central number cues to explicitly examine whether attention orientating in response to these cues was exogenous (bottom-up) or endogenous (top-down). Their results suggest that whilst response to a predictive (valid) arrow cue was faster than to a predictive number cue, both were endogenous; response times when the cue was accurate (did indicate the correct target location), but in a nonpredictive block of trials (cue was only correct on 25% of the trials), were slower than when the cues were predictive (indicated the correct location on 80% of the trials). This suggests participants could choose whether or not to deploy their attention to the location predicted by the cue, rather than their attention being automatically deployed based on the cue. The results of Experiment 9 support the findings of Ristic and Kingstone (2006); as the cue became less predictive, participants could choose to deploy their attention to items other than those cued by the target, resulting in a more efficient search. In order to gain a better understanding of how attention is being deployed to the distractor items under experimental conditions such as those in Experiments 8 and 9, it would be interesting to carry out an eye-tracking experiment to ascertain whether participants are looking at any of the like-coloured, preview distractors, or searching mainly through the like-coloured search distractors.

In their report, Wolfe and Horowitz (2014) discuss the role of priming in search tasks, and note how seeing a feature of a target repeatedly (even a task irrelevant feature) can increase participants' sensitivity to those features and result in a speed search responses (see Wolfe et al., 2004). Whilst Chapter 3 touched upon this concept in cueing the colour of the target, it would be interesting to see whether repeating the target colour in a valid cue condition would have an impact on the relative inefficiency seen in the cued preview search. If so, would this be as efficient as a standard preview search? Or would top-down feature guidance still prove to be a less efficient search strategy?

6.3.4. The rotation of faces

Results from Chapter 4, although inconclusive, suggest that the way in which we respond to faces that have been rotated through to profile is different to how we respond to faces looking straight at us. Ways in which the experiment could have been adapted include

focussing first on the effects of rotation and emotion in just a HEB, varying the experimental design until it is sensitive enough to detect differences, and then building up to examine FEB and preview search from there.

Further research could also look more specifically at the effect of gaze: for example, is it harder to ignore an angry rotated face if the eyes are still looking at you than if gaze is in the same direction as the face itself? If it is, the lack of effect of emotion seen when faces are rotated may not be due merely to a lack of facial information (as proposed in Chapter 4), but because of a lack of emotional relevance. Due to peripheral vision, we would be able to see if something threatening to either our left or right is near enough to require an immediate response. However, as we cannot see behind us, threatening objects approaching from this direction could potentially get very near before we become aware of them. As such, we rely on the expressions of those who can see behind us in order to react to danger in a timely manner. It could be, therefore, that a face which is in profile but with eyes directed at the participant would elicit more of a response than when the eyes are directed to the side.

6.3.5. Further areas of interest

A recent article by Wolfe and Horowitz (2017) proposed that there are five factors of attentional guidance in visual search: bottom-up, stimulus-driven capture of attention; top-down, goal-driven guidance; guidance based on prior search history; guidance based on the visual scene; and guidance based on the value of items. Whilst the first three of these have been covered extensively by previous preview literature and this thesis, the latter two have not been addressed and so provide areas of potential future research, as discussed below.

The role of guidance based on scenic properties touches upon some of the aforementioned issues relating to ecological validity. In everyday life, we have expectations as to where we might find objects based on both our knowledge of the world and its properties such as gravity (known as syntactic guidance) as well as our own knowledge of where items usually belong, such as expecting to find a book on the bookshelf rather than in the fridge

(semantic guidance). The results of Chapter 2 provide the basis for further research into this area: based on their prior knowledge of where the target was and was not likely to appear, search in Experiment 5 was more efficient when the number of possible target locations was constrained due to the expected location of distractor items. However, if suitably controlled and realistic preview searches could be designed, it would be of interest to see whether preview benefit is disrupted when the target appears in a place that is either syntactically or semantically invalid, e.g. an apple floating in the air or located on the sink.

The value of target items in search is a comparatively new area of research, having only arisen in earnest since the start of the 2010s (Anderson, Laurent, & Yantis, 2011; Anderson & Yantis, 2013; MacLean & Giesbrecht, 2015), therefore the contribution of this field of research to preview research has not yet been explored. Based on our understanding of preview search, though, we may be able to make some predictions on how, or even whether, adding an element of reward will affect efficiency. Firstly, under usual conditions (such as those in the original experiments in Watson & Humphreys (1997)) preview search is already an efficient form of search. It therefore seems unlikely that adding a reward which is compatible with the search task in the first place (e.g. reward when locating a blue item, in the search for a blue target). However, if reward was incompatible, such as reward for locating a red item when the target is blue, then it is likely that this would disrupt the high-capacity memory system, resulting in a diminished preview benefit (unless, of course, the number of previewed items does not exceed 4 items).

6.3.6. Conclusion

The results of this thesis have shown the importance of secondary task load on preview search (Chapter 1); the role of search history and learning in the ability to inhibit distractors in visual search (Chapter 2); the impact of feature anticipation on preview search and factors which may affect search strategy (Chapter 3); and the effect rotation has on the way faces are attended to (Chapter 4). The findings support a multi-channel theory of attention and contribute to the current understanding of how different forms of top-down

guidance of attention (e.g. inhibition or anticipation) may interact to produce differing degrees of efficiency in visual search.

Appendix

Number of participants per paper, by experiment. Average is given at the end of the table.

Paper	Experiment no.	No. of ppt
Allen, Humphreys and Matthews (2008).	Experiment 1	16
Braithwaite and Humphreys (2003).	Experiment 1	16
	Experiment 2	18
	Experiment 3	17
	Experiment 4	13
Braithwaite, Humphreys and Hodsoll (2004).	Experiment 1	17
	Experiment 2	15
Braithwaite, Humphreys, Watson and Hulleman (2005).	Experiment 1	16
	Experiment 2	21
	Experiment 3	23
Donk, and Theeuwes (2001).	Experiment 1	8
	Experiment 2	8
	Experiment 3	8
Donk and Theeuwes (2003).	Experiment 1	12
	Experiment 2	12
	Experiment 3	8
Donk and Verburg (2004).	Experiment 1	12
Gibson and Jiang (2001).	Experiment 1	38
	Experiment 2	18
	Experiment 3	21
Humphreys, Stalmann and Olivers (2004).	Experiment 1	13
	Experiment 2	24
	Experiment 3a	14
	Experiment 3b	14
	Experiment 4	8
Humphreys, Watson and Jolicoeur (2002).	Experiment 1	12
	Experiment 2	12
	Experiment 3	12
	Experiment 4	12
	Experiment 5	7
Kunar, Humphreys and Smith (2003).	Experiment 1	15
Kunar, Humphreys, Smith and Hulleman (2003).	Experiment 1	15
	Experiment 2	15
	Experiment 3	13

	Experiment 4	18
Kunar, Humphreys, Smith and Watson (2003).	Experiment 1	16
	Experiment 2	21
	Experiment 3a	11
	Experiment 3b	6
Olivers and Humphreys (2002).	Experiment 1	19
	Experiment 2	48
	Experiment 3	30
	Experiment 4	21
Olivers and Humphreys (2003).	Experiment 1	13
	Experiment 2	18
	Experiment 3	18
	Experiment 4	20
Olivers, Watson and Humphreys (1999).	Experiment 1	12
	Experiment 2	12
	Experiment 3	12
	Experiment 4	12
	Experiment 5	12
	Experiment 6	18
Pratt, Theeuwes and Donk (2007).	Experiment 1	12
	Experiment 2	12
	Experiment 3	12
Watson and Humphreys (1997).	Experiment 1	12
	Experiment 2	4
	Experiment 3a	12
	Experiment 3b	12
	Experiment 4a	12
	Experiment 4b	12
	Experiment 5	12
	Experiment 6	12
	Experiment 7	8
	Experiment 8	12
	Experiment 9	10
Watson and Humphreys (1998).	Experiment 1	12
	Experiment 2	14
Watson and Humphreys (2000).	Experiment 1	5
	Experiment 2	5
	Experiment 3	3
Average		**14.33**

Bibliography

Agter, F., & Donk, M. (2005). Prioritized selection in visual search through onset capture and color inhibition: evidence from a probe-dot detection task. *Journal of Experimental Psychology: Human Perception and Performance, 31*(4), 722-730.

