Author(s): Elisabeth Blagrove and Derrick G. Watson
Article Title: Visual Marking and Facial Affect: Can an Emotional Face Be Ignored?
Year of publication: 2010
Link to published article:
http://dx.doi.org/10.1037/a0017743

Visual Marking and facial affect: Can an emotional face be ignored?

Elisabeth Blagrove

and

Derrick G. Watson

University of Warwick, UK

Address for correspondence:
Derrick G. Watson
Department of Psychology
University of Warwick
Coventry CV4 7AL
UK
Telephone: +44 (0)2476 522763
Email: d.g.watson@warwick.ac.uk

Keywords: visual marking, emotion, face processing, expression, visual search

Abstract

Previewing a set of distractors allows them to be ignored in a subsequent visual search task (D. G. Watson & G. W. Humphreys, 1997). Seven experiments investigated whether this preview benefit can be obtained with emotional faces and whether negative and positive facial expressions differ in the extent to which they can be ignored. Experiments 1-5 examined the preview benefit with neutral, negative and positive previewed faces. These results showed that a partial preview benefit occurs with face stimuli, but that the valence of the previewed faces has little impact. Experiments 6 and 7 examined the time course of the preview benefit with valenced faces. These showed that negative faces were more difficult to ignore than positive faces, but only at short preview durations. Furthermore, a full preview benefit was not obtained with face stimuli even when the preview duration was extended up to 3 s. The findings are discussed in terms of the processes underlying the preview benefit, their ecological sensitivity, and the role of emotional valence in attentional capture and guidance.

Introduction

The importance of the face and facial expression is emphasized by a body of research that points to its special status within human visual processing (e.g. Tsao & Livingstone, 2008; Vuilleumier, & Pourtois, 2007; Kanwisher, McDermott & Chun, 1997; Ellis, Bruce & De Schonen, 1992; see Calder & Young, 2005, for a recent review of face processing research). This does not appear to be limited to rapid and efficient processing at the focal point of attention in the visual system, (e.g., Cooper & Langton, 2006, Eimer & Holmes, 2002; 2007; Hairiri et al., 2002) but extends to processing outside conscious awareness, when attention is purposefully directed elsewhere (e.g. Stenberg, Wilking & Dahl, 1998; Morris, Öhman & Dolan, 1998; Mogg & Bradley, 1999; Eastwood, Smilek & Merikle, 2003; Vuilleumier & Schwartz, 2001; Vuilleumier, Armony, Driver, & Dolan, 2001). Moreover, this preferential processing applies to a broad range of facial stimuli (e.g. Kanwisher et al., 1997; Sagiv & Bentin, 2001), even when the face stimulus is simplified into line drawings (e.g. Öhman, Lundqvist, & Esteves, 2001) or a highly schematic representation (e.g. Eastwood, Smilek & Merikle, 2001; Fox et al., 2000; White, 1995; Nothdurft, 1993).

Taken as a whole, the apparent breadth and flexibility of this face prioritization mechanism is highly likely to be adaptive, not only due to the high-level social significance of face and facial expression processing, but also its potential relevance to an organism’s survival. The adaptive value of this face prioritization mechanism is also signaled by its ability to distinguish between qualitatively different social signals. For example, expressions that signal potential threat to an individual (i.e. expressions of anger, fear or distress), are processed faster than either emotionally neutral faces or those displaying positive affect (e.g. Eastwood et al., 2001; Hansen & Hansen, 1988, Hampton, Purcell, Bersine, Hansen & Hansen, 1989; Fox et al., 2000; Öhman et al., 2001).

Much of the previous research in this area has focused on the ability of negative valenced stimuli (particularly faces) to efficiently attract attention to themselves, within the visual search paradigm (e.g. Hansen & Hansen, 1988; Hampton et al, 1994; Purcell, Stewart & Skov, 1996; Eastwood et al., 2001). This methodology is particularly suited to evaluating the differential ability of valenced stimuli to guide or attract attention (Eastwood et al., 2001) in that, the ease of detecting different valenced targets embedded amongst distractors can be directly compared via their RT-display size search slopes (Smilek, Eastwood & Merikle; 2000). There is an obvious adaptive advantage to the efficient detection of stimuli that signify threat. However, it is less obvious why negatively valenced stimuli might continue to dominate selective attention if further processing indicates that they are irrelevant to the current goals of the observer (or currently pose no realistic threat). This would be particularly true when explicit instruction is given to attend to another aspect of a task.

Nonetheless, a number of studies using cueing (e.g. Georgiou et al., 2005; Fox, Russo, Bowles & Dutton, 2001; Fox, Russo & Dutton, 2002), flanker (e.g., Fenske & Eastwood, 2003), and other paradigms (e.g. Eastwood et al., 2003; Vuilleumier & Schwartz, 2001) suggest that a negative affect superiority persists even when the affective nature of the stimuli is irrelevant to the task. For example, Fenske and Eastwood (2003) reported a significantly reduced flanker compatibility effect when negatively valenced faces were displayed, in comparison with positive affective stimuli, which, in turn, was abolished once the stimuli were altered to disrupt facial affect. Similarly, Eastwood et al. (2003) found it took longer to count the component features of schematic faces when these were presented as part of a negative face, in comparison with both positive and neutral faces. However, when faces were inverted to prevent holistic processing (Farah, Tanaka, & Drain, 1995; Yin, 1969), differences between neutral, positive and negative faces disappeared, despite preserving features identical to the upright faces.

In general terms, any emotionally valenced stimuli appear difficult to ignore (e.g. Pratto & John, 1991; Stenberg et al., 1998) and unsurprisingly, considering their adaptive salience, faces seem particularly resistant to suppression (e.g. Lavie, Ro & Russell, 2003). Furthermore, Lavie et al. (2003) suggested that distractor faces may require mandatory processing, providing an exception to perceptual load theory (Lavie, 1995, 2000), where successful task performance relies upon the ability to ignore distractors. These findings suggest that the processing of emotional valence in upright faces is automatic and is unlikely to be modified by top-down goals.

Overall, the attentional capture and engagement properties of negatively valenced stimuli appear robust and wide-ranging. In contrast, much less is known about the converse: whether it is possible to deliberately ignore potentially attention-grabbing stimuli over time, for example actively suppressing facial or valenced distractors.

Time-based visual selection

Previous work has shown that time of appearance can be used as a selection cue. In particular, observers are able to ignore old stimuli that have been previewed and selectively attend to new items that appear at a later point in time – the preview benefit (Watson & Humphreys, 1997, 1998). Typically in the preview paradigm, one set of irrelevant to-be-ignored distractors is presented for 1 second before the remaining search items. The target, when present, appears in the second set of items.

The participant’s task is to try to ignore the first set of stimuli and search through the second set to detect the target. Search efficiency in the preview condition can be assessed by comparing performance with a full element baseline (FEB) in which all the items appear simultaneously and a half element baseline (HEB) which consists of only the second set of items from the preview condition.

Watson and Humphreys (1997) found that search in the preview condition matched that of the HEB and was reliably more efficient than that in the FEB. Thus, observers appeared to be able to restrict their search to the new items. Several theories have emerged to account for the preview benefit. These include: the top-down limited capacity inhibition of the old stimuli (Visual Marking; Watson & Humphreys, 1997; for an overview see Watson, Humphreys & Olivers, 2003), automatic capture by the abrupt onsets associated with the new items (Donk & Theeuwes, 2001, 2003), and the segregation and selective attention to temporally distinct groups (Jiang, Chun & Marks, 2002).

Purpose of the current study

The current study addressed three main questions: Firstly, we aimed to establish whether observers can effectively ignore old (previewed) face stimuli. Given the numerous reasons why facial stimuli are important to us, it is quite possible that faces simply cannot be ignored. Second, was to determine whether facial valence influences the ability to ignore faces. If negative stimuli are particularly potent within the attentional system, then they might be much more difficult to ignore than positively valenced stimuli. Finally, we were interested in whether the typical advantage for negative stimuli (i.e., as search targets) would persist under temporal selection conditions.

Throughout the present work, we used schematic face stimuli as opposed to more realistic line drawings or photographic stimuli. For the initial establishment of the basic properties of time-based selection with faces, these appeared to be the most appropriate stimuli. Given that schematic faces are relatively straightforward to control in terms of their consistent basic features (e.g., Öhman et al., 2001), disambiguity of expression (e.g., Fox et al., 2000) and lack of potential perceptual confounds, such as luminance differences or distinguishing features (see Purcell et al., 1996), this type of stimulus seemed particularly suitable for the experimental manipulation required (see also Eastwood et al., 2001). Considering then, that schematic face stimuli effectively communicate their emotional content (e.g., Aronoff, Barclay & Stevenson, 1988; McKelvie, 1973), and demonstrate equivalent neural correlates to photographed faces (Sagiv & Bentin, 2001), these benefits render them most appropriate for use in the present work.

Experiment 1: Preview Search with Valenced Targets and Neutral Distractors

Experiment 1 examined preview search for positively or negatively valenced schematic face targets amongst neutral face distractors. These types of stimuli are known to produce a negative valence advantage in standard visual search tasks (e.g, Eastwood et al., 2001). Thus Experiment 1 served to establish whether a basic preview benefit occurred with face stimuli, and whether the usual advantage for negative faces would persist during time-based selection conditions.

Method

Participants. Eighteen students at the University of Warwick (16 female, 2 male) participated in this study, either for payment or course credit. Participants were aged between 18 and 21 years (m=19.72 years), and 17 were right handed. All participants self-reported normal or corrected to normal vision.

Stimuli & Apparatus. A Gateway GP6 400 computer was used to present all displays and record participant responses in this and subsequent experiments. Stimuli were displayed on a 17 inch Gateway VX 700 monitor, with 800 x 600 pixels resolution and 75 Hz refresh rate, positioned at eye-level and at a viewing distance of approximately 60 cm. Stimuli were essentially the same as those used by Eastwood et al., (2001), and similar to those in a number of previous studies (i.e., Fox et al., 2000; Nothdurft, 1993; White, 1995; Horstmann, 2007). All stimuli were drawn in light grey (RGB values = 200, 200, 200) against a black background. Targets consisted of positive and negative valenced stimuli and distractors had a neutral expression (see Figure 1). All face stimuli had a diameter of 13 mm, subtending a visual angle of approximately 1.2°

Search displays were generated by randomly positioning items within an invisible 6 x 6 matrix with an inter-element display spacing of 75 pixels (approximately 29.25 mm). Stimulus positions were then jittered by up to +/- 4 pixels in both x and y axes. HEB displays consisted of display sizes of 2, 4, 6 and 8, divided equally between the right and left sides of the screen, with a valenced target (positive or negative) replacing one of the neutral distractors. The target was displayed equally to the left or right of the midline. FEB and Preview displays (i.e. the final search array in the preview condition) consisted of total display sizes of 4, 8, 12 and 16, with a valenced target, when present, replacing a distractor. On catch trials, no target face was present.

Design and Procedure. The experiment was conducted in a dimly lit, sound attenuated room and took approximately 1 hour to complete. The experiment was based on a 3 (Condition: HEB, FEB, Preview) x 4 (Display size) x 2 (Target Valence: positive or negative) within-subjects design. Each search condition was run in a separate block of 160 experimental trials with a further 16 catch trials, where no target was present. Within a block, equal numbers of negative and positive targets were presented, at each display size. On half the number of search trials, the target was on the left and on the remainder, on the right. Targets were not presented in the centre two columns of the matrix (i.e., were only presented in columns 1, 2, 5 & 6), to ensure that they could be easily distinguished from the midline of the display (and RTs were therefore not influenced by difficulty in differentiating between the sides of the screen). Trial order was randomized within a block and the order of search conditions was fully counterbalanced. Each participant completed one block of trials per search condition, with a practice block of 20 trials preceding each condition.

A trial in the HEB and FEB conditions consisted of a blank screen (1000 ms), followed by a light grey central fixation dot (2mm x 2mm) for 1000 ms, followed by the search display. The preview condition was similar, except that half of the distractors were presented for 1000 ms before the second set which contained the target when present (see Figure 2). Participants were asked to locate an “odd-one-out” target and indicate whether it was to the left or the right of the display center by pressing the Z or M key respectively, or to make no response if the target was absent. The fixation dot remained visible throughout the trial and participants were asked to remain fixated until the final search display appeared. In the preview search condition, participants were instructed to ignore the first display (which contained distractors only), and to search through the subsequently added new items, which would contain the target (when present).

In all conditions, the search display remained on screen until the participant responded or for 6000 ms, after which the next trial began. If an error was made, or no response was given when a target was presented, feedback was given in the form of a short tone (1000 Hz, 500 ms).

Results

Reaction Time Data: All RTs < 150 ms were discarded and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. Overall mean correct RTs are shown in Figures 3a and 3b, with search slopes statistics presented in Table 1.

As in previous research on the preview benefit, search slopes were plotted and calculated using the same display sizes as for the FEB. This procedure gives the values that would be expected if observers were able to fully ignore the old items in the preview condition, and enables direct comparison of the preview condition with both baseline conditions (i.e. HEB and FEB). An ANOVA was first conducted including all three conditions (HEB, FEB, Preview), in order to confirm that there was a difference in performance across the three versions of the search task. Additional follow-up ANOVAs (comparing the Preview condition with the FEB and Preview condition with the HEB individually) were then conducted to determine the extent to which a preview benefit occurred. A full preview benefit would be indicated if performance in the preview condition differed from the FEB, but not from the HEB. In contrast, no preview benefit would be indicated if the preview differed from the HEB, but not from the FEB (see Watson & Humphreys, 1997, for further details).

Accordingly, full evaluation of performance in the preview condition was conducted via ANOVA for all search conditions followed by planned comparisons between conditions.

HEB vs FEB vs Preview Condition. Mean correct RTs were analyzed using a 3 (condition) x 4 (display size) x 2 (target valence) within-subjects ANOVA. There were highly significant main effects of Condition, $F(2,34)=30.45$, $MSE= 52756.72$, $p<.001$, Display Size, $F(3,51)= 157.57$, $MSE= 23572.49$, $p<.001$, and Target Valence, $F(1,17)= 86.29$, $MSE= 39107.67$, $p<.001$. Overall RTs were longest in the FEB and shortest in the HEB, increased as display size increased, and were shorter for negative than for positive valence targets.

There were also significant Condition x Target, $F(2,34)=9.57$, $MSE= 10795.76$, $p<.005$) and Target x Display Size, $F(3, 51)=27.71$, $MSE= 6801.93$, $p< .001$) interactions, indicating that the overall effect of valence differed across condition (impairing search efficiency more when searching for a positive target in the FEB and Preview condition, compared with the HEB), and that display size had a smaller effect on negative valence targets than on positive valence targets (the search slopes for negative targets were shallower). Both the Condition x Display Size, and the Condition x Target x Display Size interaction, proved unreliable, both Fs < 1.25, ps > 0.28.

HEB versus FEB. All three main effects proved significant. RTs were shorter overall in the HEB than in the FEB, $F(1,17)=46.67$, $MSE= 64418.90$, $p<.001$, and were shorter for negative targets than positive, $F(1,17)= 84.61$, $= 28863.57$, $p<.001$, and increased as Display Size increased, $F(3,51)= 119.81$, $MSE= 19933.36$, $p<.001$. There were also significant Target Valence x Display Size, $F(3, 51)=12.24$, $MSE= 8308.15$, $p< .001$, and Condition x Target, $F(1,17)= 14.12$, $MSE= 13802.56$, $p<.005$, interactions, with RTs increasing more steeply with increasing display size for positively valenced targets, and more in the FEB than the HEB. Both the Condition x Display Size, and the Condition x Target Valence x Display Size, interaction were not significant, both *F*s < 1.74, *p*s > .16.