Al-Aidroos, N., Emrich, S. M., Ferber, S., & Pratt, J. (2012). Visual working memory supports the inhibition of previously processed information: Evidence from preview search. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(3), 643-663.

Allen, H. A., & Humphreys, G. W. (2007). Previewing distracters reduces their effective contrast. *Vision Research, 47*(23), 2992-3000.

Allen, H. A., Humphreys, G. W., & Matthews, P. M. (2008). A neural marker of content-specific active ignoring. *Journal of Experimental Psychology: Human Perception and Performance, 34*(2), 286-297.

Allport, D. A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single channel hypothesis. *The Quarterly Journal of Experimental Psychology, 24*(2), 225-235.

Alvarez, G. A., & Cavanagh, P. (2004). The capacity of visual short-term memory is set both by visual information load and by number of objects. *Psychological Science, 15*(2), 106-111.

Anderson, B. A. & Yantis, S. (2013). Persistence of value-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance, 39*(1), 6-9.

Anderson, B. A., Laurent, P. A. & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences*, *108*(25), 10367-10371.

Anderson, U. S., Perea, E. F., Becker, D. V., Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., & Kenrick, D. T. (2010). I only have eyes for you: Ovulation redirects attention (but not memory) to attractive men. *Journal of Experimental Social Psychology, 46*(5), 804-808.

Aronoff, J., Barclay, A. M., & Stevenson, L. A. (1988). The recognition of threatening facial stimuli. *Journal of Personality and Social Psychology, 54*(4), 647-655.

Atchley, P., Kramer, A. F., & Hillstrom, A. P. (2000). Contingent capture for onsets and offsets: Attentional set for perceptual transients. *Journal of Experimental Psychology: Human Perception and Performance, 26*(2), 594-606.

Awh, E., Barton, B., & Vogel, E. K. (2007). Visual working memory represents a fixed number of items regardless of complexity. *Psychological Science, 18*(7), 622-628.

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics, 55*(5), 485-496.

Bacon, W. F., & Egeth, H. E. (1997). Goal-directed guidance of attention: evidence from conjunctive visual search. *Journal of Experimental Psychology: Human Perception and Performance, 23*(4), 948-961.

Banks, W. P., & Bahber, G. (1977). Color information in iconic memory. *Psychological Review, 84*(6), 536-546.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin, 133*(1), 1-24.

Barrett, D. J., Shimozaki, S. S., Jensen, S., & Zobay, O. (2016). Visuospatial working memory mediates inhibitory and facilitatory guidance in preview search. *Journal of Experimental Psychology: Human Perception and Performance, 42*(10), 1533-1546.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2004). Orienting of attention via observed eye gaze is head-centred. *Cognition, 94*(1), 1-10.

Becker, S. I. (2008). The stage of priming: Are intertrial repetition effects attentional or decisional? *Vision Research, 48*(5), 664-684.

Becker, S. I., & Horstmann, G. (2009). A feature-weighting account of priming in conjunction search. *Attention, Perception, & Psychophysics, 71*(2), 258-272.

Beesley, T., & Shanks, D. R. (2012). Investigating cue competition in contextual cuing of visual search. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(3), 709-725.

Benoni, H., & Tsal, Y. (2010). Where have we gone wrong? Perceptual load does not affect selective attention. *Vision Research, 50*(13), 1292-1298.

Benoni, H., & Tsal, Y. (2013). Conceptual and methodological concerns in the theory of perceptual load. *Frontiers in Psychology, 4,* 522. doi:10.3389/fpsyg.2013.00522

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*(6), 551-565.

Bindemann, M., Burton, A. M., Hooge, I. T., Jenkins, R., & De Haan, E. H. (2005). Faces retain attention. *Psychonomic Bulletin & Review, 12*(6), 1048-1053.

Bindemann, M., Burton, A. M., Langton, S. R., Schweinberger, S. R., & Doherty, M. J. (2007). The control of attention to faces. *Journal of Vision, 7*(10): 15, 1-8.

Blagrove, E., & Watson, D. G. (2010). Visual marking and facial affect: Can an emotional face be ignored? *Emotion, 10*(2), 147-168

Borger, R. (1963). The refractory period and serial choice-reactions. *Quarterly Journal of Experimental Psychology, 15*(1), 1-12.

Brady, T. F., & Chun, M. M. (2007). Spatial constraints on learning in visual search: modeling contextual cuing. *Journal of Experimental Psychology: Human Perception and Performance, 33*(4), 798-815.

Braithwaite, J. J., & Humphreys, G. W. (2003). Inhibition and anticipation in visual search: Evidence from effects of color foreknowledge on preview search. *Attention, Perception, & Psychophysics, 65*(2), 213-237.

Braithwaite, J. J., Humphreys, G. W., & Hodsoll, J. (2003). Color grouping in space and time: evidence from negative color-based carryover effects in preview search. *Journal of Experimental Psychology: Human Perception and Performance, 29*(4), 758-778.

Braithwaite, J. J., Humphreys, G. W., Watson, D. G., & Hulleman, J. (2005). Revisiting preview search at isoluminance: New onsets are not necessary for the preview advantage. *Attention, Perception, & Psychophysics, 67*(7), 1214-1228.

Bratzke, D., Rolke, B., & Ulrich, R. (2009). The source of execution-related dual-task interference: Motor bottleneck or response monitoring? *Journal of Experimental Psychology: Human Perception and Performance, 35*(5), 1413-1426.

Broadbent, D. E. (1952). Listening to one of two synchronous messages. *Journal of Experimental Psychology, 121*(2), 125-127.

Broadbent, D. E. (1953). Noise, paced performance and vigilance tasks. *British Journal of Psychology, 44*(4), 295-303.

Broadbent, D. E. (1958). The Effects of Noise on Behaviour. In D. E. Broadbent, *Perception and communication*, (pp. 81-107). London: Pergamon Press.

Brown, V., Huey, D., & Findlay, J. M. (1997). Face detection in peripheral vision: do faces pop out? *Perception, 26*(12), 1555-1570.

Bruce, V., Valentine, T., & Baddeley, A. (1987). The basis of the 3/4 view advantage in face recognition. *Applied Cognitive Psychology, 1*(2), 109-120.

Cardoso-Leite, P., Kludt, R., Vignola, G., Ma, W. J., Green, C. S., & Bavelier, D. (2015). Technology consumption and cognitive control: Contrasting action video game experience with media multitasking. *Attention, Perception, & Psychophysics*, *78*(1), 218-241

Carlisle, N. B., Arita, J. T., Pardo, D., & Woodman, G. F. (2011). Attentional templates in visual working memory. *Journal of Neuroscience, 31*(25), 9315-9322.

Carlson, J. M., & Aday, J. (2018) In the presence of conflicting gaze cues, fearful expression and eye-size guide attention. *Cognition & Emotion 32*(6), 1178-1188

Carrier, L. M., Rosen, L. D., Cheever, N. A., & Lim, A. F. (2015). Causes, effects, and practicalities of everyday multitasking. *Developmental Review, 35*(1), 64-78.

Chan, L. K., & Hayward, W. G. (2013). Visual search. *Wiley Interdisciplinary Reviews: Cognitive Science, 4*(4), 415-429.

Chelazzi, L., Duncan, J., Miller, E. K., & Desimone, R. (1998). Responses of neurons in inferior temporal cortex during memory-guided visual search. *Journal of Neurophysiology, 80*(6), 2918-2940.