FEB versus Preview Condition. All three main effects proved significant. RTs were faster in the Preview Condition than in the FEB, *F*(1,17)=33.00, *MSE*= 48148.64, *p*<.001, negative targets were detected more quickly than positive, *F*(1,17)= 83.45, *MSE*= 34189.28, *p*<.001 and RTs increased as Display Size increased, *F*(3,51)= 143.03, *MSE*= 18866.17, *p*<.001. There was also a significant Target x Display Size, *F*(3, 51)=21.18, *MSE*= 7532.27, *p*< .001, and Condition x Target interaction, *F*(1,17)=9.01, *MSE*= 11015.17, *p*<.05, indicating that, search was more efficient for the negative target and that the overall difference between positive and negative targets was greater in the FEB condition. Neither the Condition x Display Size, nor the Condition x Display Size x Target, interaction reached significance, both *F*s < 1.

HEB versus Preview Condition. All three main effects were significant: RTs were faster overall in the HEB; Condition, *F*(1,17)=4.90, *MSE*= 45702.61, *p*<.05, increased with Display Size, *F*(3,51)= 139.06, *MSE*= 16920.13, *p*<.001, and negative targets were detected faster than positive, *F*(1,17)= 50.97, *MSE*= 25958.26, *p*<.001. The difference between positive and negative targets increased with Display Size, *F*(3,51)=32.39, *MSE*= 3755.62, *p*<.001. However, no other interactions reached significance, all *F*s < 2.12, *p*s > 0.16.

Effects of valence in each condition. In order to determine whether there was a negative target advantage in all conditions separate 2 (Target Valence) x 4 (Display Size) repeated measures ANOVAs were calculated for the HEB, FEB and Preview condition. This revealed that negative valenced targets were detected faster overall than positive targets in all three conditions, HEB, *F*(1,17)= 40.58, *MSE*=15494.75, *p*<.001, FEB, *F*(1,17)= 73.91, *MSE*=27171.38, *p*<.00, Preview condition, *F*(1,17)= 52.35, *MSE*=18033.07, *p*<.001. RTs also increased as display size increased, HEB, *F*(3,51)=97.95, *MSE*=10518.63, *p*<.001, FEB, *F*(3,51)=, *MSE*=17156.84, *p*<.001, Preview condition, *F*(3,51)=102.27, *MSE*=13046.39, *p*<.001. Finally, the Target Valence x Display size conditions were significant for all three conditions indicating that search slopes for negative targets were shallower (search rate was faster) for negative targets than for positive targets: HEB, *F*(3,51)=9.27, *MSE*=7570.60, *p*<.001, FEB, *F*(3,51)=6.06, *MSE*=5924.48, *p*<.005, Preview Condition, *F*(3,51)=17.84, *MSE*=5291.26, *p*<.001.

Error Data. Mean percentage errors are shown in Table 2. On search trials, errors were low overall (1.75%) and were logarithmically transformed in order to avoid compression issues. These transformed data were then analyzed with a 3 (Condition) x 4 (Display Size) x 2 (Target Valence) repeated measures ANOVA. There was a marginally significant main effect of Target Valence, *F*(1,17)=4.15, *MSE* =0.16, *p*=.06, with more errors made when searching for a positive target. There was also a significant Target Type x Display Size interaction, *F*(3,51)=4.16, *MSE*= 0.09, *p*< .05, indicating that errors increased more with Display Size for positive valence targets. No other main effects or their interaction reached significance, all *F*s < 1.45, *p*s > .20.

Overall error rate on catch trials was 9.38%. These data were analyzed with a 3 (Condition) x 4 (Display Size) repeated measures ANOVA, and showed a significant main effect of Display Size, *F*(3,51)=8.48, *MSE*=194.21, *p*<.001. The main effect of Condition and the Condition x Display Size interaction, failed to reach significance, both *F*s < 1.18, *p*s > .32.

Discussion

Experiment 1 aimed to explore the efficiency of preview search with facial stimuli. The first finding was that the typical negative face superiority effect was obtained (e.g., Eastwood et al., 2001; Fox et al., 2000) across all conditions, measured both in terms of overall RTs and search slopes. According to the visual marking account of the preview benefit, ignoring old distractors requires the top-down commitment of attentional resources and is capacity limited (Watson & Humphreys, 1997). Thus, it might have been expected that the search advantage for negatively valenced stimuli would have been reduced in the preview search condition, due to the commitment of attentional resources elsewhere. However, this did not appear to be the case, with a strong RT advantage for negative targets present, even in the preview condition (see below for rationale in evaluating preview benefit using RT and search slope measures). This finding supports the notion that the detection of threat stimuli is mediated via a relatively low level or automatic set of processes (e.g., Vuilleumier et al., 2001, LeDoux, 1996; Hansen & Hansen, 1988; Öhman, 1993; Mogg & Bradley, 1999).

The second finding relates to whether a preview benefit would be obtained with facial stimuli. Typically, the preview benefit is indicated by both a reduction in search slope and overall RTs, relative to a FEB in which there is no opportunity to ignore any of the old items. Considering search slopes first, slopes in the preview condition did not differ from either baseline. Moreover, search slopes in the HEB and FEB were statistically equivalent. This suggests that detecting the target became relatively easier (reducing the search slope) as display size increased, most likely because as search displays became more crowded, the contrast between the odd-one-out target and the background distractors became more salient (e.g., Wolfe, Butcher, Lee & Hyle, 2003; Nothdurft, 2001; Bravo & Nakayama, 1992). Here this effect would thus render the search slope measure unreliable in terms of indicating a preview benefit.

In contrast, based on the second measure of preview performance (overall RTs), responses in the preview condition were reliably faster than in the FEB, but slower than the HEB. This suggests that a partial, although not complete, preview benefit was obtained when trying to ignore face stimuli with a neutral expression (see Hodsoll & Humphreys, 2005, and Braithwaite, Humphreys & Hulleman, 2005, for previous assessments of the preview benefit based on overall RT differences). Thus, Experiment 1 provides initial evidence that faces might be more difficult to ignore over time than more abstract stimuli, perhaps due to their special status for human interactions.

In contrast to neutral faces, Experiments 3 and 4 examined preview efficiency when ignoring valenced faces. However, examining this in the preview paradigm entails observers knowing the valence of the target face in advance, (as valence of the preview items would define the valence of the target item). Conversely, the majority of the previous research on face-based valence effects in visual search has required participants to detect an odd-one-out target (e.g., Hansen & Hansen, 1988; Eastwood et al., 2001), without knowledge of the particular target-defining expression.

Moreover, Williams, Moss, Bradshaw and Mattingley (2005) found a reversal of the standard search advantage for negatively valenced face targets, when participants were aware of the target’s valence. Therefore, it is possible that the negative-superiority effect might be reduced, abolished or even reversed when the valence of the target is known in advance. Accordingly, to evaluate these effects for our subsequent methodology, we first examined search efficiency for valenced targets in Experiment 2, with and without top-down knowledge of the target valence, and using the same type of stimuli presented in Experiment 1.

Experiment 2: Comparison of visual search for valenced faces with and without top-down knowledge of the target.

Previous work demonstrating negative face superiority effects has predominantly used an “odd-one-out” paradigm (e.g., Hansen & Hansen, 1988; Hampton et al., 1994; Purcell et al., 1996; Eastwood et al., 2001), where the valence of the target was not known beforehand. However, Williams et al. (2005) found a search advantage for happy face targets amongst neutral face distractors (in comparison with fearful face targets), when the target valence was known prior to search, although later work, (Williams, McGlone, Abbott & Mattingley, 2008) indicated no behavioral differentiation, nor any modulation of amygdalar activity according to top-down task demands (i.e. instructions to search for face of particular valence). Experiment 2 examined whether an equivalent advantage for negative face detection, as shown in Experiment 1, would hold when the valence of the target was known in advance.

Although many models of attentional control encompass mechanisms by which behavioral goals or attentional set interact with bottom-up stimulus property effects (e.g., Folk, Remington & Johnson, 1992; Folk, Remington & Wright, 1994), it is unknown whether such top-down facilitation of target detection would add to valence-driven effects or reduce them. For example, the advantage gained by knowing the target identity might outweigh any automatically generated bottom-up advantage for negative stimuli. Similarly, repeating only a negative target throughout a block of trials might increase habituation to the stimulus, to the point it is no longer perceived as a threat. This behavioral effect would mirror the rapid amygdalar habituation to valenced facial stimuli seen in neuroimaging studies (e.g., Wright, et al., 2001; Breiter et al., 1996; Morris et al., 1996; see also Carretie, Hinojosa, & Mercado, 2003, for ERP data on neural habituation to emotional stimuli).

Thus, in Experiment 2, participants performed in two conditions. In one condition, the target valence remained fixed throughout a block, and so they had prior knowledge of the target identity on every trial (i.e. either a positive or negative face). In this condition, they could potentially use valence-based top-down knowledge in order to guide their search to the target. In the other condition, targets were mixed within the block, so that participants had no foreknowledge of the target on a trial-by-trial basis, and guidance by valence was not possible. Thus, this condition was equivalent to the HEB and FEB of Experiment 1, in which the target was the “odd-one-out”, and showed a strong negative target advantage.

Method

Participants. Twelve students at the University of Warwick (8 female, 4 male) participated for course credit. Participants were aged between 18 and 37 years (m=21.50 years) and 11 were right handed. All participants self-reported normal or corrected to normal vision.

Stimuli & Apparatus. Stimuli and apparatus were identical to that in Experiment 1, with the exception of display sizes, which were 6, 8 and 10 (three display sizes were used in this experiment in order to keep the total number of trials similar to those of the following preview experiments).

Design and Procedure. The experiment was based on a 3 x 2 x 2 within-participant design (Display Size x Block Type x Target Valence). Each block (negative target, positive target, mixed negative/positive target) comprised 120 experimental trials and a further 12 catch trials, where no target was present. Where a target was presented, it appeared to the right of the screen for half of the trials, with the remainder presented on the left side. Each participant completed four blocks of trials (one positive target, one negative target and two mixed target blocks). The order of block type and target valence was counterbalanced, with alternating mixed and single target blocks. Participants were instructed to locate the “odd-one-out” in a mixed target block, and to detect the negative or positive face, according to whichever single target block was being presented.

Results

Reaction Time Data. Mean correct RTs are shown in Figure 4 and search slope statistics in Table 3. Overall, search was more efficient for negative targets, with no clear advantage for single valence target or mixed valence target blocks. A 3 (Display size) x 2 (Target valence) x 2 (Block type) repeated-measures ANOVA showed that negative targets were detected faster than positive, $F(1,11)=118.54$, $MSE = 16789.24$, $p<.001$, and RTs increased as display size increased, $F(2,22)=83.31$, $MSE=4534.23$, $p<.001$. However, there was no significant effect of Block type, $F < 1$.

In addition, there was a significant Target x Display size interaction, $F(2,22)=11.72$, $MSE = 2635.58$, $p<.001$, showing that search slopes were shallower for negative targets than for positive targets. Importantly, neither the Block type x

Display size, $F < 1$, Block x Target valence, $F(1,11) = 3.43$, $MSE = 12695.38$, $p = .09$, interactions, nor the 3-way interaction, $F < 1$ reached significance. Thus, the negative target advantage did not differ between mixed and single valence blocks of trials.

Error Data. Mean percentage errors rates are shown in Table 4. Error rates on search trials were low overall (1.48 %) and were logarithmically transformed, as in Experiment 1. These data were subjected to a 3 (Display Size) x 2 (Target) x 2 (Block type) repeated-measures ANOVA. There was a significant main effect of Target, $F(1,11) = 11.47$, $MSE = 0.03$, $p < .05$, with errors more frequent in trials with a positive target. No other main effects or their interaction approached significance, all *F*s < 1.89, *p*s > .17.

The overall error rate on catch trials was 3.3% and was analyzed with a 2 (Block type) x 3 (Display Size) ANOVA. No main effects or their interaction approached significance, all *F*s < 1.79, all *p*s > 0.19.

Discussion

The main purpose of Experiment 2 was to establish whether a negative superiority effect would remain when observers knew the valence of the target on every trial (as is the case in the following experiments). One possibility is that top-down knowledge might have outweighed any automatic stimulus-driven negative advantage, particularly given the enhanced detection of happy faces found by Williams et al. (2005b), when target identity was known beforehand by participants. Another is that the repetition of a negative stimulus may have led to neural and possibly behavioral habituation.

Clearly this was not the case, with a negative target advantage evident in the single block conditions, both in terms of overall RTs and search slopes. Indeed, numerically, there was a greater difference in search slopes in the blocked conditions than in the mixed condition. The finding that top-down knowledge neither helped nor hindered search for negative valenced targets is consistent with the negative superiority effect being based on a relatively automatic or low level processing advantage (e.g., Vuilleumier et al., 2001, LeDoux, 1996; Hansen & Hansen, 1988; Öhman, 1993; Mogg & Bradley, 1999).

Experiment 3: Ignoring positive faces

Experiment 1 established that a robust, albeit partial, preview benefit emerged when the task was to ignore neutral faces and detect a valenced face amongst additional neutral faces. In Experiment 3, we determine whether positively valenced faces can also be effectively ignored. As we are assessing the effects of stimuli presented in the preview, this necessarily entails focusing on the ability to ignore valenced preview distractors, rather than the ability to detect a valenced target.

Several results are possible here. If positive faces are evaluated as being non-threatening, and therefore, are relatively ineffective at capturing and holding attention, then we would expect to obtain a robust preview benefit. Indeed, if the ability to ignore old distractors increases as they become less negative, then we might expect a stronger preview benefit than in Experiment 1 (if we accept that positive faces are less negative than neutral faces). Alternatively, if any kind of emotional expression (positive or negative) tends to draw attention, according to a general emotionality effect (e.g., Fox et al., 2000; Martin, Williams & Clark; 1991), then the preview benefit might be reduced further, relative to ignoring neutral expression distractors.

Method

Participants. Twelve students at the University of Warwick (7 female, 5 male) participated in this study for payment or course credit. Participants were aged between 19 and 27 years (m=23.33 years), and ten of these were right handed. All other participants self-reported normal or corrected to normal vision.

Stimuli & Apparatus. Stimuli and apparatus were identical to those in Experiment 1, except that target stimuli were always negative faces. In the preview condition, 2, 4, 6 or 8 positive faces were presented for 1000ms followed by 2, 4, 6 or 8 (respectively) neutral face distractors, with the target negative face taking the place of one of the distractors on non-catch trials. Thus, the final full preview search array consisted of a negative target (when present) amongst neutral and positive face distractors. The FEB was the same, except that all the items appeared simultaneously. In the HEB, only the second set of items from the preview condition was presented.

Design and Procedure. The experiment was based on a blocked 3 (condition: Preview, FEB, HEB) x 3 (Display size) within-subjects design. Each search condition block (HEB, FEB and Preview) comprised 160 experimental trials and a further 16 catch trials, where no target was present. As in Experiment 1, when a target was presented, it was shown either to the right or left side of the screen with participants indicating target location, see Figure 5 for an example preview trial.

Results

Reaction Time Data. Mean correct RTs are shown in Figure 6 and search slope statistics in Table 5. Search slope statistics were calculated in the same way as in Experiment 1, as was evaluation of preview benefit, relative to both baseline conditions. Similarly to Experiment 1, search was most efficient in the HEB, and least efficient in the FEB

HEB vs FEB vs Preview Condition. Search data were subjected to an initial 3 x 4 repeated-measures ANOVA, where significant main effects of both Search Condition, *F*(2,22)=40.14, *MSE*= 39113.89, *p*<.001, and Display Size, *F*(3,33)=70.18, *MSE*= 12466.38, *p*<.001, were found. Faster responses were produced in the HE baseline and Preview conditions than in FE baseline and overall, RTs increased as Display size increased. However, there was a significant Condition x Display Size interaction, *F*(6,66)= 9.30, *MSE*= 4993.21, *p* < .001, showing that search efficiency differed across conditions.

HEB versus FEB. RTs were overall shorter in the HEB than in the FEB, *F*(1,11)=51.26, *MSE*= 55335.62, *p*<.001 and increased with Display Size, *F*(3,33)=55.22, *MSE* = 11176.34, *p*<.001. In addition, RTs increased more with Display Size in the FEB than the HEB, *F*(3,33)=13.61, *MSE*= 6642.97, *p*<.001, with search slopes shallower in the HEB than in the FEB.

HEB versus Preview Condition. RTs were shorter overall in the HEB than in the Preview condition, *F*(1,11)=12.70, *MSE*= 10490.50, *p*<.005, and also increased with Display Size, *F*(3,33)=64.18, *MSE*= 5737.06, *p*<.001. Of most interest was a significant Condition x Display Size interaction, *F*(3,33)=10.00, *MSE*= 1446.59, *p*<.001, showing that search slopes were greater in the preview condition.

FEB versus Preview Condition. RTs were shorter overall in the Preview Condition, *F*(1,11)=33.78, *MSE*= 51515.55, *p*<.001, and increased with Display Size, *F*(3,33)=62.32, *MSE*= 13012.56, *p*<.001. In addition, search slopes were shallower in the preview condition than in the FEB, *F*(3,33)=4.99, *MSE*= 6890.06, *p*<.05.

Error Data. Mean percentage errors are shown in Table 6. Errors rates in search trials remained low overall (0.99 %), and were subjected to similar logarithmic transformation as in Experiments 1 and 2. These transformed data differed across conditions, *F*(2,22)= 6.21, *MSE*= 0.07 , *p*<.05, and increased as Display size increased, *F*(3,33) = 3.46, *MSE*= 0.05, *p*<.05. There were also some non-systematic differences across conditions as a function of display size, as revealed by a significant Condition x Display Size interaction, *F*(6,66)= 5.24, *MSE*=0.05 , *p*<.001.

Overall error rate on catch trials was 5.56%. The data were analyzed with a 3 (Condition) x 4 (Display Size) repeated-measures ANOVA, and showed a significant main effect of Display Size, *F*(3,33)=5.50, *MSE*=98.91, *p*<.005. The effect of Condition and the Condition x display size interaction did not approach significance, both *F*s < 1.

Discussion

Experiment 3 examined the efficiency of ignoring faces showing positive affect. One potential outcome was that the preview search would be equally, or more efficient than when ignoring neutral faces (as in Experiment 1), if the ability of a stimulus to capture and hold attention decreases as positive affect increases. Another possibility was that ignoring positive faces would be relatively difficult if emotional affect, either positive or negative, was effective at capturing and holding attention. Overall, the results showed that, as in Experiment 1, a robust preview benefit was obtained. In this case, the benefit was observed in terms of both overall RTs and search slopes (note that a robust difference between the FEB and HEB was demonstrated here). However, as in Experiment 1, a full preview benefit was not obtained, with the overall RTs and search slopes remaining higher in the preview condition than in the HEB. Thus, similar to our finding with neutral stimuli, previewing positive affect faces produced a partial preview benefit. In Experiment 4, we examine the efficiency of ignoring negative old stimuli.

Experiment 4: Ignoring negative faces

In Experiment 4, we examined the efficiency of ignoring negative valenced faces. Given the previously demonstrated ability of negative faces to attract and hold attention (e.g., Lavie et al., 2003; Fox et al., 2000, 2001, 2002; Georgiou et al., 2005), we might expect that it would be particularly difficult to ignore them during time-based visual search tasks, leading to a greatly reduced or abolished preview benefit. Accordingly, in the preview condition of Experiment 4, observers were given a preview of negative faces, after which an additional set of neutral faces and a positive target (when present) was added.

Method

Participants. Thirteen students at the University of Warwick (8 female, 5 male) participated for payment or course credit. All were aged between 18 and 26 years (m=20.31 years), and ten were right handed. One participant was excluded due to visual defects that were likely to have compromised performance. All other participants self-reported normal or corrected to normal vision.

Stimuli & Apparatus. Stimuli and apparatus were identical to that of Experiment 3, except that the preview display comprised negative faces, and the target was positively valenced.

Design and Procedure. The design and procedure were the same as in Experiment 3.

Results

Reaction Time Data. Mean correct RTs are shown in Figure 7 and search slopes statistics are shown in Table 7. Search slope statistics and assessment of preview benefit (relative to baseline conditions) were calculated in the same way as in Experiments 1 and 3 above. Similarly to Experiment 3, search was most efficient in the HEB, and least efficient in the FEB.

HEB, FEB and Preview Condition. Search data were subjected to an initial 3x4 repeated-measures ANOVA, with significant main effects of Search Condition, *F*(2,22)=44.08, *MSE*= 135530.74, *p*<.001, and Display Size, *F*(3,33)=309.59, *MSE* = 13364.35, *p*<.001. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, *F*(6,66)=11.18, *MSE*= 18629.07, *p*<.001, indicating that search efficiency differed across conditions.

HEB versus FEB. RTs were faster overall in the HEB, *F*(1,11)=64.87, *MSE*= 169464.02, *p*<.001, and increased with Display Size, *F*(3,33)=177.24, *MSE*= 15299.87, *p*<.001. The Condition x Display Size interaction, *F*(3,33)=22.80, *MSE*= 17254.96, *p*<.001 was also significant, indicating that the search slope was shallower in the HEB.

HEB versus Preview Condition. RTs were faster in the HEB than in Preview Condition, *F*(1,11)=16.38, *MSE*= 40161.99, *p*<.005, increased as Display Size increased, *F*(3,33)=125.87, *MSE*= 14779.38, *p*<.001, and the search slope in the HEB was shallower than in the Preview Condition, *F*(3,33)=14.04, *MSE* = 8551.34, *p*<.001.

FEB versus Preview Condition. RTs were faster in the Preview Condition than FEB *F*(1,11)=31.85, *MSE*= 196966.21, *p*<.001, and increased with Display Size, *F*(3,33)=255.99, *MSE*= 15278.52, *p*<.001. Of particular interest was a significant

Condition x Display Size interaction, *F*(3,33)=3.69, *MSE*= 30080.90, *p*<.05, indicating that the preview search slope was shallower than the FEB slope.

Error Data. Error data can be seen in Table 8. Overall, errors rates remained low on search trials (1.18%), and were logarithmically transformed before analysis. The transformed error rates increased as display size increased, *F*(3,33) = 8.82, *MSE*= 0.08, *p*<.001 However, there were no significant differences across conditions, *F*(2,22)= 2.43, *p*=.11, nor was there a significant Condition x Display Size interaction, *F*<1.

The overall error rate on catch trials was 4.86% and showed a significant main effect of Condition, *F*(2,22)=3.96, *MSE*=80.10, *p*<.05. The main effect of Display Size and the Condition x DS interaction were not significant, both *F*s < 2.21, *p*s > .10.

Discussion

Experiment 4 examined the efficiency of ignoring negative faces, presented as a preview. Given previous findings that negative faces can be particularly effective in capturing and holding attention, one might have expected that the preview benefit would have been greatly weakened or abolished completely, in comparison to when neutral (Experiment 1) or positive (Experiment 3) faces had to be ignored. However in contrast (and as in Experiments 1 and 3), we obtained a robust (albeit partial) preview benefit for ignoring negative faces, measured both in terms of overall RTs and search slopes. Thus, the present experiment provides a rare example of when negative faces do not seem to hold a special status for the visual attention system (see also Pessoa, Kastner & Ungerleider, 2002; Holmes, Vuilleumier & Eimer, 2003, but cf. Fox et al., 2002; Georgiou et al., 2005; Eastwood et al., 2001; Hansen & Hansen, 1988; Hampton et al., 1989). We return to why this might be the case in Experiments 6 and 7 and in the General Discussion.

However, it should be noted that, although Experiments 3 and 4 show that a robust preview benefit can be obtained with both positive and negative old distractors, it is difficult to determine whether there is any quantifiable difference between ignoring positive and negative faces with the current form of analysis. A simple between-experiment comparison is complicated by the fact that the baseline search slopes differ between experiments, due to the overall effect of target valence on search efficiency, even in standard visual search conditions.

Accordingly, we calculated measures of preview search efficiency (PE) that were independent of the overall baseline search rates. Two measures of preview search efficiency were calculated, one based on overall RTs ($PE_{overall}$) (1), and the other based on search slopes (PE_{slope}) (2). These measures were determined by calculating the difference between the FEB and preview search conditions, divided by the difference between the FEB and HEB search conditions for each individual participant[1], for both Experiments 3 and 4 (see Herrero, Crawley, van Leeuwen, & Raffone (2007), for an earlier use of a similar procedure).

$$PE_{overall} = \frac{FEB_{overall} - PRE_{overall}}{FEB_{overall} - HEB_{overall}} \qquad (1)$$

$$PE_{slope} = \frac{FEB_{slope} - PRE_{slope}}{FEB_{slope} - HEB_{slope}} \qquad (2)$$

Calculated this way, as preview search becomes more efficient, PE tends towards 1, and as it becomes less efficient, it tends towards 0, with calculations bounded by 0 and 1. This analysis showed that the preview benefit was numerically larger for ignoring positive faces than for negative faces, in both RT ($PE_{positive}$ =0.75 ; $PE_{negative}$=0.70) and search slope analyses ($PE_{positive}$ = 0.61; $PE_{negative}$=0.46). However, this difference did not approach significance for either overall RTs, $t(22)= 0.47$, $p=.64$, or search slopes, $t(21)= 0.92$, $p = .37$. Nonetheless, in order to provide a stronger test of any differences between ignoring positive and negative faces, we replicated Experiments 3 and 4, using a more powerful within-subjects design.

Experiment 5: Replication of Experiments 3 & 4 using a within-participants design

Experiment 5 replicated Experiments 3 and 4, using a within-subjects design, to provide a more robust test of any potential differences in the ability to ignore positive and negative faces. In addition to using a within-subjects design, we also doubled the number of participants in order to increase power.

Method

Participants. Twenty four students at the University of Warwick (15 female, 9 male) participated in this study for payment. Participants were aged between 18 and 30 years (M=20 years), and 20 were right handed. All other participants self-reported normal or corrected to normal vision.

Stimuli & Apparatus. Stimuli and apparatus were identical to those for Experiments 3 and 4.

Design & Procedure. Experiment 5 was identical in design and procedure to Experiments 3 and 4. Half the participants completed three blocks of trials associated with ignoring negative faces (i.e. HEB, FEB, Preview), followed by the blocks associated with ignoring positive faces (i.e. HEB, FEB, Preview), presented in the same order. For the remaining participants, this order was reversed. In addition, block order (i.e. HEB, FEB, Preview) was counterbalanced across participants. A short practice block was presented directly before each full block of trials.

Results

Overall Reaction Time Data. Mean correct RTs are shown in Figures 8a and 8b, and search slopes statistics in Table 9. We first assessed whether the basic findings from Experiment 3 and 4 were replicated by comparing search in the preview conditions with their respective baselines.

Ignoring positive faces:

Reaction Time Data.

HEB, FEB and Preview Condition. Search data were subjected to an initial 3 x 4 repeated-measures ANOVA, with significant main effects of Search Condition, $F(2,46)=85.24$, $MSE= 66207.73$, $p<.001$, and Display Size, $F(3,69)=111.71$, $MSE = 19834.07$, $p<.001$. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, $F(6,138)=22.40$, $MSE= 6494.41$, $p<.001$, indicating that search slopes differed across conditions.

HEB versus FEB. RTs were faster overall in the HEB, $F(1,23)=123.87$, $MSE= 85256.63$, $p<.001$, and increased with Display size, $F(3,69)=100.37$, $MSE= 14333.43$, $p<.001$. The Condition x Display Size interaction, $F(3,69)=30.76$, $MSE= 9316.28$, $p<.001$ was also significant, indicating a shallower search slope in the HEB condition.

HEB versus Preview Condition. RTs were faster in the HEB, than in the Preview condition, $F(1,23)=19.21$, $MSE= 40908.09$, $p<.001$, and also increased as Display Size increased, $F(3,69)=113.19$, $MSE= 8084.19$, $p<.001$. Of most importance, the search slope in the HEB was shallower, as demonstrated by a significant Condition x Display Size interaction, $F(3,69)=25.43$, $MSE = 3538.65$, $p<.001$.

FEB versus Preview Condition. RTs were faster in the Preview Condition than the FEB, $F(1,23)=77.07$, $MSE= 72458.48$, $p<.001$, and increased with Display Size, $F(3,69)=93.63$, $MSE=23744.94$, $p<.001$. There was also a significant Condition x Display Size interaction, $F(3,69)=9.03$, $MSE= 6628.31$, $p<.001$, indicating a shallower search slope for the Preview condition than for the FEB.

Error Data.

All error data can be seen in Table 10. Overall, errors rates remained low in search trials (1.07%), and were according log transformed as described above. These data differed across conditions, $F(2,46)= 3.87$, $MSE=0.07$, $p<.05$, with more errors made in the FEB and increasing more with Display size in the FEB condition, $F(6,138)= 3.08$, $MSE=0.06$, $p<.05$. The main effect of Display Size, did not approach significance, $F < 1$.

The overall error rate on catch trials was 5.47%, and increased with Display Size, $F(3,69)= 9.02$, $MSE= 103.57$, $p<.001$. However, the main effect of Condition and the Condition x Display Size interaction did not approach significance, both Fs < 1.23, ps > .29.

Ignoring negative faces:

Reaction Time Data.

HEB, FEB and Preview Condition. Search data were subjected to an initial 3x4 repeated-measures ANOVA, with significant main effects of Search Condition, $F(2,46)=149.67$, $MSE= 101701.84$, $p<.001$, and Display Size, $F(3,69)=285.52$, $MSE = 25370.08$, $p<.001$. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, *F*(6,138)=39.16, *MSE*= 11202.99, *p*<.001, indicating that search efficiency differed across conditions.

HEB versus FEB. RTs were faster overall in the HEB, *F*(1,23)=206.67, *MSE*= 129861.14, *p*<.001, and increased with Display Size, *F*(3,69)=234.01, *MSE*= 21564.03, *p*<.001. The Condition x Display Size interaction, *F*(3,69)=69.80, *MSE*= 12149.17, *p*<.001 was also significant, indicating a shallower search slope in the HEB condition.

HEB versus Preview Condition. Similarly, RTs were faster in the HEB, than in the Preview condition, *F*(1,23)=29.30, *MSE*= 30852.71, *p*<.001), and also increased as Display Size increased, *F*(3,69)=245.25, *MSE*= 22825.56, *p*<.001. A significant Condition x Display Size interaction, *F*(3,69)=25.63, *MSE* = 6523.72, *p*<.001, indicated that the HEB search slope was shallower than the Preview slope.

FEB versus Preview Condition. RTs were faster in the Preview Condition than the FEB, *F*(1,23)=123.91, *MSE*= 144391.66, *p*<.001, and increased with Display Size, *F*(3,69)=244.44, *MSE*=28395.64, *p*<.001. A significant Condition x Display Size interaction, *F*(3,69)=20.14, *MSE*= 14936.10, *p*<.001, also indicated a shallower search slope for the Preview condition than for the FEB.

Error Data.

Mean percentage errors are shown in Table 10. Error rates were low overall (1.85%), and were transformed as described above. The transformed error rates increased as Display Size increased, *F*(3,69) = 8.11, *MSE*= 0.09, *p*<.001. In addition, there were significant differences across conditions, *F*(2,46)= 16.18, *MSE*= 0.11, *p*<.001, with higher error rates in the FEB and Preview conditions. A marginally significant Condition x Display Size interaction, F(6,138)= 2.02, *p*=.07, was also evident.