Chen, X., & Zelinsky, G. J. (2006). Real-world visual search is dominated by top-down guidance. *Vision Research, 46*(24), 4118-4133.

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. *The Journal of the Acoustical Society of America, 25*(5), 975-979.

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology, 36*(1), 28-71.

Conci, M., & Müller, H. J. (2012). Contextual learning of multiple target locations in visual search. *Visual Cognition, 20*(7), 746-770.

Conci, M., Sun, L., & Müller, H. J. (2011). Contextual remapping in visual search after predictable target-location changes. *Psychological Research, 75*(4), 279-289.

Corteen, R. S., & Dunn, D. (1974). Shock-associated words in a nonattended message: A test for momentary awareness. *Journal of Experimental Psychology, 102*(6), 1143-1158.

Creamer, L. R. (1963). Event uncertainty, psychological refractory period, and human data processing. *Journal of Experimental Psychology, 66*(2), 187-199.

Damasio, A. R., Tranel, D., & Damasio, H. (1990). Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli. *Behavioural Brain Research, 41*(2), 81-94.

de Fockert, J. W., Rees, G., Frith, C. D., & Lavie, N. (2001). The role of working memory in visual selective attention. *Science, 291*(5509), 1803-1806.

De Renzi, E., Perani, D., Carlesimo, G. A., Silveri, M. C., & Fazio, F. (1994). Prosopagnosia can be associated with damage confined to the right hemisphere—an MRI and PET study and a review of the literature. *Neuropsychologia, 32*(8), 893-902.

Desimone, R. (1991). Face-selective cells in the temporal cortex of monkeys. *Journal of Cognitive Neuroscience, 3*(1), 1-8.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*(1), 193-222.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review, 70*(1), 80-96.

Do-Joon, Y., Woodman, G. F., Widders, D., Marois, R., & Chun, M. M. (2004). Neural fate of ignored stimuli: dissociable effects of perceptual and working memory load. *Nature Neuroscience, 7*(9), 992-1010.

Donk, M., & Theeuwes, J. (2001). Visual marking beside the mark: Prioritizing selection by abrupt onsets. *Attention, Perception, & Psychophysics, 63*(5), 891-900.

Donk, M., & Verburg, R. C. (2004). Prioritizing new elements with a brief preview period: Evidence against visual marking. *Psychonomic Bulletin & Review, 11*(2), 282-288.

Downing, P. E. (2000). Interactions between visual working memory and selective attention. *Psychological Science, 11*(6), 467-473.

Driver IV, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition, 6*(5), 509-540.

Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology, 92*(1), 53-78.

Driver, J., & Spence, C. (1998). Attention and the crossmodal construction of space. *Trends in Cognitive Sciences, 2*(7), 254-262.

Dube, B., Basciano, A., Emrich, S. M., & Al-Aidroos, N. (2016). Visual working memory simultaneously guides facilitation and inhibition during visual search. *Attention, Perception, & Psychophysics, 78*(5), 1232-1244.

Duncan, J. (1980). The locus of interference in the perception of simultaneous stimuli. *Psychological Review, 87*(3), 272-280.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*(3), 433-445.

Duncan, J., Martens, S., & Ward, R. (1997). Restricted attentional capacity within but not between sensory modalities. *Nature, 387*(6635), 808-820.

Egeth, H. E., Virzi, R. A., & Garbart, H. (1984). Searching for conjunctively defined targets. *Journal of Experimental Psychology: Human Perception and Performance, 10*(1), 32-39

Eimer, M. (1998). Does the face-specific N170 component reflect the activity of a specialized eye processor? *Neuroreport, 9*(13), 2945-2948.

Eimer, M. (2000a). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology, 111*(4), 694-705.

Eimer, M. (2000b). The face-specific N170 component reflects late stages in the structural encoding of faces. *Neuroreport, 11*(10), 2319-2324.

Eimer, M. (2000c). Effects of face inversion on the structural encoding and recognition of faces: Evidence from event-related brain potentials. *Cognitive Brain Research, 10*(1), 145-158.

Eimer, M., Van Velzen, J., & Driver, J. (2002). Cross-modal interactions between audition, touch, and vision in endogenous spatial attention: ERP evidence on preparatory states and sensory modulations. *Journal of Cognitive Neuroscience, 14*(2), 254-271.

Eltiti, S., Wallace, D., & Fox, E. (2005). Selective target processing: Perceptual load or distractor salience? *Attention, Perception, & Psychophysics, 67*(5), 876-885.

Emrich, S. M., Ruppel, J. D., Al-Aidroos, N., Pratt, J., & Ferber, S. (2008). Out with the old: Inhibition of old items in a preview search is limited. *Perception & Psychophysics, 70*(8), 1552-1557.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Attention, Perception, & Psychophysics, 16*(1), 143-149.

Eriksen, C. W., & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Attention, Perception, & Psychophysics, 14*(1), 155-160.

Farah, M. J. (1996). Is face recognition 'special'? Evidence from neuropsychology. *Behavioural Brain Research, 76*(1), 181-189.

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is" special" about face perception? *Psychological Review, 105*(3), 482.

Ferreira, V. S., & Pashler, H. (2002). Central bottleneck influences on the processing stages of word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(6), 1187-1194.

Fischer, R., & Plessow, F. (2015). Efficient multitasking: parallel versus serial processing of multiple tasks. *Frontiers in Psychology, 6*(4), 1366-1378.

Fischer, R., & Schubert, T. (2008). Valence processing bypassing the response selection bottleneck? Evidence from the psychological refractory period paradigm. *Experimental Psychology, 55*(3), 203-211.

Fischer, R., Miller, J., & Schubert, T. (2007). Evidence for parallel semantic memory retrieval in dual tasks. *Memory & Cognition, 35*(7), 1685-1699.

Folk, C. L., & Remington, R. W. (1996). When knowledge does not help: Limitations on the flexibility of attentional control. In A. F. Kramer, M. G. H. Coles, & G. D. Logan (Eds.), *Converging operations in the study of visual selective attention,* (pp. 271-295). Washington, DC, US: American Psychological Association.

Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology: Human Perception and Performance, 20*(2), 317-325.

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition & Emotion, 14*(1), 61-92.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130*(4), 681-688.

Fox, E., Russo, R., & Dutton, K. (2002) Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition & Emotion, 16*(3), 355-379.

Friedman-Hill, S. R., & Wolfe, J. M. (1995) Second-order parallel processing: visual search for the odd item in a subset. *Journal of Experimental Psychology: Human Perception and Performance, 21*(2), 531–551.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5*(3), 490-495.

George, N., Evans, J., Fiori, N., Davidoff, J., & Renault, B. (1996). Brain events related to normal and moderately scrambled faces. *Cognitive Brain Research, 4*(2), 65-76.

Gerritsen, C., Frischen, A., Blake, A., Smilek, D. & Eastwood, J. D. (2008). Visual search is not blind to emotion. *Perception & Psychophysics. 70*(5), 1047-1059

Geyer, T., Müller, H. J., & Krummenacher, J. (2006). Cross-trial priming in visual search for singleton conjunction targets: Role of repeated target and distractor features. *Attention, Perception, & Psychophysics, 68*(5), 736-749.

Gibson, B. S., & Jiang, Y. (2001). Visual marking and the perception of salience in visual search. *Perception & Psychophysics, 63*(1), 59-73.

Goh, H. T., Sullivan, K. J., Gordon, J., Wulf, G., & Winstein, C. J. (2012). Dual-task practice enhances motor learning: a preliminary investigation. *Experimental Brain Research, 222*(3), 201-210.

Goolsby, B. A., & Suzuki, S. (2001). Understanding priming of color-singleton search: Roles of attention at encoding and "retrieval". *Attention, Perception, & Psychophysics, 63*(6), 929-944.