The overall error rate on catch trials was 5.99%, and showed significant main effects of Condition, *F*(2,46)=4.76 *MSE*=182.01, *p*<.05, and Display Size, *F*(3,69)= 11.52, *MSE*= 146.34, *p*<.001, with errors increasing with display size, and a higher error rate reflected in the HEB. The Condition x Display Size interaction, *F*(6,138)=2.41, *MSE*= 125.02, *p* <.05, also proved significant.

Comparing preview search efficiency for ignoring positive and negative faces

Similarly to Experiments 3 and 4 above, a preview efficiency analysis was conducted on the data to quantify the numerical strength of the preview benefit. This analysis replicated the findings of the previous analysis, in that similar trends emerged for ignoring both valences (i.e., a partial preview benefit was demonstrated in both cases), and that PE indices were similar. However, in this instance, the numerical strength of the effect reversed, with the preview benefit larger for ignoring negative faces than for positive faces, in both RT ($PE_{positive}$ =0.70 ; $PE_{negative}$=0.79) and search slope analyses ($PE_{positive}$ = 0.48; $PE_{negative}$=0.54). This difference did not approach significance in either RT analyses, t(46)=1.23, *p*= .22, or search slopes, t(45)= 0.69, *p*=.49.

Discussion

The main aim of Experiment 5 was to provide a more powerful within-participants evaluation of whether ignoring negative faces is more difficult than ignoring positive faces. As in the previous experiments, there was a search advantage for negative valenced faces, compared with positive faces in standard search conditions (search rates were approximately double). We also found a partial, although robust, preview benefit for both ignoring positive and negative faces. However, of most interest was whether it would be more difficult to ignore negative faces compared to positive faces. Here the results were quite clear. Not only was there a non-significant difference between the efficiency of ignoring positive and negative faces, (based on overall RTs and slopes) but the numeric trend went in the opposite direction (ignoring positive faces was more difficult). Thus, these data strongly contradict the suggestion, based on the comparison between Experiments 3 and 4,that negative faces may be more difficult to ignore than positive ones.

Time course of preview benefit with positive and negative faces

Experiments 1 to 5 have examined observers' ability to ignore negatively valenced compared to positively valenced faces. Two main findings have emerged: (i) a full preview benefit has not been observed, with search efficiency in the preview conditions falling between the two baselines. This suggests that, in contrast to other types of stimuli (e.g., letters, simple shapes), face stimuli cannot be fully ignored, and that (ii) negative faces appear to be ignored as easily as positive faces. This is perhaps surprising given the numerous previous findings showing that attention is allocated more rapidly, and tends to he held for longer, by negative rather than positive stimuli (e.g., Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Eastwood et al,. 2001; Hansen & Hansen, 1988; Hampton et al., 1989). These negative valence effects may well be due to negative stimuli signaling a potentially greater threat to our survival or well-being. Thus, one might also have expected that negative faces would be more difficult to ignore than positive faces.

However thus far, the old (to be ignored) preview faces have always been presented for a fixed preview interval of 1000 ms before the new (to be searched) stimuli have been shown. It is possible that any differences in the ability to ignore positive and negative faces occur relatively early following the presentation of the preview display, and thereafter, dissipate through the 1000 ms preview period. Indeed, neurophysiological evidence suggests that there is an initial rapid differentiation of valenced stimuli (see Smith, Cacioppo, Larsen & Chartrand, 2003) at relatively short latencies, (80-100 ms; see also Eimer & Holmes, 2002; Vuilleumier & Pourtois, 2007, Ashley, Vuilleumier & Swick, 2003, for related findings with face stimuli, and Eimer & Holmes, 2007, for a review). Moreover, previous studies examining attentional effects of schematic faces in a cueing paradigm (see Fox et al., 2001) have demonstrated an impaired ability to disengage from negatively valenced faces (angry facial stimuli) at much shorter latencies than those we have used in Experiments 3, 4 and 5 (i.e. 250- 300 ms post stimulus onset). It follows that any differences in the ability to ignore negative and positive faces might only emerge at shorter preview durations.

With respect to our finding of only a partial preview benefit, it is possible that a 1000 ms preview is insufficient time to fully suppress facial stimuli (either positive or negative), if faces represent a particularly salient and powerful stimulus for the attentional system. Indeed, previous work has shown that some stimuli (e.g., those isoluminant with their background) require more than 1000 ms in order for them to be fully suppressed (e.g., Braithwaite, Hulleman, Watson, & Humphreys, 2006**;** see also Watson & Humphreys, 1997; Humphreys, Olivers & Braithwaite, 2006; Humphreys, Stalmann & Olivers, 2004; Humphreys, Kyllinsbaek et al., 2004, for other studies examining the time course of the preview benefit).

If differential valence effects occur relatively early on, then we would expect to find differences between ignoring positive and negative faces for preview durations of less than 1000 ms. In addition, if fully suppressing face stimuli takes additional time, as is the case with isoluminant stimuli, then we might expect to find an increasing (perhaps full) preview benefit beyond a 1000 ms preview duration. The following experiments addressed these issues directly by varying the preview period from 250 ms to 750 ms (Experiment 6) and 1000 ms to 3000 ms (Experiment 7).

Experiment 6a & 6b

Reducing the preview duration with positive and negative preview displays

Experiment 6 examined preview search performance with positively (Experiment 6a) and negatively (Experiment 6b) valenced preview displays, using preview durations of 250, 500 and 750 ms.

Method.

Participants. Thirty six students (13 male, 23 female) aged 18 to 36 years (M=20.9) from the University of Warwick participated, either for payment or course credit. Eighteen participants were randomly allocated to each experiment (6a and 6b), and all reported normal or corrected to normal vision.

Stimuli and Apparatus. Stimuli and apparatus were identical to Experiment 1

Design and Procedure. Each participant completed 5 blocks of experimental trials, consisting of two HEB blocks and 3 preview search blocks (one block for each of the 3 durations). Each block of preview trials contained 112 experimental search trials, with a target present on the left or right of the display and 16 catch trials, where no target was present. Within each block there was an equal number of each displays size (4, 8, 12, 16 items), and target side was combined equally with all display sizes.

A preview search trial in Experiment 6a consisted of a preview of positive faces, after which a search display of neutral distractor faces and a negative target appeared.

In Experiment 6b, the preview consisted of negative faces followed by neutral faces and a positive target. Directly before each preview block was a 20-trial practice block. Half the participants received the shortest preview condition first and the longest last, and for the other half this was reversed. In addition to the preview conditions, participants also completed two blocks (56 search trials and 8 catch trials) of a HEB condition (one directly before and one after the three preview blocks) which consisted of only the second set of elements from the associated preview conditions.

Results

Here, we were most interested in how preview search performance would change over time across the various conditions. Our previous experiments have already established the characteristics of preview search as a function of valence based on both search slopes and overall RT measures. Accordingly, for clarity of analysis and presentation, in this instance we focus our attention on search slope analyses, which have been taken in previous work to be the most reliable indicator of preview search performance. To achieve this, the data were first screened as described in Experiment 1, and search slopes were then calculated individually for each participant and condition (based on correct responses only). These slope data were then used as the primary measure in our analyses.

Experiment 6a: Ignoring positive faces

Mean search slope statistics are shown in Table 11. The RTs from the two HEB blocks were examined for differences attributable to block order (whether HEB block was presented at the start or end of the procedure). Paired samples t-tests showed no significant difference, in either overall RTs, *t*(17)= 0.36, *p*=.72, or Search Slopes, *t* (17)= 0.25, *p*= .81 and so, the data from both HEB blocks were combined.

Search Slope Data: As changes in search efficiency as a function of preview duration were of most interest, search slopes for each condition (HEB, 250, 500, 750 ms preview), and were analyzed with a one-way within-subjects ANOVA. This revealed a main effect of Search Condition, *F*(3,51)=2.40, *MSE*= 100.27, *p*=.08, which approached significance. As shown in Table 11, search was most efficient in the HEB (23 ms/item), and least efficient in the preview conditions (approximately 30 ms/item). However, the three preview conditions did not differ significantly (*F*<1).

Error Data: Mean percentage error rates are shown in Table 12. Error data from HEB blocks was examined for differences attributable to block order. Paired sample t-tests showed no significant difference between the blocks, in both search trial errors, *t*(17)= 0.96, *p*= .35, and catch trial errors, *t*(17)= 0.27, *p*= .79, therefore, both search error and catch error data were collapsed across the two blocks.

Generally, error rates on search trials were low (3.39%), and were transformed logarithmically before analysis. A 4 (Search Condition) x 4 (Display Size) ANOVA, revealed a significant main effect of Search Condition, *F*(3,51)= 3.14, *MSE*= 0.12, *p* <.05, with fewer errors produced in the HEB. In addition, error rates increased with Display Size, *F*(3,51)= 4.37, *MSE*=0.21, *p*<.05 and this increase was greatest in the preview conditions, *F*(9,153)=2.95, *MSE*= 0.10, *p*<.05. Taking preview trials alone, there remained a significant main effect of Display Size, *F(*3,51)=5.79, *MSE*= 0.25, *p*<.005, although the main effect of Condition, *F*<1, did not prove reliable. The Condition x Display Size interaction, *F*(6,102)=2.17, *MSE*= 0.08, *p*=.05, approached significance.

Catch trial error rates were relatively low overall (4.34%) but increased as Display Size increased, *F*(3,51)=9.51, *MSE*= 126.25, *p*<.001. However, neither the main effect of Condition nor the Condition x Display Size interaction approached significance, both *F*s < 1.

Experiment 6b: Ignoring negative faces

There were no significant differences between the two HEB blocks, for either overall RTs, *t*(17)= 0.23, *p*= .82, or search slopes, *t*(17)= 0.77, *p*= .45, therefore, data were collapsed across the two blocks.

Search Slope Data. There was a significant main effect of Search Condition (HEB, 250, 500, 750 ms preview), *F*(3,51)=14.49, *MSE*= 128.84, *p*=.001. As shown in Table 13, slopes decreased as a function of preview duration and were shallowest in the HEB. Considering preview slopes alone, there remained a significant main effect of Preview Duration, *F*(2,34)=5.69, *MSE*=132.58, *p*=.05, indicating that search efficiency increased with preview duration.

Error Data: Error rates are shown in Table 14. There was no significant difference between error rates in the first and last HEB blocks, for both search, *t*(17)= -1.23, *p*= .24, and catch trials, *t*(17)= 0.37, *p*= .72, therefore the data were collapsed across the two blocks. Generally, error rate in search trials was low overall (3.39%), and were transformed as described above. A 4 x 4 (Search Condition x Display Size) ANOVA revealed a main effect of Display Size, *F*(3,51)= 13.08, *MSE*=0.20, *p*<.001 and a significant Condition x Display Size interaction, *F*(9,153)=3.42, *MSE*= 0.10, *p*<.005. Errors increased with display size and this increase tended to be larger in the preview conditions. However, the effect of Search Condition, *F*(3,51)= 1.58, *p*=.21, did not approach significance. Taking preview trials alone, there remained a significant main effect of Display Size, *F(*3,51)=19.24, *MSE*= 0.18, *p*<.001, although the Condition x Display Size interaction did not prove statistically reliable, *F* < 1. However, there was a trend towards differential processing between preview durations, *F*(2,34)=2.62, *MSE* = 0.10, *p*= .09, with more errors being made in the shortest preview duration (250 ms).

Catch trial error rates were also low overall, (4.34%). Errors decreased with Display Size, *F*(3,51)=5.20, *MSE* = 100.93, *p*<.005, however, neither the main effect of Condition nor the Condition x Display Size interaction approached significance, both *F*s < 1.01

Comparison of Search Slope Data across Experiments 6a & 6b

To determine whether the time course for ignoring negative and positive faces differed, the slopes from the preview conditions of Experiment 6a (ignoring positive faces) and 6b (ignoring negative faces) were compared using a 3 (Preview Duration) x 2 (Experiment 6a/6b) mixed ANOVA. Overall, search slopes were greater when ignoring negative faces *F*(1,34)= 40.34, *MSE*= 600.23, *p*<.001, and there was a trend for search slopes to decrease with increasing preview duration, *F*(2,68) = 2.90, *MSE* = 124.25, *p*=0.06. However, of most interest was a significant Preview Duration x Experiment interaction, *F*(2,68)=3.59, *MSE*= 124.25, *p*<.05, showing that search slopes decreased as a function of preview duration when ignoring negative faces, but remained relatively constant when ignoring positive faces.

Discussion

As in previous experiments, based on search slope measures, there was an advantage for detecting a negative compared with a positive target[2]. However, the main aim of Experiment 6 was to determine whether the time course for ignoring positive and negative faces differed over relatively short preview durations (250-750ms). We note that the lack of a FEB in this experiment prevents us from calculating a preview benefit efficiency measure. Nonetheless, consistent with Experiments 1 to 5, search in the preview conditions was less efficient overall than search in the HEB, suggesting that a full preview benefit was not obtained. However, of most interest, there were clear differences in the time course of ignoring positive compared with negative faces. When ignoring positive faces, preview search was relatively efficient even with a preview duration of 250 ms, and remained relatively constant as the duration increased. In contrast, when ignoring negative faces, preview search was relatively inefficient at the shortest preview duration, but became more efficient as the preview duration increased.

This finding is consistent with the well-documented negative superiority effect, previously demonstrated in visual search tasks (i.e., Hansen & Hansen, 1988; Hampton et al., 1989; Eastwood et al., 2001) and those using a cueing paradigm (i.e., Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005). These studies have illustrated that negatively valenced faces both draw and hold attentional resources, a finding which was, somewhat surprisingly, unsupported by Experiments 3-5. However in this instance, the difference between ignoring negative and positive faces at short previews suggests that valence-based effects interact with the temporal aspects of the standard preview search paradigm, and that whilst positive affective faces can be ignored effectively following relatively brief preview durations, the same is not true of negative faces.

Experiment 7a & 7b:

Increasing the preview duration with positive and negative preview distractors

Experiments 1 to 5 have demonstrated a robust but partial preview benefit when ignoring face stimuli. However, the lack of a full benefit might be because 1000 ms is insufficient time to fully suppress face stimuli (perhaps due to their strong ecological importance) compared with other less socially relevant stimuli (e.g., abstract letters, shapes). Accordingly, in Experiment 7, we examined whether increasing the preview duration up to 3000 ms would produce a full (or at least an increased) preview benefit (cf. Braithwaite et al., 2006).

Method

Participants. Twenty four students at the University of Warwick (20 female, 4 male) aged 18 to 28 years (M=20.17) participated in this study, either for payment or course credit. Twelve participants were randomly allocated to each version of the experiment, and all reported normal or corrected to normal vision.

Stimuli & Apparatus. All stimuli and apparatus were identical to those in Experiments 6a and 6b.

Design and Procedure. Design and procedure was identical to Experiment 6a and 6b, except that preview durations of 1000, 2000 and 3000 ms were used instead of 250, 500 and 750 ms.

Results

Experiment 7a: Ignoring positive faces

Data were screened as described in Experiment 1. Paired sample t-tests showed no significant difference between the two HEB blocks, in either overall RT, *t*(11)= -0.35, *p*= 0.73, or search slopes, *t*(11)= 0.36, *p*= 0.73, therefore, data was collapsed across the two blocks. Search slope statistics are presented in Table 15.

Search Slope Data: A one-way repeated-measure ANOVA revealed that search efficiency differed across search conditions (HEB, 1000, 2000, 3000 ms preview), *F*(3,33)=3.96, MSE = 83.20, *p*<.05, with search being more efficient in the HEB than in the preview conditions. However, taking the preview conditions alone, there remained a significant main effect of Preview Duration, *F* (2,22)=3.42, *MSE*= 95.04, *p*= .05. As shown in Table 15, slopes tended to decrease, and then increase, between 1000 and 3000 ms.

Error Data. Error data is shown in Table 16. There was no significant difference between error rates in the two HEBs for both search, *t*(11)= 0, *p*= 1, and catch trials, *t*(11)= -1.60, *p*= .14, and so these data were collapsed. Search error rates were low overall (2.05%), and thus, were logarithmically transformed in accordance with previous data treatment. Errors tended to increase with Display Size, *F*(3,33)=2.37, *MSE*= 0.22, *p*=.09. However, neither the main effect of Condition, nor the Condition x Display Size interaction reached significance, both *Fs* <1. Considering just the preview conditions, no main effects or their interaction proved significant, all *Fs* < 2.09, all *ps* > .11

The overall error rate on catch trials was 5.86%. Error rates were greater at the smaller display sizes, *F*(3,33)=4.06, *MSE*= 118.47, *p*<.05. However, neither the main effect of Condition, nor the Condition x Display Size interaction approached significance, both *F*s < 1.61, *p*s > .20.

Experiment 7b Ignoring negative faces

There were no significant differences between the two HEBs, in either RT, *t*(11)= 0.32, *p*= .76, or search slopes, *t*(11)= 0.48, *p*= .64, therefore, data was collapsed across the two blocks. Table 17 shows the search slope statistics.

Search Slope Data: Search was more efficient in the HEB than in the Preview Conditions (1000, 2000, 3000 ms preview), *F*(3,33)=7.01, *MSE*= 143.22, *p*<.005. However, search efficiency did not differ as a function of Preview Duration, *F* < 1.

Error Data: Error rates were low overall (4.09%) and are shown in Table 18. There was no significant difference between the first and last HEB blocks, in either search trial errors, *t*(11)= 1, *p*= .34, or catch trial errors, *t*(11)= 0.89, *p*= .39, and so the data were collapsed across the two blocks. Following log transformation of the data, a 4 (Condition) x 4 (Display size) ANOVA revealed main effects of Display Size *F*(3,33)=21.67, *MSE*= 0.12, *p*<.001 and of Search Condition, *F*(3,33)= 4.76, *MSE*= 0.11, *p*<.05. with error rates increasing with increasing display size, and being higher in the shortest preview duration (1000ms). The Condition x Display size interaction, *F*(9,99)=1.98, *MSE*= 0.13, *p* = .05, was also significant. Considering just the preview conditions, errors increased with Display Size, *F(*3,33)=37.96, *MSE*= 0.08, *p*<.001, however again, neither the main effect of Duration, nor the Duration x Display size interaction approached significance, both *Fs* < 1.08.

Catch trial error rates were 7.42% overall, and increased with Display Size, *F*(3,33)=4.32, *MSE*= 155.56, *p*<.05. However, neither the main effect of Condition nor the Condition x Display Size interaction proved statistically significant, both *F*s < 1.22, *p*s > .29.

Comparison of Search Slope Data across Experiments 7a & 7b:

A 3 (Preview duration, 1000, 2000, 3000 ms) x Experiment (7a/b) mixed ANOVA revealed a main effect of preview duration that approached significance, *F*(2, 44)= 2.98, *MSE*= 135.56, *p*=.06, suggesting that search was less efficient when searching for a positive target, *F*(1,22)= 41.68, *MSE*= 462.99, *p*<.001. However, the Preview Duration x Experiment interaction did not approach significance, *F* < 1.

Discussion

As in the previous experiments, based on search slopes there was a clear search advantage for detecting a negative face target compared with a positive face target[3]. As for Experiment 6a/b we note a preview benefit efficiency measure could not be calculated. However, the main aim of Experiment 7 was to determine whether a full preview benefit would be obtained if the preview duration was extended up to 3s. This might be the case if fully suppressing socially relevant stimuli takes longer overall than suppressing more abstract stimuli. On this issue the results were clear, even with extended preview duration of 3s, search slopes in the preview condition did not reduce to the level obtained in the HEB. This means that even increasing the preview benefit duration to 3s did not result in a full preview benefit. Furthermore, this finding held for ignoring both negative and positive valenced faces.

General Discussion

Summary of main findings

The main aim of this study was to examine the efficiency of time-based visual selection with face stimuli that show either neutral, negative or positive affect. Three main findings emerged. First, a robust but not full preview benefit was obtained when ignoring face stimuli (Experiments 1 to 5), which held even when the preview duration was extended up to 3s (Experiment 7). Second, a negative target face search advantage remained during time-based selection conditions, irrespective of whether or not the valence of the target was known in advance (Experiments 1-7). Third, ignoring negative faces took longer than ignoring positive faces, but this difference had dissipated by approximately 750-1000 ms (Experiment 6). We consider each of these findings in more detail below.

Ignoring face stimuli

One question was whether it is possible to intentionally ignore face stimuli at all, given their salience and behavioral relevance. It is possible that the suppressive mechanism proposed to account for the preview benefit (Watson & Humphreys, 1997) would be sufficiently strong to effectively exclude face stimuli. The alternative was that if the mechanisms underlying the preview benefit are sensitive to ecological constraints (see Watson & Humphreys, 2002; Watson, Braithwaite & Humphreys, 2008), then faces might be relatively difficult to suppress.

Throughout our experiments, we consistently found a robust but partial preview benefit. This suggests that, compared with the more abstract stimuli used in previous studies of time-based selection, faces may be generally more difficult to ignore. This result meshes with previous work highlighting the importance of faces to our social functioning (Carey, 1992) and their salience in the visual field. Indeed, evidence suggests that the mere presence of faces demands allocation of processing resources (Lavie et al., 2003), and it is possible that this may result in the delayed disengagement from face stimuli (Fox et al., 2001, 2002; Georgiou et al., 2005). In other words, the relatively impaired preview benefit may derive from the fact that faces are simply too important to be able to ignore fully. In addition, the potentially automatic allocation of attention to faces might result in reduced resources being available for suppressing the preview stimuli, thus leading to a reduced preview benefit (see below).

This general result differs from a recent finding in which previewed face stimuli were used. Allen, Humphreys and Matthews (2008) presented observers with a preview consisting of blue tinted faces, followed by the addition of new red house distractors and a blue house target. In contrast to our work, in this condition a statistically full preview benefit was obtained, which indicates that those faces could be fully suppressed. One possibility for this difference in findings is that in the Allen et al., study, participants might have been able to suppress the blue previewed faces more effectively, on the basis of their color (see Braithwaite, Humphreys & Hodsoll, 2003, 2004; Braithwaite et al, 2007).

This would follow Watson, Braithwaite & Humphreys' (2008) recent study, where they showed that color differences between old and new items could be used in preview search conditions to reduce the effects of large luminance changes in the old items (compared to monochromatic old and new items). However, if color based inhibition were playing a role, then we might expect the inhibition to carry over to the new target sharing the color of the previewed faces (blue). This would make its detection particularly inefficient; reducing or abolishing any preview benefit (Braithwaite et al., 2003). Alternatively, Allen et al.'s full preview benefit might have been attributable to a lack of power in their design. Indeed, their search was substantially less efficient numerically in their preview condition (11.5ms/item) than in their associated half element baseline (-6ms/item), with a condition x display size interaction that approached significance, *p*=.078.

It should be noted that, in the current work, we have not differentiated between the potentially differing effects of emotionally valenced distractor sets and emotionally valenced targets. It is possible that the valenced targets themselves may tend to attract attention and thus, attenuate the preview benefit. A valuable goal for future work will be to disentangle the possible differing effects of distractor versus target valence in time based selection. This could be achieved by using similar, but non-facial stimuli, for example, a scrambled face target (or simple geometric shape) amongst non-scrambled face distractors (and vice versa; see Hershler & Hochstein, 2005, for an example of visual search with scrambled photographic faces).

The effects of stimulus valence

A second aim was to determine whether facial valence influences the ability to intentionally ignore faces presented in a preview. We reasoned that if negative stimuli are particularly potent within the attentional system, then they might be much more difficult to ignore than positively valenced stimuli, resulting in a diminished or abolished preview benefit. Alternatively, it is also possible that faces showing any emotion per se (compared to a neutral expression), are more difficult to ignore as a general class of stimuli (see Fox et al., 2000; Martin et al., 1991; General Emotionality Hypothesis).

The results of Experiments 3 to 5, in which the old stimuli were previewed for 1000ms were clear. Ignoring valenced stimuli produced a partial preview benefit (as was the case for ignoring neutral faces), although there was no difference in the efficiency of ignoring negative compared with positive faces. However, importantly, when preview duration was reduced from 1000ms (as per the standard preview search paradigm) to 250, 500 and 750 ms, differential processing of negative and positive faces was demonstrated (Experiment 6). Ignoring positive face previews was consistently efficient from the shortest preview duration to the longest. However, efficiency was significantly hampered at the shortest preview durations for negative face previews, and did not approach optimum performance until approximately 750ms. Thus, the time course of ignoring negative and positive faces differed, with negative faces being selectively more difficult to suppress at short preview durations.

Why are negative faces more difficult to intentionally suppress?

Our finding that negative faces are more difficult to ignore at short preview durations is consistent with many aspects of previous studies examining the effects of negatively valenced faces. For example, evidence that differentiation of negative and positive stimuli occurs at very short latencies (Smith et al, 2003), and that attention is allocated rapidly to face stimuli (Eimer & Holmes, 2002; 2007) might lead us to expect that differences between valenced faces would be most likely to be demonstrated early in their processing. Furthermore, this might be considered even more pertinent in light of evidence from cueing studies (Fox et al., 2001), where negatively valenced schematic faces have elicited delayed disengagement at comparable latencies to the preview durations used in Experiments 6a and b (i.e. approximately 250 – 300 ms post stimulus onset).

In addition, this finding may also be considered alongside much of the literature exploring visual search for emotional faces, in that we would expect negative faces to capture and hold attention, in preference to positive faces (e.g., Hansen & Hansen, 1988; Hampton et al., 1989; Öhman et al., 2001; Eastwood et al., 2001). This is clearly demonstrated in preview search, at least at preview durations shorter than those typically used to date (i.e. 1000 ms).

If we accept, that a broad discrimination between positive and negative valenced face stimuli may be made as early as 100ms post-onset (Smith et al., 2003), why should negative face stimuli require a longer preview duration to reach, in relative terms, their optimum preview benefit? As evidence suggests (Wagner, MacDonald, & Manstead, 1986; but see Russell, 1994, for a review) that it is more difficult for humans to distinguish between negative basic expressions, than to make a broad negative versus positive discrimination, it is possible that attentional resources are engaged in these stimuli until such further evaluation can be undertaken and a realistic assessment of threat can be made. In this case, the active top-down suppression of negative stimuli might simply take longer to initiate, effectively having to wait until resources are released from processing the negative stimuli. Alternatively, the resources needed to inhibit the negative faces may be reduced initially, as the negative stimuli may automatically draw attention to themselves (e.g., Vuilleumier et al., 2001; Hansen & Hansen, 1988; Mogg & Bradley, 1999; Eastwood et al., 2003).

Note that, consistent with this possibility are previous findings showing that, when available attentional resources are reduced during preview search, via competing tasks (Watson & Humphreys, 1997; Humphreys, Watson & Joliceour, 2002) or stimuli (Kunar, Humphreys, Smith & Watson, 2003), a reduced preview benefit is demonstrated. Either way, this would result in a reduction of the speed at which the old negative stimuli would be suppressed.

Another possibility is that negative faces provide a more powerful signal for the attentional system, which simply takes longer to suppress to some minimum level than the signal associated with positive or neural stimuli. It is not clear at this point how convincingly these explanations might account for the data individually or in combination – indeed, the above accounts need not be mutually exclusive. However, , differentiating between them, or establishing their relative contributions, might be possible in future work by examining search efficiency with preview displays, in which both face and abstract neutral symbolic stimuli (e.g., letters) are presented. For example, if the negative faces simply possess a stronger or more salient representation, then their presence should not interfere with the rate of suppressing the accompanying abstract stimuli. However, if the negative faces capture/consume attentional resources, then they should also reduce the ease with which the previewed neutral abstract stimuli can be suppressed (compared with, for example, when the abstract stimuli are paired with positive faces).

Extending the preview duration

Extending the preview duration up to 3000 ms did not affect the relative efficiency of ignoring either negative or positive faces, either within or between valence – there remained only a partial preview benefit. This result contrasts with previous work showing that stimuli resistant to suppression at a 1000ms preview (e.g., those isoluminant with their background, Braithwaite et al., 2006) could elicit a full preview benefit, when given sufficient time to suppress them.

Thus, our findings support the notion that faces, whether valenced or neutral, cannot be fully ignored, even if we allow additional time for this function. That said, given the social importance attached to the face and its potential for communicating behavioral intention, the inability to extinguish the face’s hold over attentional resources might still be considered adaptive (see also Watson & Humphreys, 2002; Watson, Braithwaite & Humphreys, 2008), despite the impact on top-down cognitive flexibility. Moreover, it suggests that any further evaluative processing needed to establish threat may have been undertaken by 750-1000 ms post stimulus onset, and from this time point onwards, the social relevance of any emotional face becomes equivalent, in terms of being able to fully suppress the stimuli.

The negative target search advantage and time-based selection

The final focus of this study was to establish whether the typical advantage for negative stimuli would persist under time-based selection conditions. Note that direct comparison with much of the previous work exploring visual search with emotionally valenced faces is not without issue. Most pertinently, the primary focus of many of these studies has been the attention-capturing properties of valenced faces as targets, rather than the effects of a valenced distractor set (although this point has been discussed in some of that work, see Williams et al., 2005b; Eastwood et al., 2001; Fox et al., 2000; Hampton et al., 1989; Hansen & Hansen, 1988). The preview search paradigm not only evaluates the attentional effects of part of that distractor set, but also relies on the reverse attentional function (i.e., ignoring stimuli rather than detecting them). However, leaving aside these differences, it is clear that we obtained a search advantage for negative targets throughout our experiments. In terms of search alone, detection of a negative face amongst neutral or positive faces was more rapid than detection of a positive face amongst neutral or negative faces. Moreover, this effect was strongly evident throughout all of the experiments presented in this study. Taken as a whole then, this study should be taken as support for the negative superiority effect. However, our findings extend this superiority effect to conditions of temporal selection.

Another new finding was that, contrary to the findings of Williams et al. (2005, but see Williams et al.,2008), we found no reliable effect of whether or not participants knew (or could predict) the identity of the target valence. This held for both negative and positive targets. One possibility is that the effect of top-down knowledge on search might have been stronger than any valence based bottom-up effects, leading to an equivalence between searching for positive and negative faces. In practical terms, this finding allowed us to extend the use of schematic emotional face search beyond simple spatial selection. However, more importantly, it indicates that the attentional biases elicited by emotionally valenced faces are not overridden by top-down awareness of target identity or emerging top-down task demands in this context. It is not clear why we obtained different results to those found by Williams et al. (2005), since our methodology matched that study relatively closely. However, the face stimuli used in Williams' study were photographic, and may have introduced confounds on the basis of distinctive features (i.e., stimuli comprising a display of teeth) or target-distractor similarity (i.e., the features displayed in less-well detected stimuli may have resembled the emotionally neutral face distractors to a greater degree). However, in a recent neuroimaging study, Williams et al. (2008) also found no effects of instruction set (i.e., knowledge of target identity) on target valence, in either behavioral or neuroimaging data. Clearly the exact conditions under which top-down knowledge can impact on the effects of stimulus valence remain to be determined.

Implications for theories of time-based selection

Alternative accounts to the inhibitory visual marking theory (Watson & Humphreys, 1997) of the preview benefit have been proposed. The abrupt onset account (Donk & Theeuwes, 2001) argues that the preview benefit occurs because the abrupt luminance onsets of new items capture attention automatically, leading to the prioritized selection of those elements. The temporal asynchrony account (Jiang et al., 2002) proposes that elements within each set of stimuli (old and new) group independently based on their common, but asynchronous onset. Attention can then be applied to either group, depending upon task demands. Both of these accounts have difficulty explaining the present set of findings. If the preview benefit is simply due to new abrupt luminance onsets capturing attention automatically, then we should have obtained a full preview benefit with the present stimuli, equally strong as those observed previously with more abstract stimuli. Similarly, a pure luminance onset account cannot explain the differential effect of negative and positive faces at short preview durations.