Gray, J. A., & Wedderburn, A. A. I. (1960). Shorter articles and notes grouping strategies with simultaneous stimuli. *Quarterly Journal of Experimental Psychology, 12*(3), 180-184.

Halvorson, K. M., & Hazeltine, E. (2015). Do small dual-task costs reflect ideomotor compatibility or the absence of crosstalk? *Psychonomic Bulletin & Review, 22*(5), 1403-1409.

Hampton, C., Purcell, D. G., Bersine, L., Hansen, C. H., & Hansen, R. D. (1989). Probing 'pop-out': Another look at the face-in-the-crowd effect. *Bulletin of the Psychonomic Society, 27*(2), 563-566

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917-923.

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science, 293*(5539), 2425-2430.

Hazeltine, E., & Ruthruff, E. (2006). Modality pairing effects and the response selection bottleneck. *Psychological Research, 70*(6), 504-513.

Hazeltine, E., & Wifall, T. (2011). Searching working memory for the source of dual-task costs. *Psychological Research, 75*(6), 466.

Hazeltine, E., Ruthruff, E., & Remington, R. W. (2006). The role of input and output modality pairings in dual-task performance: Evidence for content-dependent central interference. *Cognitive Psychology, 52*(4), 291-345.

Hillstrom, A. P. (2000). Repetition effects in visual search. *Attention, Perception, & Psychophysics, 62*(4), 800-817.

Hodsoll, J. P., & Humphreys, G. W. (2005). Preview search and contextual cuing. *Journal of Experimental Psychology: Human Perception and Performance, 31*(6), 1346-1357.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience, 3*(1), 80-98.

Hooker, C.I., Paller, K.A., Gitelman, D.R., Parrish, T.B., Mesulam, M.M., & Reber, P.J. (2003). Brain networks for analyzing eye gaze. *Cognitive Brain Research, 17*(1), 406-418.

Huang, L., Holcombe, A. O., & Pashler, H. (2004). Repetition priming in visual search: Episodic retrieval, not feature priming. *Memory & Cognition, 32*(1), 12-20.

Humphreys, G. W., Quinlan, P. T., & Riddoch, M. J. (1989). Grouping processes in visual search: Effects with single-and combined-feature targets. *Journal of Experimental Psychology: General, 118*(3), 258-267.

Humphreys, G. W., Stalmann, B. J., & Olivers, C. (2004). An analysis of the time course of attention in preview search. *Attention, Perception, & Psychophysics, 66*(5), 713-730.

Humphreys, G. W., Watson, D. G., & Jolicœur, P. (2002). Fractionating the preview benefit in search: Dual-task decomposition of visual marking by timing and modality. *Journal of Experimental Psychology: Human Perception and Performance, 28*(3), 640-663.

Hyman, I. E., Boss, S. M., Wise, B. M., McKenzie, K. E. & Caggiano, J. M. (2010). Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. *Applied Cognitive Psychology, 24*(3), 597-607.

Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. *Neuroimage, 15*(2), 353-372.

Janczyk, M., Pfister, R., Hommel, B., & Kunde, W. (2014). Who is talking in backward crosstalk? Disentangling response-from goal-conflict in dual-task performance. *Cognition, 132*(1), 30-43.

Jeffreys, D. A. (1989). A face-responsive potential recorded from the human scalp. *Experimental Brain Research, 78*(1), 193-202.

Jiang, Y., Chun, M. M., & Marks, L. E. (2002). Visual marking: Selective attention to asynchronous temporal groups. Journal of Experimental Psychology: *Human Perception and Performance, 28*(3), 717-732.

Jiménez, L., & Vázquez, G. A. (2011). Implicit sequence learning and contextual cueing do not compete for central cognitive resources. *Journal of Experimental Psychology: Human Perception and Performance, 37*(2), 222-235.

Johnson, D. N., McGrath, A., & McNeil, C. (2002). Cuing interacts with perceptual load in visual search. *Psychological Science, 13*(3), 284-287.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. *Attention and Performance, 21*(1) 187-203.

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics, 43*(4), 346-354.

Kahneman, D. (1970). Remarks on attention control. *Acta Psychologica, 33(3)*, 118-131.

Kamal, M., & Dong, Y. (2017). A cross country analysis of multitasking with technology in academic settings. *MWAIS 2017 Proceedings, 14,* 1-6.

Kaptein, N. A., Theeuwes, J., & Van der Heijden, A. H. C. (1995). Search for a conjunctively defined target can be selectively limited to a color-defined subset of elements. *Journal of Experimental Psychology: Human Perception and Performance, 21*(5), 1053-1068.

Karlin, L., & Kestenbaum, R. (1968). Effects of number of alternatives on the psychological refractory period. *Quarterly Journal of Experimental Psychology, 20*(2), 167-178.

Keele, S. W., & Neill, W. T. (1978). Mechanisms of attention. In Carterette, E., & Friedman, M. (Ed.), *Handbook of Perception: Perceptual Processing*, 3-47. Cambridge, MA, USA: Academic Press,

Klapetek, A., Ngo, M. K., & Spence, C. (2012). Does crossmodal correspondence modulate the facilitatory effect of auditory cues on visual search? *Attention, Perception, & Psychophysics, 74*(6), 1154-1167.

Klapp, S. T., Maslovat, D., & Jagacinski, R. J. (2018). The bottleneck of the psychological refractory period effect involves timing of response initiation rather than response selection. *Psychonomic Bulletin & Review, 32*(1), 1-19.

Klein, R. (1988). Inhibitory tagging system facilitates visual search. *Nature, 334*(6181), 430-431.

Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences, 4*(4), 138-147.

Knudsen, E. I. (2007). Fundamental components of attention. *Annual Review of Neuroscience, 30*(1), 57-78.

Ko, Y. T., & Miller, J. (2014). Locus of backward crosstalk effects on Task 1 in a psychological refractory period task. *Experimental psychology, 61*(1), 30-37.

Koch, I., Lawo, V., Fels, J., & Vorländer, M. (2011). Switching in the cocktail party: exploring intentional control of auditory selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 37*(4), 1140-1156.

Kristjánsson, A. (2006). Simultaneous priming along multiple feature dimensions in a visual search task. *Vision Research, 46*(16), 2554-2570.

Kristjánsson, A. (2009). Independent and additive repetition priming of motion direction and color in visual search. *Psychological Research, 73*(2), 158-166.

Kristjánsson, Á., & Driver, J. (2008). Priming in visual search: Separating the effects of target repetition, distractor repetition and role-reversal. *Vision Research, 48*(10), 1217-1232.

Kristjánsson, A., Wang, D., & Nakayama, K. (2002). The role of priming in conjunctive visual search. *Cognition, 85*(1), 37-52.

Kuehn, S. M., & Jolicoeur, P. (1994). Impact of quality of the image, orientation, and similarity of the stimuli on visual search for faces. *Perception, 23*(1), 95-122.

Kunar, M. A., & Watson, D. G. (2011). Visual search in a multi-element asynchronous dynamic (MAD) world. *Journal of Experimental Psychology: Human Perception and Performance, 37*(4), 1017-1031

Kunar, M. A., Flusberg, S., Horowitz, T. S., & Wolfe, J. M. (2007). Does contextual cuing guide the deployment of attention? *Journal of Experimental Psychology: Human Perception and Performance, 33*(4), 816-831.

Kunar, M. A., Humphreys, G. W., & Smith, K. J. (2003a). History matters: The preview benefit in search is not onset capture. *Psychological Science, 14*(2), 181-185.

Kunar, M. A., Humphreys, G. W., & Smith, K. J. (2003b). Visual change with moving displays: more evidence for color feature map inhibition during preview search. *Journal of Experimental Psychology: Human Perception and Performance, 29*(4), 779-796.