These same issues apply to the temporal asynchrony account (Jiang et al., 2002). If temporal differences alone were crucial, then this account cannot explain why we obtained only a partial preview benefit with face stimuli, when the temporal asynchrony (temporal difference between the presentation of the old and new) was identical to that used in previous studies in which a full preview benefit was obtained. Likewise, this account predicts that, provided the temporal difference between the old and new groups remains the same, then the preview benefit should remain the same. However, this was not the case at the shorter preview durations, where there was a differential effect of preview duration, depending upon the valence of the previewed items. In contrast, as described earlier, the inhibitory account of the preview benefit, in which old stimuli have to be intentionally suppressed, can readily explain both of these features of the data.

Possible influence of participant anxiety levels

Several studies have identified the importance of self-reported anxiety (SRA) where valenced faces are used in visual attention paradigms (e.g., visual search, probe detection and cueing studies). Typically differential effects of negatively valenced faces are demonstrated by high anxiety participants compared with low anxiety participants (e.g., Fox et al., 2001; Georgiou et al., 2005; Mogg & Bradley, 1999). In the experiments reported here, we did not measure SRA, and because participants were randomly allocated to experiments/conditions, we assume that anxiety levels would not have varied systematically across any of our tests. Nonetheless, a potentially important goal for future work will be to assess the possible influence of anxiety on time-based visual selection with valenced stimuli. Specifically, it might be more difficult for high SRA individuals to ignore negative valence faces, or it might take longer for them to ignore them. We would add that in future work it might be useful to measure SRA levels as a confirmatory check that anxiety levels do not differ across conditions.

Conclusion

The present work has shown it is possible to ignore face stimuli over time in order to prioritize newly appearing information. However, we consistently found that, compared with previous work using more abstract stimuli, faces were more difficult to ignore, and this led to a partial rather than a full preview benefit. This accords with previous findings, suggesting that the mechanisms involved in producing the preview benefit are sensitive to ecological issues (Watson & Humphreys, 2002, 2008). Thus, it follows that we might expect highly behaviorally and socially relevant stimuli, such as emotional faces, to be less readily suppressed than more abstract stimuli. This work also showed that negative faces were more difficult to ignore than positive faces, but only at short preview durations. By approximately 750 to 1000ms, any differential effects of ignoring positive compared with negative faces had disappeared. Again, this could be considered adaptive, since 1000ms might provide sufficient time to evaluate potential threat relevance. Once this evaluation has been made, stimuli that are no longer considered threat-relevant could be discarded or suppressed in order to focus processing on future events.

Footnotes

[1] In instances where the HEB value exceeded that of the FEB, that case was excluded from the analysis.

[2] We note that of secondary interest, as in the previous experiments, there was also an overall RT advantage (collapsed across condition and display size) for detecting a negative (823.2 ms) compared with a positive target (1106.1 ms), $t(34) = 5.05$, $p<.001$.

[3] There was also an overall RT advantage (collapsed across condition and display size) for detecting a negative target (800.1 ms) compared with a positive target (1040.3 ms), $t(22) = 4.47$ $p < .001$.

References

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

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

Ashley, V., Vuilleumier, P., & Swick, D. (2003). Time course and specificity of event-related potentials to emotional expressions. *Neuroreport*, *15*, 211–216.

Braithwaite, J.J., Humphreys, G.W., & Hodsoll, J. (2004). Effects of colour on preview search: Anticipatory and inhibitory biases for colour. *Spatial Vision, 17,* 389-425.

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 & Performance, 29,* 758-778.

Braithwaite, J.J., Humphreys., G.W., Hulleman, J, & Watson, D.G. (2007). Early color grouping and late color inhibition: Evidence for distinct temporal windows for separate processes in preview search. *Journal of Experimental Psychology: Human Perception & Performance, 33,* 503-517.

Braithwaite, J.J., Humphreys, G.W., & Hulleman, J. (2005) Color-based grouping and inhibition in visual search: Evidence from a probe detection analysis of preview search, *Perception & Psychophysics,* 67, 81-101.

Braithwaite, J.J., Hulleman, J., Watson, D.G. & Humphreys, G.W. (2006). Is it impossible to inhibit isoluminant items or does it simply take longer? Evidence from preview search. *Perception & Psychophysics, 68,* 290-300.

Bravo, M.J., & Nakayama, K. (1992). The role of attention in different visual search tasks. *Perception & Psychophysics, 51(5),* 465-472.

Breiter, H.C., Etcoff, N.L., Whalen, P.J., Kennedy, W.A., Rauch, S.L., Buckner, R.L., Strauss, M.M., Hyman, S.E., & Rosen, B. R. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron, 17,* 875-887.

Calder, A.J. and Young, A.W. (2005*).* Understanding the recognition of facial idenitity and facial expression. *Nature Reviews: Neuroscience, 6,* 641-651.

Carey, S. (1992). Becoming a face expert. *Philosophical Transactions of the Royal Society, London B, 335,* 95-103.

Carretie, L., Hinojosa, J. A., & Mercado, F. (2003). Cerebral patterns of attentional habituation to emotional visual stimuli. *Psychophysiology, 40,* 381–388.

Cooper, R.M. & Langton, S.R.H. (2006) Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy, 44,* 1321–1329.

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

Donk, M., & Theeuwes, J. (2003). Prioritizing selection of new elements: Bottom-up versus top-down control. *Perception and Psychophysics, 65,* 1231-1242.

Eastwood, J., Smilek, D., & Merikle, P.M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception &*

Psychophysics, 63, 1004-1013.

Eastwood, J. D., Smilek, D., & Merikle, P. M. (2003). Negative facial expression captures attention and disrupts performance. *Perception & Psychophysics, 65,* 352-358.

Eimer, M., & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Neuroreport, 13*, 427–431.

Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia, 45,* 15–31.

Ellis, H.D., Bruce, V. De Schonen, S. (1992). The Development of Face Processing Skills [and Discussion]. *Philosophical Transactions: Biological Sciences,* Vol. 335, No. 1273, Processing the Facial Image. (Jan. 29, 1992), pp. 105-111.

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception & Performance, 21,* 628-634.

Fenske, M. J., & Eastwood, J. D., (2003). Modulation of focused attention by faces expressing emotion: Evidence from flanker tasks. *Emotion, 3 (4),* 327–343

Folk, C.L., Remington, R.W., & Johnson, J.C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030-1044.

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,* 317-329.

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,* 61-92.

Fox, E., Russo, R., Bowles, R.J., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety. *Journal of Experimental Psychology: General, 130,* 681-700.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition & Emotion, 16 (3),* 335-379.

Georgiou, G.A., Bleakley, C., Hayward, J., Russo, R., Dutton, K., Eltiti, S and Fox, E. (2005). Focusing on fear: Attentional disengagement from emotional faces. *Visual Cognition, 12 (1),* 145-158.

Hariri, A.R., Tessitore,A., Mattay, V.S. Fera, F. and Weinberger, D.R. (2002) The Amygdala Response to Emotional Stimuli: A Comparison of Faces and Scenes *NeuroImage, 17,* 317–323.

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,* 563-566.

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality & Social Psychology, 54,* 9 17-924.

Herrero, J. L., Crawley, R., van Leeuwen, C., & Raffone, A. (2007). Visual marking and change detection. *Cognitive Processing, 8,* 233-244.

Hershler, O., & Hochstein, S. (2005) At first sight: A high-level pop out effect for faces. *Vision Research, 45,* 1707-1724.

Hodsoll, J.P., & Humphreys, G.W. (2005). Preview search and contextual cuing.

Journal of Experimental Psychology: Human Perception and Performance, 31, 1346-1358.

Holmes, A.,Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gate by spatial attention: Evidence from event-related brain potentials. *Cognitive Brain Research, 16*, 174-184.

Horstmann, G. (2007). Preattentive face processing: What do visual search experiments with schematic faces tell us? *Visual Cognition, 15(7),* 799 - 833.

Humphreys, G.W., Kyllingsbaek, S., Watson, D.G., Olivers, C.N.L., Law, I., & Paulson, O.B. (2004). Parieto-occipital areas involved in efficient filtering in search: A time course analysis of visual marking using behavioral and functional imaging procedures. *Quarterly Journal of Experimental Psychology, 57A,* 610–635.

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

Humphreys, G.W., Olivers, C.N.L., & Braithwaite, J. J. (2006). The time course of preview search with color-defined, not luminance-defined, stimuli. *Perception & Psychophysics, 68*, 1351-1358.

Humphreys, G.W., Watson, D.G., & Jolicoeur, P. (2002). Fractionating the preview benefit: Dual-task decomposition by timing and modality. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 640-660.

Jiang, Y., Chun, M.M., & Marks, L.E. (2002b). Visual marking: Selective attention to asynchronous temporal groups. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 717-730.

Kanwisher, N., McDermott, J., & Chun, M.M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience, 17(11),* 4302–4311.

Kunar, M., Smith, K.J., Humphreys, G.W. & Watson, D.G. (2003). When a re-appearance is old news: Visual marking survives occlusion. *Journal of Experimental Psychology: Human Perception and Performance, 29,* 185-198.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *21,* 451-468.

Lavie, N. (2000). Selective attention and cognitive control: dissociating attentional functions through different types of load. *In S. Monsell & J. Driver (Eds.).* Attention and performance XVIII, *pp. 175-194. Cambridge, Massachusetts: MIT press.*

Lavie, N., Ro, T., & Russell, C. (2003). The role of perceptual load in processing distractor faces. *Psychological Science, 14 (5),* 510-515.

LeDoux, J.E. (1996) *The emotional brain*. New York: Simon & Schuster.

McKelvie,S. J. (1973). The meaningfulness and meaning of schematic faces. *Perception & Psychophysics, 14,* 343-348.

Martin, M., Williams, R., & Clark, D. (1991). Does anxiety lead to selective processing of threat-related information? *Behaviour Research and Therapy*, *29,* 147- 160.

Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition & Emotion, 13 (6),* 713 -740.

Morris, J.S., Frith, C.D., Perett, D.I., Rowland, D., Young, A.W., Calder, A.J. & Dolan, R.J. (1996). A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature, 38*3, 812-815.

Morris, J.S., Öhman, A., & Dolan, R.J. (1998). Conscious and unconscious emotional learning in the human amygdala. *Nature, 393,* 467-470.

Nothdurft, H.C. (2001). Salience from feature contrast: Variations with texture density. *Vision Research, 40,* 3181-3200.

Nothdurft, H.C. (1993). Faces and facial expressions do not pop out. *Perception, 22,* 1287-1298.

Öhman, A. (1993). Fear and anxiety as emotional phenomena: clinical phenomenology, evolutionary perspectives, and information processing mechanisms. In M. Lewis & J.M. Haviland (Eds.), *Handbook of emotions*. New York:Guilford.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality & Social Psychology, 80,* 381–396.

Pessoa, L., Kastner, S., & Ungerleider, L.G. (2002) Attentional control of the processing of neutral and emotional stimuli. *Cognitive Brain Research, 15,* 31-45.

Pratto, F., & John, O.P. (1991). Automatic vigilance: The attention- grabbing power of negative social information. *Journal of Personality & Social Psychology, 61,* 380- 391.

Purcell, D.G., Stewart, A.L., & Skov, R.B.(1996). It takes a confounded face to pop out of a crowd. *Perception, 25,* 1091-1108.

Russell, J.R. (1994). Is there universal recognition of emotion from facial expression? A review of the cross-cultural studies? *Psychological Bulletin, 115 (1),* 102-141.

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.

Smilek, D., Eastwood, J. D., & Merikle, P. (2000). Does unattended information facilitate change detection? *Journal of Experimental Psychology: Human Perception & Performance, 26,* 480-487.

Smith, N.K., Cacioppo, J.T., Larsen, J.T., Chartrand, T.L., (2003) May I have your attention, please: Electrocortical responses to positive and negative stimuli. *Neuropsychologia, 41*, 171–183.

Stenberg, G., Wilking, S., & Dahl, M. (1998). Judging words at face value: Interference in a word processing task reveals automatic processing of affective facial expressions. *Cognition & Emotion, 12,* 755-782.

Tsao, D.Y., & Livingstone, M.S. (2008). Mechanisms of face perception. *Annual Review of Neuroscience, 31*, 411-437.

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., Armony, J. L., Driver, J., & Dolan, R.J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron, 30,* 829-841.

Vuilleumier, P., & Schwartz, S. (2001). Emotional expressions capture attention. *Neurology, 56,* 153-158.

Wagner, H.C., MacDonald, C.J., & Manstead, A.S.R. (1986) Communication of individual emotions from spontaneous facial expression. *Journal of Personality & Social Psychology, 50,* 737- 743.

Watson, D.G., Braithwaite, J.J. & Humphreys, G.W. (2008). Resisting change: The influence of luminance changes on visual marking and the preview benefit. *Perception & Psychophysics, 70,* 1526-1539.

Watson, D. G., Humphreys, G. W., & Olivers, C. N. L. (2003). Visual marking: Using time in visual selection. *Trends in Cognitive Sciences*, *7,* 180-186.

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,*90-122.

Watson, D.G. & Humphreys, G.W. (2005). Visual Marking: The effects of irrelevant changes on preview search. *Perception & Psychophysics, 67,* 418-434.

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,* 946-962.

Watson, D.G., & Humphreys, G.W. (2002). Visual marking and visual change. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 379-395.

White, M. (1995) Preattentive analysis of facial expressions of emotion. *Cognition & Emotion, 9,* 439-460.

Williams, M.A., McGlone, F., Abbott, D.F., & Mattingley, J.B. (2008). Stimulus-driven and strategic neural responses to fearful and happy facial expressions in humans. *European Journal of Neuroscience, 27,* 3074–3082.

Williams, M.A., Moss, S.A., Bradshaw, J. L., Mattingley, J.B. (2005). Look at me, I'm smiling: Visual search for threatening and non-threatening facial expressions. *Visual Cognition, 12 (1),* 29-50.

Wolfe, J.M., Butcher, S.J., Lee, C., & Hyle, M. (2003). Changing your mind: On the contribution of top-down and bottom-up guidance in visual search for feature singletons. *Journal of Experimental Psychology: Human Perception & Performance, 29(2),* 483-502.

Yin, R. K. (1969) Looking at upside-down faces. *Journal of Experimental Psychology, 81,* 141-145.

Acknowledgements

We thank Liam Gilligan, Tom Barry and Cherelle MacDonald for assistance with some of the data collection and Friederike Schlaghecken for comments on an earlier draft of this manuscript.

Table 1. Search slopes statistics for Experiment 1, by search condition and target valence.

	Search Condition and Target Valence					
	HEB		FEB		Preview	
Slope Statistics	Negative	Positive	Negative	Positive	Negative	Positive
Slope (ms/item)	26.61	38.70	29.22	45.87	27.33	47.05
Intercept	514.37	525.58	640.54	710.24	548.06	512.83
R^2	0.99	0.99	0.99	0.98	0.99	1.00

Table 2. Mean percentage error rates for Experiment 1, by search condition, target valence and display size.

	Display Size				
	2	4	6	8	
Condition	4	8	12	16	Mean
HEB					
Negative Target	0.83	2.22	0.83	1.11	1.25
Positive Target	1.11	2.50	2.22	1.67	1.88
Catch Trials	20.83	6.94	6.94	5.56	10.07
FEB					
Negative Target	1.11	1.94	1.39	1.11	1.39
Positive Target	2.78	1.39	0.83	3.89	2.22
Catch Trials	11.11	11.11	4.17	5.56	7.99
Preview					
Negative Target	1.94	1.67	1.67	0.56	1.46
Positive Target	1.67	1.67	2.22	3.61	2.29
Catch Trials	18.06	13.89	4.17	4.17	10.07

Table 3. Search slope statistics for Experiment 2, by search condition and target valence.

	Block Type and Target Valence			
	Single Target		Mixed Target	
Slope Statistics	Negative	Positive	Negative	Positive
Slope (ms/item)	29.62	59.22	33.50	53.48
Intercept	628.34	661.46	639.12	679.65
R^2	0.99	0.96	0.99	0.99

Table 4. Mean percentage error rates for Experiment 2, by block type, target valence and display size

	Display Size			
Block Type	6	8	10	Mean
Single Target				
Negative Target	0.21	1.04	0.42	0.56
Positive Target	0.83	0.42	0.63	0.63
Catch Trials	4.17	1.04	3.13	2.78
Mixed Target				
Negative Target	1.04	1.25	1.04	1.11
Positive Target	1.67	1.25	1.25	1.39
Catch Trials	6.25	2.08	3.13	3.82

Table 5. Search slope statistics for Experiment 3 for detecting negative targets amongst positive and neutral distractors, by search condition.

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	19.29	42.75	28.43
Intercept	476.62	585.85	459.76
R^2	0.97	1.00	0.99

Table 6. Mean percentage error rates for Experiment 3 by search condition and display size.

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search trials					
HEB	1.04	1.88	1.25	0.83	1.25
FEB	1.25	0.21	0.83	2.92	1.30
Preview	0.00	0.21	0.42	1.04	0.42
Catch Trials					
HEB	10.42	2.08	2.08	4.17	4.69
FEB	12.50	4.17	8.33	0.00	6.25
Preview	10.42	8.33	2.08	2.08	5.73

Table 7. Search slope statistics for Experiment 4 for detecting positive targets amongst negative and neutral distractors, by search condition.

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	40.56	89.10	67.14
Intercept	532.14	723.57.	431.89
R^2	0.99	0.99	1.00

Table 8. Mean percentage error rates for Experiment 4, by search condition and display size.

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	0.42	0.21	0.42	1.67	0.68
FEB	0.83	1.04	1.67	2.71	1.56
Preview	0.21	1.04	0.83	3.13	1.30
Catch Trials					
HEB	8.33	12.50	2.08	8.33	7.81
FEB	6.25	4.17	2.08	0.00	3.13
Preview	6.25	6.25	2.08	0.00	3.65

Table 9. Search slope statistics for Experiment 5 as a function of search condition and preview distractor valence.

Ignoring positive faces

Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	18.43	48.35	35.03
Intercept	521.18	691.02	484.08
R^2	0.97	1.00	1.00

Ignoring negative faces

	HEB	FEB	Preview
Slope (ms/item)	36.75	88.00	58.93
Intercept	535.67	770.98	451.15
R^2	0.98	0.99	1.00

Table 10. Mean percentage error rates for Experiment 5, by search condition, target valence and display size.

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
Ignoring Positive					
HEB	1.25	0.73	0.73	0.73	0.86
FEB	0.42	1.46	2.50	1.77	1.54
Preview	0.83	0.42	1.04	0.94	0.81
Ignoring Negative					
HEB	0.83	0.73	0.83	1.04	0.86
FEB	1.88	1.98	2.40	5.30	2.89
Preview	1.56	1.25	1.98	2.40	1.80
Catch Trials					
Ignoring Positive					
HEB	12.50	4.17	5.21	2.08	5.99
FEB	7.29	4.17	3.13	2.08	4.17
Preview	12.50	5.21	3.13	4.17	6.25
Ignoring Negative					
HEB	16.67	14.58	4.17	1.04	9.11
FEB	9.38	0.00	1.04	2.08	3.13
Preview	11.46	5.21	5.21	1.04	5.73

Table 11. Search slope statistics for Experiment 6a, ignoring positive preview faces, by block type and preview duration.

	Block Type and Preview Duration			
	HEB	Preview		
Slope Statistics		250 ms	500ms	750 ms
Slope (ms/item)	23.00	30.08	27.93	31.28
Intercept	510.28	645.94	528.81	590.16
R^2	0.99	0.97	0.98	1.00

Table 12. Mean percentage error rates for Experiment 6a by block type, preview duration and display size.

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	1.59	1.19	1.79	1.19	1.44
Preview: 250ms	0.79	1.19	4.17	5.36	2.88
Preview: 500ms	1.39	1.98	3.37	3.77	2.63
Preview: 750ms	1.98	2.18	2.58	3.17	2.53
Catch Trials					
HEB	15.28	4.17	2.78	4.17	6.60
Preview: 250ms	11.11	5.56	5.56	6.94	7.29
Preview: 500ms	13.89	5.56	4.17	1.39	6.25
Preview: 750ms	8.33	5.56	4.17	0.00	4.51

Table 13. Search slope statistics for Experiment 6b, ignoring negative preview faces, by block type and preview duration.

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		250 ms	500ms	750 ms
Slope (ms/item)	42.30	66.65	58.65	53.83
Intercept	545.64	627.64	524.73	532.79
R^2	0.99	0.99	1.00	0.99

Table 14. Mean percentage error rates for Experiment 6b, by block type, preview duration and display size.

	Display Size				
	2	4	6	8	Mean
	4	8	12	16	
Search trials					
HEB	2.78	3.57	3.17	3.17	3.17
Preview: 250ms	1.59	2.58	4.56	7.54	4.07
Preview: 500ms	0.99	2.18	4.17	5.75	3.27
Preview: 750ms	0.20	1.98	3.77	6.15	3.03
Catch trials					
HEB	8.33	4.17	4.17	4.17	5.21
Preview: 250ms	5.56	1.39	2.78	1.39	2.78
Preview: 500ms	5.56	2.78	1.39	4.17	3.47
Preview: 750ms	13.89	5.56	4.17	0.00	5.90

Table 15. Search slopes for Experiment 7a, ignoring positive previewed faces, by Block Type and Preview Duration

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		1000 ms	2000ms	3000 ms
Slope (ms/item)	21.31	23.64	25.32	33.38
Intercept	536.96	578.47	543.39	509.13
R^2	0.94	0.98	1.00	0.98

Table 16. Mean percentage error rates for Experiment 7a, by block type, preview duration and display size.

	Display Size				
	2	4	6	8	Mean
	4	8	12	16	
Search trials					
HEB	1.79	1.79	2.38	2.38	2.09
Preview 1000ms	0.89	0.89	2.08	3.87	1.86
Preview 2000ms	0.89	2.98	2.08	2.98	2.09
Preview 3000ms	0.60	1.79	2.38	2.98	1.79
Catch trials					
HEB	10.42	6.25	2.08	8.33	6.77
Preview 1000ms	12.50	4.17	4.17	6.25	6.77
Preview 2000ms	10.42	6.25	4.17	4.17	6.25
Preview 3000ms	8.33	2.08	2.08	2.08	3.65

Table 17. Mean search slopes for experiment 7b, ignoring negative previewed faces by block type and preview duration.

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		1000 ms	2000ms	3000 ms
Slope (ms/item)	42.62	59.08	57.76	63.73
Intercept	536.58	486.91	469.17	462.07
R^2	0.99	1.00	0.98	1.00

Table 18. Mean percentage error rates for Experiment 7b, by block type, preview duration and display size.

	Display Size				
	2	4	6	8	Mean
Search Trials	4	8	12	16	
HEB	1.49	2.68	2.68	4.46	2.83
Preview 1000ms	1.19	3.27	5.95	9.82	5.06
Preview 2000ms	1.19	1.79	5.95	7.14	4.02
Preview 3000ms	0.60	2.38	7.14	7.74	4.46
Catch Trials					
HEB	6.25	8.33	8.33	6.25	7.29
Preview 1000ms	10.42	4.17	8.33	6.25	7.29
Preview 2000ms	16.67	6.25	6.25	2.08	7.81
Preview 3000ms	18.75	4.17	0.00	6.25	7.29

Figure Captions

Figure 1. Examples of the schematic face targets and distractors

Figure 2. An example preview search trials with a positive face target and display size of 8 from Experiment 1.

Figure 3. Mean correct RTs for detecting negative targets (Panel A) and positive Targets (Panel B) as a function of condition and display size for Experiment 1. Error bars indicate ±1 standard error.

Figure 4. Mean correct RTs for as a function of condition and display size for Experiment 2. Error bars indicate ±1 standard error.

Figure 5. An example preview search trial with a negative target and positive preview distractors from Experiment 3.

Figure 6. Mean correct RTs for as a function of condition and display size for Experiment 3. Error bars indicate ±1 standard error.

Figure 7. Mean correct RTs for as a function of condition and display size for Experiment 4. Error bars indicate ±1 standard error.

Figure 8. Mean correct RTs for ignoring positive distractors (Panel A) or negative distractors (Panel B) as a function of condition and display size for Experiment 5. Error bars indicate ±1 standard error.

Figure 1. Examples of the schematic face targets and distractors.

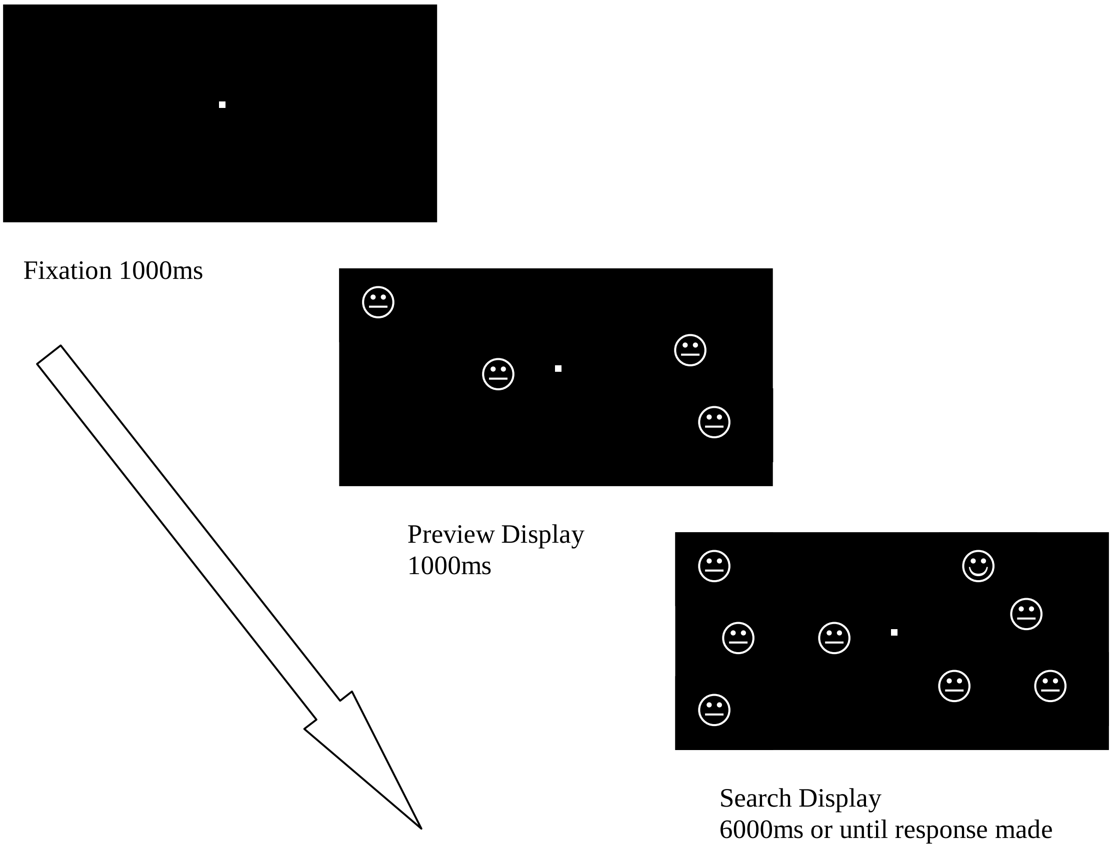
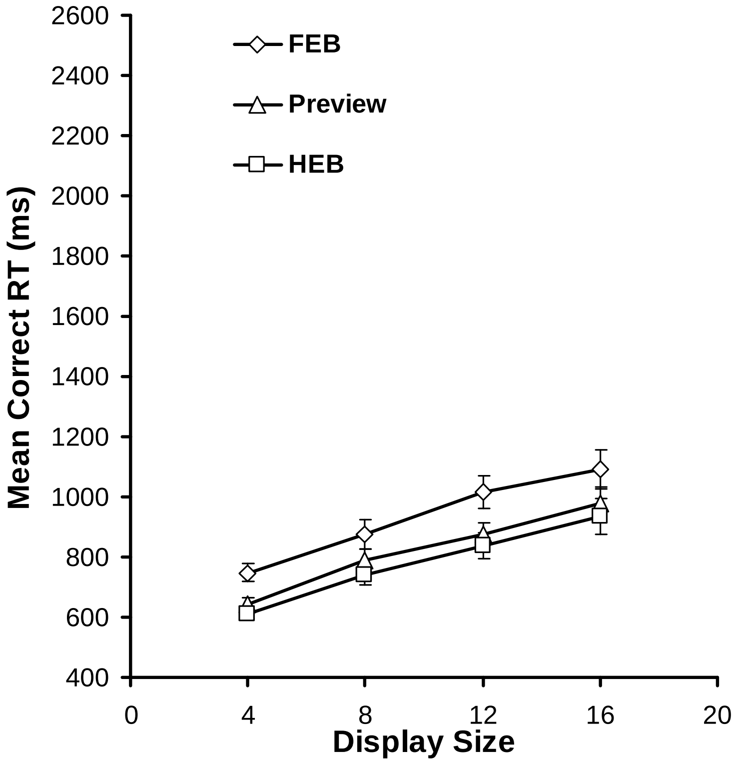


Figure 2. An example preview search trials with a positive face target and display size of 8 from Experiment 1.

A) Negative targets amongst neutral distractors.



B) Positive targets amongst neutral distractors.

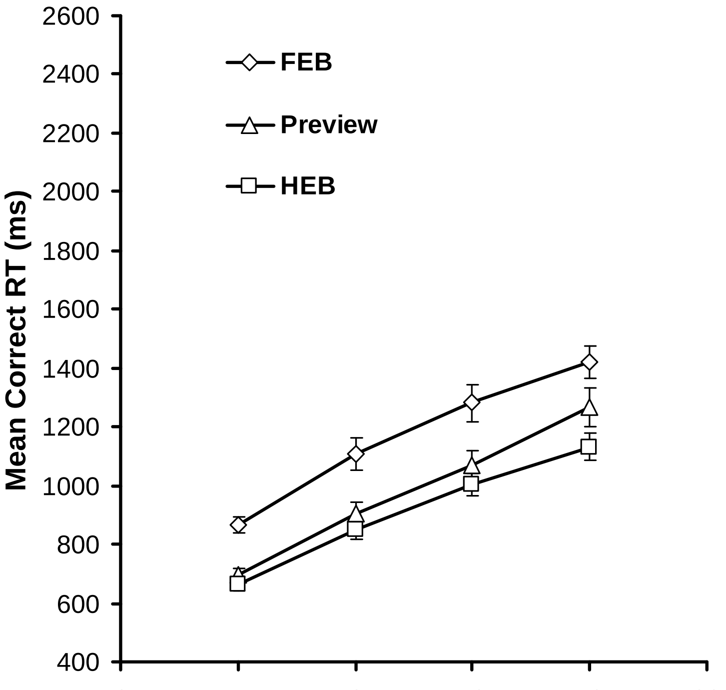


Figure 3. Mean correct RTs for detecting negative targets (Panel A) and positive Targets (Panel B) as a function of condition and display size for Experiment 1. Error bars indicate ±1 standard error.