Kunar, M. A., Humphreys, G. W., Smith, K. J., & Hulleman, J. (2003). What is "marked" in visual marking? Evidence for effects of configuration in preview search. *Attention, Perception, & Psychophysics, 65*(6), 982-996.

Kunar, M. A., Humphreys, G. W., Smith, K. J., & Watson, D. G. (2003). When a reappearance is old news: Visual marking survives occlusion. *Journal of Experimental Psychology: Human Perception and Performance, 29*(1), 185-199.

Kunar, M. A., Shapiro, K. L., & Humphreys, G. W. (2006). Top-up search and the attentional blink: A two-stage account of the preview effect in search. *Visual Cognition, 13*(6), 677-699.

Kunar, M. A., Thomas, S. V., & Watson, D. G. (2017). Time-based selection in complex displays: Visual marking does not occur in multi-element asynchronous dynamic (MAD) search. *Visual Cognition, 25*(3), 215-224.

Lachter, J., Forster, K. I., & Ruthruff, E. (2004). Forty-five years after Broadbent (1958): still no identification without attention. *Psychological Review, 111*(4), 880-891.

Langton, S. R., Law, A. S., Burton, A. M., & Schweinberger, S. R. (2008). Attention capture by faces. *Cognition, 107*(1), 330-342.

Langton, S. R., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences, 4*(2), 50-59.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 451-466.

Lavie, N., & Cox, S. (1997). On the efficiency of visual selective attention: Efficient visual search leads to inefficient distractor rejection. *Psychological Science, 8*(5), 395-396.

Lavie, N., & Fox, E. (2000). The role of perceptual load in negative priming. *Journal of Experimental Psychology: Human Perception and Performance, 26*(3), 1038-1045.

Lavie, N., & Torralbo, A. (2010). Dilution: A theoretical burden or just load? A reply to Tsal and Benoni (2010). *Journal of Experimental Psychology: Human Perception and Performance, 36*(6), 1657-1664.

Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Attention, Perception, & Psychophysics, 56*(2), 183-197.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133*(3), 339-356.

Leder, H., & Bruce, V. (2000). When inverted faces are recognized: The role of configural information in face recognition. *The Quarterly Journal of Experimental Psychology: Section A, 53*(2), 513-536.

LeDoux, J. (1998). Fear and the brain: where have we been, and where are we going?. *Biological Psychiatry, 44*(12), 1229-1238.

Lien, M. C., Ruthruff, E., Kouchi, S., & Lachter, J. (2010). Even frequent and expected words are not identified without spatial attention. *Attention, Perception, & Psychophysics, 72*(4), 973-988.

Logan, G. D. (1978). Attention in character-classification tasks: Evidence for the automaticity of component stages. *Journal of Experimental Psychology: General, 107*(1), 32-45.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*(3), 291-308.

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature, 390*(6657), 279-281.

Luck, S. J., & Vogel, E. K. (2013). Visual working memory capacity: from psychophysics and neurobiology to individual differences. *Trends in Cognitive Sciences, 17*(8), 391-400.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces (KDEF). CD ROM from Department of Clinical Neuroscience, *Psychology Section, Karolinska Institutet*, 91-630.

Mack, A., Pappas, Z., Silverman, M., & Gay, R. (2002). What we see: Inattention and the capture of attention by meaning. *Consciousness and Cognition, 11*(4), 488-506.

MacLean, M. & Giesbrecht, B. (2015). Irrelevant reward and selection histories have different influences on task-relevant attentional selection. *Attention, Perception & Psychophysics. 77*, 1515-1528.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*(1), 15-24.

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory & Cognition, 22*(6), 657-672.

Maljkovic, V., & Nakayama, K. (1996). Priming of pop-out: II. The role of position. *Attention, Perception, & Psychophysics, 58*(7), 977-991.

Manginelli, A. A., & Pollmann, S. (2009). Misleading contextual cues: How do they affect visual search? *Psychological Research, 73*(2), 212-221.

Marois, R., & Ivanoff, J. (2005). Capacity limits of information processing in the brain. *Trends in Cognitive Sciences, 9*(6), 296-305.

Martín-Arévalo, E., Kingstone, A., & Lupiáñez, J. (2013). Is “Inhibition of Return” due to the inhibition of the return of attention? *The Quarterly Journal of Experimental Psychology, 66*(2), 347-359.

Maslovat, D., Chua, R., Spencer, H. C., Forgaard, C. J., Carlsen, A. N., & Franks, I. M. (2013). Evidence for a response preparation bottleneck during dual-task performance: effect of a startling acoustic stimulus on the psychological refractory period. *Acta Psychologica, 144*(3), 481-487.

Mavritsaki, E., & Humphreys, G. (2016). Temporal binding and segmentation in visual search: A computational neuroscience analysis. *Journal of Cognitive Neuroscience, 28*(10), 1553-1567.

Mavritsaki, E., Allen, H., & Humphreys, G. (2008). Model based analysis of fMRI-data: applying the sSoTS framework to the neural basic of preview search. *In International Workshop on Attention in Cognitive Systems* (pp. 124-138). Springer, Berlin, Heidelberg.

Mavritsaki, E., Heinke, D., Allen, H., Deco, G., & Humphreys, G. W. (2011). Bridging the gap between physiology and behavior: Evidence from the sSoTS model of human visual attention. *Psychological Review, 118*(1), 3-18

Mavritsaki, E., Heinke, D., Humphreys, G. W., & Deco, G. (2006). A computational model of visual marking using an inter-connected network of spiking neurons: The spiking search over time & space model (sSoTS). *Journal of Physiology: Paris, 100*(1-3), 110-124.

McCann, R. S., & Johnston, J. C. (1989, November). The locus of processing bottlenecks in the overlapping-tasks paradigm. *In Bulliten of the Psychonomic Society, 27*(6), 490-490. Austin, TX: Psychonomic Society Inc.

McCann, R., & Johnston, J. (1992). Locus of the single-channel bottleneck in dual-task interference. *Journal of Experimental Psychology: Human Perception and Performance, 18*(2), 471-484.

McKelvie, S. J. (1995). Emotional expression in upside-down faces: Evidence for configurational and componential processing. *British Journal of Social Psychology, 34*(3), 325-334.

McLeod, P. (1977). A dual task response modality effect: Support for multiprocessor models of attention. *The Quarterly Journal of Experimental Psychology, 29*(4), 651-667.

McLeod, P., Driver, J., & Crisp, J. (1988). Visual search for a conjunction of movement and form is parallel. *Nature, 332*(6160), 154-155.

Mewhort, D. J. K., Campbell, A. J., Marchetti, F. M., & Campbell, J. I. (1981). Identification, localization, and "iconic memory": An evaluation of the bar-probe task. *Memory & Cognition, 9*(1), 50-67.

Mogg, K., & Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behaviour Research and Therapy, 40*(12), 1403-1414.

Moore, C. M., & Egeth, H. (1998). How does feature-based attention affect visual processing? *Journal of Experimental Psychology: Human Perception and Performance, 24*(4), 1296-1305.

Moran, J., & Desimone, R. (1985). Selective attention gates visual processing in the extrastriate cortex. *Frontiers in Cognitive Neuroscience, 229*, 342-345.

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 11*(1), 56-60.

Moray, N. (1969). Listening and attention. Harmondsworth, Middlesex, England: Penguin Books.

Morris, J. S., DeGelder, B., Weiskrantz, L., & Dolan, R. J. (2001). Differential extrageniculostriate and amygdala responses to presentation of emotional faces in a cortically blind field. *Brain, 124*(6), 1241-1252.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: a two-process theory of infant face recognition. *Psychological Review, 98*(2), 164-181.

Müller, H. J., & Mühlenen, A. V. (2000). Probing distractor inhibition in visual search: Inhibition of return. *Journal of Experimental Psychology: Human Perception and Performance, 26*(5), 1591-1605.

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*(2), 315-324.