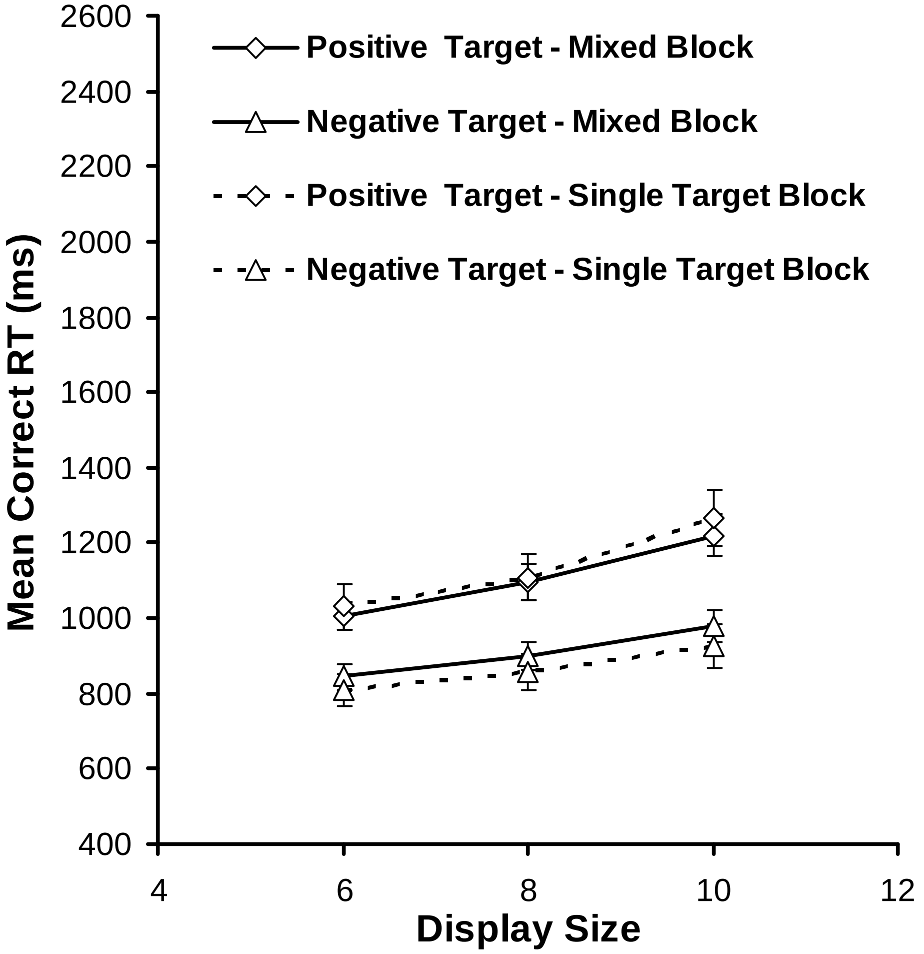


Figure 4. Mean correct RTs for as a function of condition and display size for Experiment 2. Error bars indicate ±1 standard error.

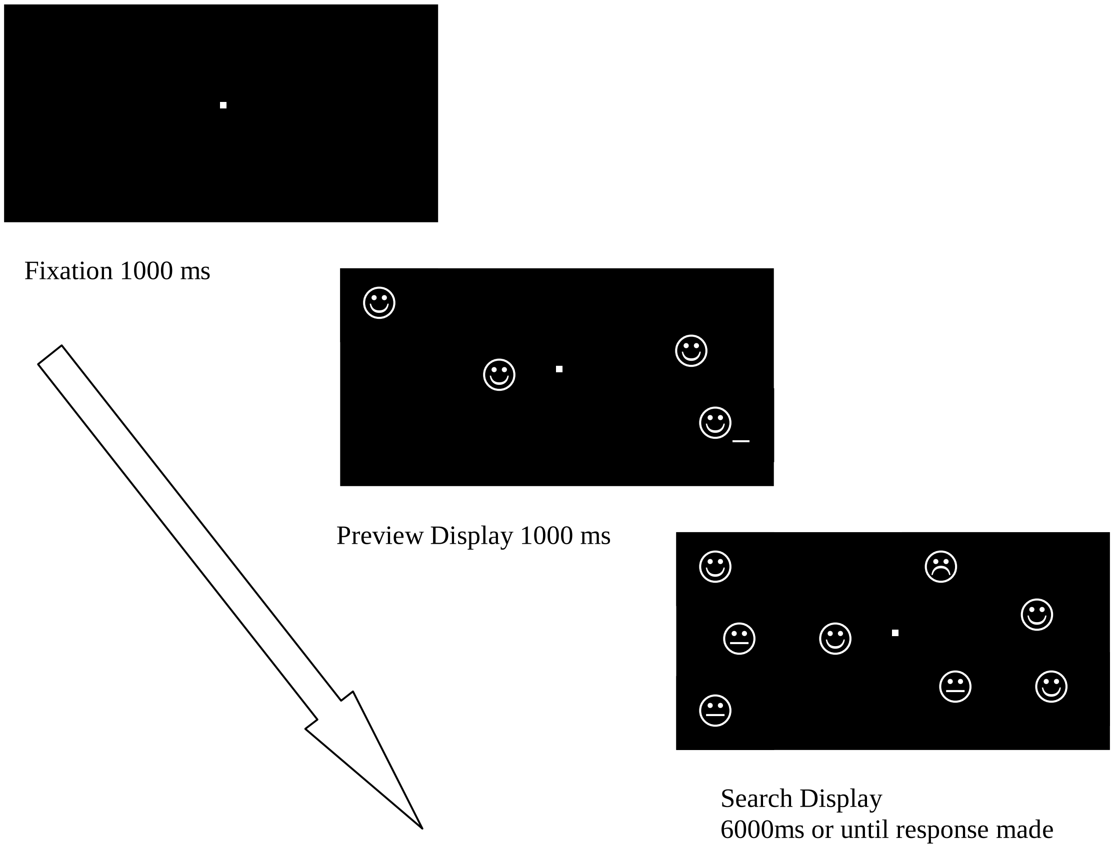


Figure 5. An example preview search trial with a negative target and positive preview distractors from Experiment 3.

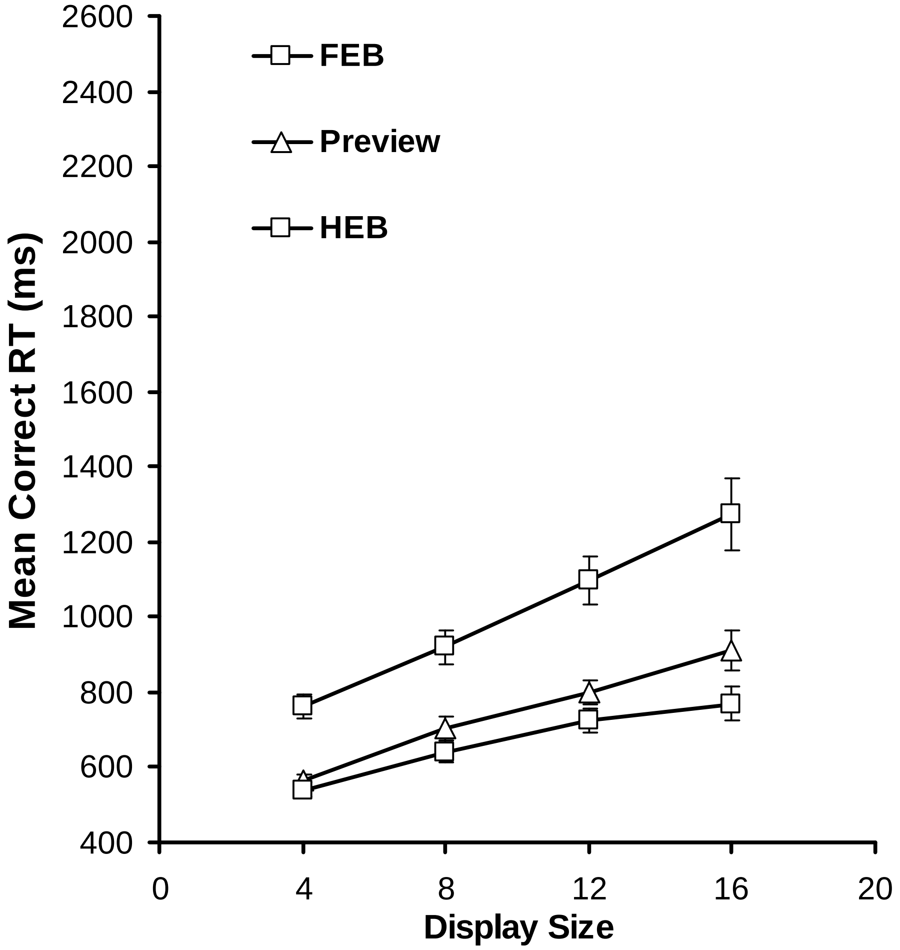


Figure 6. Mean correct RTs for as a function of condition and display size for Experiment 3. Error bars indicate ±1 standard error.

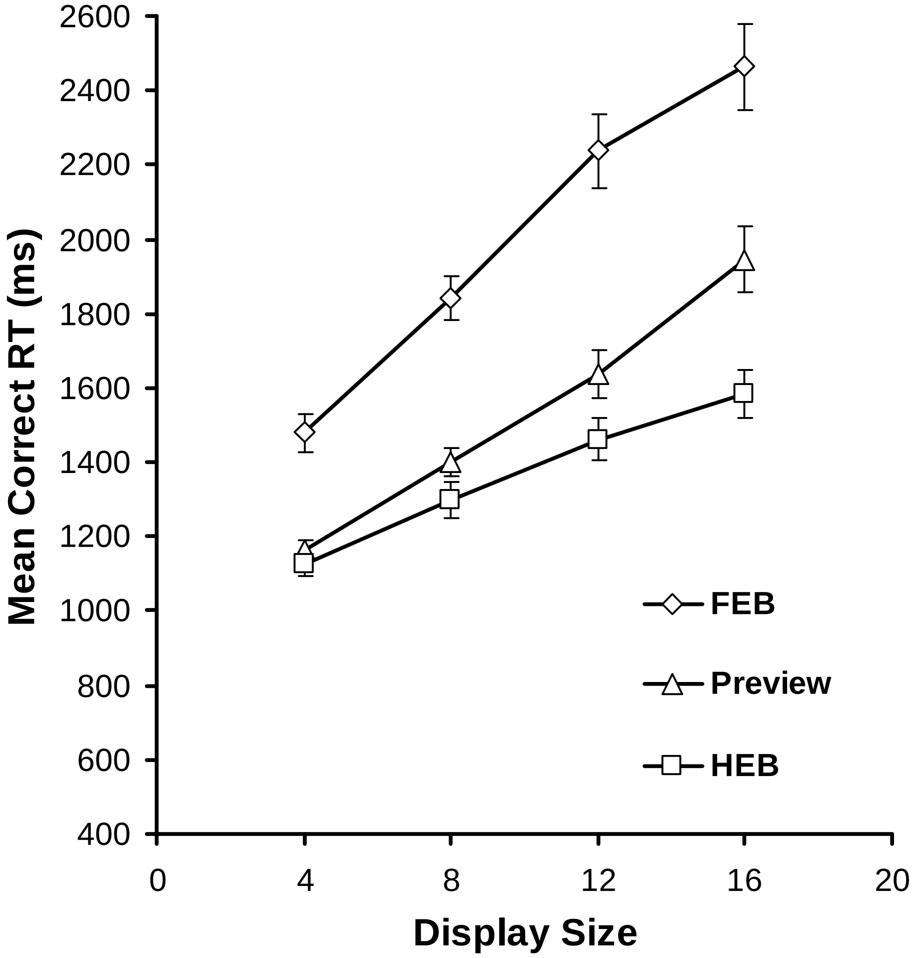
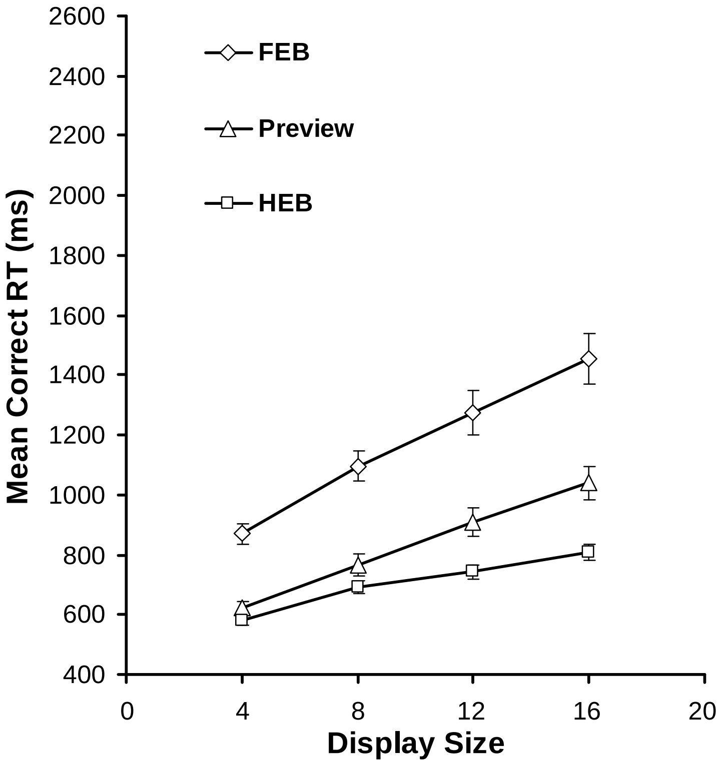


Figure 7. Mean correct RTs for as a function of condition and display size for Experiment 4. Error bars indicate ±1 standard error.

A) Ignoring positive faces



B) Ignoring negative faces

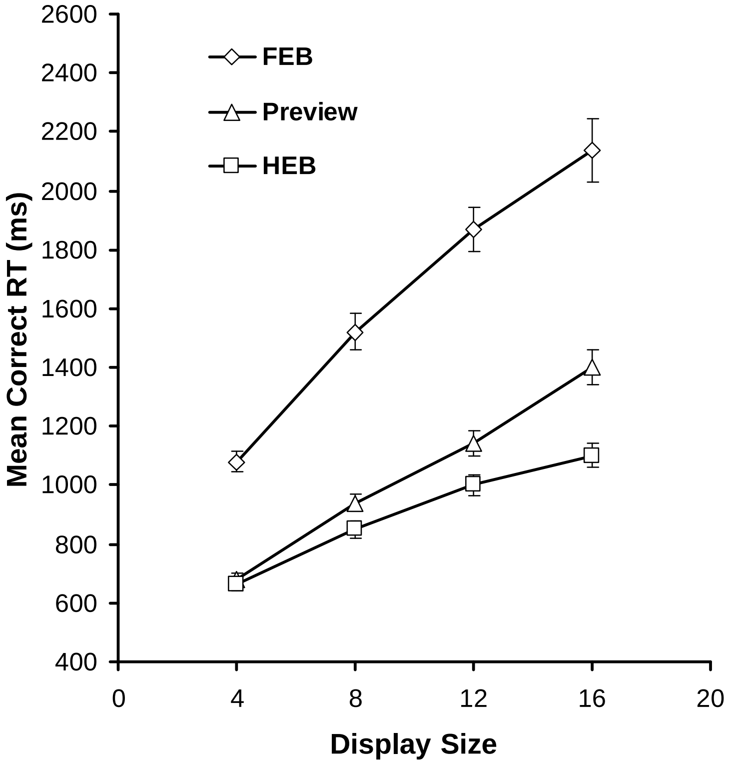


Figure 8. Mean correct RTs for ignoring positive distractors (Panel A) or negative distractors (Panel B) as a function of condition and display size for Experiment 5. Error bars indicate ±1 standard error.