Nakayama, K., & Silverman, G. H. (1986). Serial and parallel processing of visual feature conjunctions. *Nature, 320*(6059), 264-265.

Nordfang, M., & Wolfe, J. M. (2014). Guided search for triple conjunctions. *Attention, Perception & Psychophysics. 76*(5), 1535–1559

Öhman, A. (2002). Automaticity and the amygdala: Nonconscious responses to emotional faces. *Current Directions in Psychological Science, 11*(2), 62-66.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: a threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381-398.

Olivers, C. N., & Humphreys, G. W. (2002). When visual marking meets the attentional blink: More evidence for top-down, limited-capacity inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 28*(1), 22-35.

Olivers, C. N., & Humphreys, G. W. (2003). Visual marking inhibits singleton capture. *Cognitive Psychology, 47*(1), 1-42.

Olivers, C. N., & Meeter, M. (2006). On the dissociation between compound and present/absent tasks in visual search: Intertrial priming is ambiguity driven. *Visual Cognition, 13(*1), 1-28.

Olivers, C. N., Watson, D. G., & Humphreys, G. W. (1999). Visual marking of locations and feature maps: Evidence from within-dimension defined conjunctions. *The Quarterly Journal of Experimental Psychology: Section A, 52*(3), 679-715.

Olson, I. R., & Chun, M. M. (2002). Perceptual constraints on implicit learning of spatial context. *Visual Cognition, 9*(3), 273-302.

Osman, A., & Moore, C. M. (1993). The locus of dual-task interference: psychological refractory effects on movement-related brain potentials. *Journal of Experimental Psychology: Human Perception and Performance, 19*(6), 1292-1304.

Osugi, T., & Kawahara, J. I. (2013). Attentional set protects visual marking from visual transients. *Quarterly Journal of Experimental Psychology, 66*(1), 69-90.

Osugi, T., & Murakami, I. (2014). Previewing distractors reduces efficiency of visual processing at previewed locations. *Vision Research, 95*(1), 51-60.

Osugi, T., & Murakami, I. (2015). Onset of background dynamic noise attenuates preview benefit in inefficient visual search. *Vision Research, 112*(1), 33-44.

Osugi, T., & Murakami, I. (2017). A drastic change in background luminance or motion degrades the preview benefit. *Frontiers in Psychology, 8*(5), 1252-1272.

Osugi, T., Kumada, T., & Kawahara, J. (2010). Visual marking survives graphical change if meaning is retained. *Attention, Perception, & Psychophysics, 72*(8), 2144-2156.

Paquet, L. (2001). Eliminating flanker effects and negative priming in the flankers task: Evidence for early selection. *Psychonomic Bulletin & Review, 8*(2), 301-306.

Pashler, H. (1989). Dissociations and dependencies between speed and accuracy: Evidence for a two-component theory of divided attention in simple tasks. *Cognitive Psychology, 21*(4), 469-514.

Pashler, H. (1990). Do response modality effects support multiprocessor models of divided attention? *Journal of Experimental Psychology: Human Perception and Performance, 16*(4), 826-842.

Pashler, H. (1994). Dual-task interference in simple tasks: data and theory. *Psychological Bulletin, 116*(2), 220-234.

Pashler, H., & Johnston, J. C. (1989). Chronometric evidence for central postponement in temporally overlapping tasks. *The Quarterly Journal of Experimental Psychology, 41*(1), 19-45.

Pashler, H., Carrier, M., & Hoffman, J. (1993). Saccadic eye movements and dual-task interference. *The Quarterly Journal of Experimental Psychology, 46*(1), 51-82.

Pegna, A. J., Khateb, A., Michel, C. M., & Landis, T. (2004). Visual recognition of faces, objects, and words using degraded stimuli: where and when it occurs. *Human Brain Mapping, 22*(4), 300-311.

Perrett, D. I., Harries, M. H., Bevan, R., Thomas, S., Benson, P. J., Mistlin, A. J., Chitty, A.J., Hietanen, J.K. & Ortega, J. E. (1989). Frameworks of analysis for the neural representation of animate objects and actions. *Journal of Experimental Biology, 146*(1), 87-113.

Perrett, D. I., Hietanen, J. K., Oram, M. W., Benson, P. J., & Rolls, E. T. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 335*(1273), 23-30.

Perrett, D. I., Mistlin, A. J., & Chitty, A. J. (1987). Visual neurones responsive to faces. *Trends in Neurosciences, 10*(9), 358-364.

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., & Jeeves, M. A. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London B: Biological Sciences, 223*(1232), 293-317.

Peters, R. W. (1954). The Effect of High-Pass and Low-Pass Filtering of Side-Tone Upon Speaker Intelligibility (No. JPR-25). *Naval School of Aviation Medicine Pensacola FL*.

Pomplun, M., Reingold, E. M., & Shen, J. (2001). Investigating the visual span in comparative search: The effects of task difficulty and divided attention. *Cognition, 81*(2), 857-867.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*(1), 3-25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. *Attention and Performance: Control of Language Processes, 32*(4), 531-556.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology, 2*(3), 211-228.

Posner, M. I., & Snyder, C. R. (2004) Attention and cognitive control. *Cognitive psychology: Key Readings, 205*(1), 4-15.

Poulton, E. C. (1953). Two-channel listening. *Journal of Experimental Psychology, 46*(2), 91-101.

Poulton, E. C. (1956). Listening to overlapping calls. *Journal of Experimental Psychology, 52*(5), 334-247.

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex, 14*(6), 619-633.

Pratt, J., & Hommel, B. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(5), 835-845.

Pratt, J., Theeuwes, J., & Donk, M. (2007). Offsets and prioritizing the selection of new elements in search displays: More evidence for attentional capture in the preview effect. *Visual Cognition, 15*(2), 133-148.

Puce, A., Allison, T., Bentin, S., Gore, J. C., & McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *The Journal of Neuroscience, 18*(6), 2188-2199.

Purcell, D. G., Stewart, A. L., & Skov, R. B. (1996). It takes a confounded face to pop out of a crowd. *Perception, 25*(9), 1091-1108.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*(3), 849-867.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118*(3), 219-235.

Rees, G., Frith, C. D., & Lavie, N. (1997). Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science, 278*(5343), 1616-1619.

Rees, G., Russell, C., Frith, C. D., & Driver, J. (1999). Inattentional blindness versus inattentional amnesia for fixated but ignored words. *Science, 286*(5449), 2504-2507.

Richard, C. M., Wright, R. D., Ee, C., Prime, S. L., Shimizu, Y., & Vavrik, J. (2002). Effect of a concurrent auditory task on visual search performance in a driving-related image-flicker task. *Human Factors, 44*(1), 108-119.

Ristic, J., & Kingstone, A. (2006). Attention to arrows: Pointing to a new direction. *The Quarterly Journal of Experimental Psychology*, *59*(11), 1921-1930.

Ro, T., Friggel, A., & Lavie, N. (2007). Attentional biases for faces and body parts. *Visual Cognition, 15*(3), 322-348.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science, 12*(1), 94-99.

Rorden, C., & Driver, J. (1999). Does auditory attention shift in the direction of an upcoming saccade? *Neuropsychologia*, *37*(3), 357-377.

Rossion, B. (2008). Picture-plane inversion leads to qualitative changes of face perception. *Acta Psychologica, 128*(2), 274-289.

Ruthruff, E., Johnston, J. C., & Van Selst, M. (2001). Why practice reduces dual-task interference. *Journal of Experimental Psychology: Human Perception and Performance, 27*(1), 3-16.

Ruthruff, E., Miller, J., & Lachmann, T. (1995). Does mental rotation require central mechanisms? *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 552-563.

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: holistic and part-based processes. *Journal of Cognitive Neuroscience, 13*(7), 937-951.

Schmitt, M., Postma, A., & De Haan, E. (2000). Interactions between exogenous auditory and visual spatial attention. *The Quarterly Journal of Experimental Psychology Section A*, *53*(1), 105-130.

Schupp, H. T., Öhman, A., Junghöfer, M., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: an ERP analysis. *Emotion, 4*(2), 189-199.

Sigurdardottir, H. M., Kristjánsson, Á., & Driver, J. (2008). Repetition streaks increase perceptual sensitivity in visual search of brief displays. *Visual Cognition, 16*(5), 643-658.

Smith, M. C. (1969). The effect of varying information on the psychological refractory period. *Acta Psychologica, 30*, 220-231.

Soto, D., Heinke, D., Humphreys, G. W., & Blanco, M. J. (2005). Early, involuntary top-down guidance of attention from working memory. *Journal of Experimental Psychology: Human Perception and Performance, 31*(2), 248-256.

Soto, D., Hodsoll, J., Rotshtein, P., & Humphreys, G. W. (2008). Automatic guidance of attention from working memory. *Trends in Cognitive Sciences, 12*(9), 342-348.

Soto, D., Humphreys, G. W., & Rotshtein, P. (2007). Dissociating the neural mechanisms of memory-based guidance of visual selection. *Proceedings of the National Academy of Sciences, 104*(43), 17186-17191.

Spence, C. (2001). Crossmodal attentional capture: A controversy resolved. In C. Folk, & B. Gibson (Eds.), *Attention, distraction and action: Multiple perspectives on attentional capture*, (pp. 231-262). Amsterdam: Elsevier Science BV.

Spence, C. J., & Driver, J. (1994). Covert spatial orienting in audition: Exogenous and endogenous mechanisms. *Journal of Experimental Psychology: Human Perception and Performance, 20*(3), 555-574.

Spence, C., & Driver, J. (1996). Audiovisual links in endogenous covert spatial attention. *Journal of Experimental Psychology: Human Perception and Performance, 22*(4), 1005-1018.

Spence, C., & Driver, J. (1997). On measuring selective attention to an expected sensory modality. *Attention, Perception, & Psychophysics, 59*(3), 389-403.

Spence, C., Nicholls, M. E., Gillespie, N., & Driver, J. (1998). Cross-modal links in exogenous covert spatial orienting between touch, audition, and vision. *Attention, Perception, & Psychophysics, 60*(4), 544-557.

Spence, C., Pavani, F., & Driver, J. (2000). Crossmodal links between vision and touch in covert endogenous spatial attention. *Journal of Experimental Psychology: Human Perception and Performance*, *26*(4), 1298-1319.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs: General and Applied, 74*(11), 1-14.

Sperling, G. (1970). Model of visual adaptation and contrast detection. *Attention, Perception, & Psychophysics, 8*(3), 143-157.

Störmer, V. S., McDonald, J. J., & Hillyard, S. A. (2009). Cross-modal cueing of attention alters appearance and early cortical processing of visual stimuli. *Proceedings of the National Academy of Sciences, 106*(52), 22456-22461.

Strobach, T., Liepelt, R., Schubert, T., & Kiesel, A. (2012). Task switching: effects of practice on switch and mixing costs. *Psychological Research, 76*(1), 74-83.

Sullivan, L. (1976). Selective attention and secondary message analysis: A reconsideration of Broadbent's filter model of selective attention. *The Quarterly Journal of Experimental Psychology, 28*(2), 167-178.

Sunder, S., & Arun, S. P. (2016). Look before you seek: Preview adds a fixed benefit to all searches. *Journal of Vision, 16*(15), 1-17.

Telford, C. W. (1931). The refractory phase of voluntary and associative responses. *Journal of Experimental Psychology, 14*(1), 1-17.

Theeuwes, J. (1991). Exogenous and endogenous control of attention: The effect of visual onsets and offsets. *Perception & Psychophysics, 49*(1), 83-90.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & psychophysics, 51*(6), 599-606.

Theeuwes, J. (1993). Visual selective attention: A theoretical analysis. *Acta Psychologica, 83*(2), 93-154.

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception and Performance, 20*(4), 799-811.

Theeuwes, J. (1996). Visual search at intersections: An eye-movement analysis. *Vision in Vehicles, 5*, 125-134.

Theeuwes, J. (2013). Feature-based attention: it is all bottom-up priming. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 368*(1628), 20130055.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition, 13*(6), 657-665.

Theeuwes, J., Atchley, P., & Kramer, A. F. (1998). Attentional control within 3-D space. *Journal of Experimental Psychology: Human Perception and Performance, 24*(5), 1476-1490.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *The Quarterly Journal of Experimental Psychology, 37*(4), 571-590.

Tipper, S. P. (1992). Selection for action: The role of inhibitory mechanisms. *Current Directions in Psychological Science, 1*(3), 105-109.

Tipper, S. P., Driver, J., & Weaver, B. (1991). Object-centred inhibition of return of visual attention. *The Quarterly Journal of Experimental Psychology, 43*(2), 289-298.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic bulletin & review*, *9*(2), 314-318.

Tombu, M. N., Asplund, C. L., Dux, P. E., Godwin, D., Martin, J. W., & Marois, R. (2011). A unified attentional bottleneck in the human brain. *Proceedings of the National Academy of Sciences, 108*(33), 13426-13431.

Tong, F., & Nakayama, K. (1999). Robust representations for faces: evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 25*(4), 1016-1025.

Treisman, A. (1986). Features and objects in visual processing. *Scientific American, 255*(5), 114-125.

Treisman, A. M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12*(4), 242-248.

Treisman, A. M. (1964a). Monitoring and storage of irrelevant messages in selective attention. *Journal of Verbal Learning and Verbal Behavior, 3*(6), 449-459.

Treisman, A. M. (1964b). Verbal cues, language, and meaning in selective attention. *The American Journal of Psychology, 77*(2), 206-219.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12*(1), 97-136.

Treisman, A., & Sato, S. (1990). Conjunction search revisited. *Journal of Experimental Psychology: Human Perception and Performance, 16*(3), 459-478.

Treisman, A., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology, 14*(1), 107-141.

Treue, S., & Maunsell, J. H. (1996). Attentional modulation of visual motion processing in cortical areas MT and MST. *Nature, 382*(6591), 539-541.

Tsal, Y., & Benoni, H. (2010). Diluting the burden of load: perceptual load effects are simply dilution effects. *Journal of Experimental Psychology: Human Perception and Performance, 36*(6), 1645-1657.

Turk-Browne, N. B., Yi, D. J., & Chun, M. M. (2006). Linking implicit and explicit memory: common encoding factors and shared representations. *Neuron, 49*(6), 917-927.

Underwood, G., Chapman, P., Bowden, K., & Crundall, D. (2002). Visual search while driving: skill and awareness during inspection of the scene. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(2), 87-97.

van Hooff, J. C., Crawford, H., & Van Vugt, M. (2011). The wandering mind of men: ERP evidence for gender differences in attention bias towards attractive opposite sex faces. *Social Cognitive and Affective Neuroscience, 6*(4), 477-485.

Van Selst, M., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *The Quarterly Journal of Experimental Psychology, 47*(3), 631-650.

Volkmann, F. C., Riggs, L. A., & Moore, R. K. (1980). Eyeblinks and visual suppression. *Science, 207*(4433), 900-902.

von Mühlenen, A., Watson, D., & Gunnell, D. O. (2013). Blink and you won't miss it: The preview benefit in visual marking survives internally generated eyeblinks. *Journal of Experimental Psychology: Human Perception and Performance, 39*(5), 1279-1293.

von Wright, J. (1968). Selection in visual immediate memory. *The Quarterly Journal of Experimental Psychology, 20*(1), 62-68.

Vroomen, J., Bertelson, P., & De Gelder, B. (2001). The ventriloquist effect does not depend on the direction of automatic visual attention. *Perception & psychophysics*, *63*(4), 651-659.

Vuilleumier, P. (2000). Faces call for attention: evidence from patients with visual extinction. *Neuropsychologia, 38*(5), 693-700.

Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: evidence from functional neuroimaging. *Neuropsychologia, 45*(1), 174-194.

Vuilleumier, P., Henson, R. N., Driver, J., & Dolan, R. J. (2002). Multiple levels of visual object constancy revealed by event-related fMRI of repetition priming. *Nature Neuroscience, 5*(5), 491-503.

Wada, Y., & Yamamoto, T. (2001). Selective impairment of facial recognition due to a haematoma restricted to the right fusiform and lateral occipital region. *Journal of Neurology, Neurosurgery & Psychiatry, 71*(2), 254-257.

Wang, D., Kristjansson, A., & Nakayama, K. (2005). Efficient visual search without top-down or bottom-up guidance. *Perception & Psychophysics, 67*(2), 239-253.

Ward, L. M. (1994). Supramodal and modality-specific mechanisms for stimulus-driven shifts of auditory and visual attention. *Canadian Journal of Experimental Psychology*, *48*(2), 242-259.

Ward, L. M., Mcdonald, J. J., & Lin, D. (2000). On asymmetries in cross-modal spatial attention orienting. *Perception & Psychophysics*, *62*(6), 1258-1264.

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review, 104*(1), 90-103.

Watson, D. G., & Humphreys, G. W. (1998). Visual marking of moving objects: A role for top-down feature-based inhibition in selection. *Journal of Experimental Psychology: Human Perception and Performance, 24*(3), 946-963.

Watson, D. G., & Humphreys, G. W. (2000). Visual marking: Evidence for inhibition using a probe-dot detection paradigm. *Attention, Perception, & Psychophysics, 62*(3), 471-481.

Watson, D. G., & Humphreys, G. W. (2002). Visual marking and visual change. *Journal of Experimental Psychology: Human Perception and Performance, 28*(2), 379-395.

Watson, D. G., & Kunar, M. A. (2010). Visual marking and change blindness: Moving occluders and transient masks neutralize shape changes to ignored objects. *Journal of Experimental Psychology: Human Perception and Performance, 36*(6), 1391-1402.

Watson, D. G., & Kunar, M. A. (2012). Determining the capacity of time-based selection. *Journal of Experimental Psychology: Human Perception and Performance, 38*(2), 350-367.

Welford, A. T. (1952). The 'psychological refractory period' and the timing of high-speed performance—a review and a theory. *British Journal of Psychology, 43*(1), 2-19.

Whalen, P. J., Bush, G., McNally, R. J., Wilhelm, S., McInerney, S. C., Jenike, M. A., & Rauch, S. L. (1998). The emotional counting Stroop paradigm: a functional magnetic resonance imaging probe of the anterior cingulate affective division. *Biological Psychiatry, 44*(12), 1219-1228.

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science, 306*(5704), 2061-2061.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1988). *Cognitive Psychology and Emotional Disorders*. Oxford, England: John Wiley & Sons.

Wolfe, J. M., Cave, K. R., & Franzel, S. L. (1989). Guided search: an alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human perception and performance, 15*(3), 419-426.

Wolfe, J. M., & Pokorny, C. W. (1990). Inhibitory tagging in visual search: A failure to replicate. *Attention, Perception, & Psychophysics, 48*(4), 357-362.

Wolfe, J. M. (1994). Guided search 2.0 A revised model of visual search. *Psychonomic Bulletin & Review, 1*(2), 202-238.

Wolfe, J. M., & Gancarz, G. (1996). Guided search 3.0 basic and clinical applications of vision science. *Basic and Clinical Applications of Vision Science,* V. Lakshminarayanan, Ed. Dordrecht, Netherlands: Kluwer Academic, 189-192.

Wolfe, J. M., Butcher, S. J., Lee, C., & Hyle, M. (2003). Changing your mind: on the contributions of top-down and bottom-up guidance in visual search for feature singletons. J*ournal of Experimental Psychology: Human Perception and Performance, 29*(2), 483-491.

Wolfe, J. M., Horowitz, T. S., Kenner, N., Hyle, M., & Vasan, N. (2004). How fast can you change your mind? The speed of top-down guidance in visual search. *Vision Research, 44*(12), 1411-1426.

Wolfe, J. M. (2007). Guided search 4.0. Integrated models of cognitive systems, In W. D. Gray (Ed.), *Series on cognitive models and architectures. Integrated models of cognitive systems* (99-119). New York, NY, US: Oxford University Press.

Wolfe, J. M., & Horowitz, T. S. (2017). Five factors that guide attention in visual search. *Nature Human Behaviour*, *1*(3), Article number: 0058.

Woodman, G. F., & Arita, J. T. (2011). Direct electrophysiological measurement of attentional templates in visual working memory. *Psychological Science, 22*(2), 212-215.

Woodman, G. F., & Luck, S. J. (2004). Visual search is slowed when visuospatial working memory is occupied. *Psychonomic Bulletin & Review, 11*(2), 269-274.

Woodman, G. F., Luck, S. J., & Schall, J. D. (2007). The role of working memory representations in the control of attention. *Cerebral Cortex, 17*(1), 118-124.

Woodman, G. F., Vogel, E. K., & Luck, S. J. (2001). Visual search remains efficient when visual working memory is full. *Psychological Science, 12*(3), 219-224.

Yamauchi, K., Osugi, T., & Murakami, I. (2017). Attentional capture to a singleton distractor degrades visual marking in visual search. *Frontiers in Psychology, 8*, Article number: 801.

Yantis, S. (1993). Stimulus-driven attentional capture and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 19*(3), 676-681.

Yantis, S., & Egeth, H. E. (1999). On the distinction between visual salience and stimulus-driven attentional capture. *Journal of Experimental Psychology: Human Perception and Performance, 25*(3), 661-676.

Yantis, S., & Hillstrom, A. P. (1994). Stimulus-driven attentional capture: evidence from equiluminant visual objects. *Journal of Experimental Psychology: Human perception and Performance, 20*(1), 95-107.

Yantis, S., & Johnson, D. N. (1990). Mechanisms of attentional priority. *Journal of Experimental Psychology: Human Perception and Performance*, *16*(4), 812-825.

Yantis, S., & Jones, E. (1991). Mechanisms of attentional selection: Temporally modulated priority tags. *Attention, Perception, & Psychophysics, 50*(2), 166-178.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: voluntary versus automatic allocation. *Journal of Experimental Psychology: Human perception and performance, 16*(1), 121-134.

Yi, D. J., Woodman, G. F., Widders, D., Marois, R., & Chun, M. M. (2004). Neural fate of ignored stimuli: dissociable effects of perceptual and working memory load. *Nature Neuroscience, 7*(9), 992-996.

Yigit-Elliott, S., Palmer, J., & Moore, C. (2012). Understanding the failures of selective attention: The flanker congruency effect is consistent with failures of selection not perceptual interactions. *Journal of Vision, 12*(9), 388-388.

Zellin, M., Conci, M., von Mühlenen, A., & Müller, H. J. (2011). Two (or three) is one too many: testing the flexibility of contextual cueing with multiple target locations. *Attention, Perception, & Psychophysics, 73*(7), 2065-2076

Zellin, M., von Mühlenen, A., Müller, H. J., & Conci, M. (2014). Long-term adaptation to change in implicit contextual learning. *Psychonomic Bulletin & Review, 21*(4), 1073-1079.

Zellin, M., von Mühlenen, A., Müller, H. J., & Conci, M. (2014). Long-term adaptation to change in implicit contextual learning. *Psychonomic Bulletin & Review, 21*(4), 1073-1079.

Zohary, E., & Hochstein, S. (1989). How serial is serial processing in vision? *Perception, 18*(2), 191-200.