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Ignoring real faces: Effects of valence, threat, and salience

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Abstract Facial stimuli have been shown to accrue a special status within visual processing, particularly when attention is prioritized to one face over another on the basis of affective content. This has been examined in relation to the ability of faces to guide or hold attention, or to resist attentional suppression. Previous work has shown that schematic faces can only be partially ignored and that the emotional valence of to-be-ignored faces has little effect. Given recent debates concerning the use of schematic faces, here we examined the ease with which photorealistic faces could be ignored. Although we found evidence of a partial preview benefit for these stimuli, the findings were complex, with stimulus salience, valence, and threat content interacting to affect both the strength of the benefit and target detection efficiency (Exps. 1–3). Experiment 4 then clarified the effects of physical salience and perceived stimulus similarity in the previous experiments, demonstrating that a combination of these factors is likely to account for the search patterns observed.

Keywords Visual marking · Visual search · Faces · Emotion · Valence

Introduction

Being able to select newly arriving information with priority over already visible information provides a number of ecologically useful advantages in a rich visual environment. Previous work with relatively abstract stimuli (e.g., letters or shapes; see Donk & Theeuwes, 2001, 2003; Emrich, Ruppel, Al-Aidroos, Pratt, & Ferber, 2008; Gibson & Jiang, 2001; Jiang, Chun, & Marks, 2002; Osugi, Kumada, & Kawahara, 2009, 2010; Watson & Humphreys, 1997, 1998; for a summary, see Watson, Humphreys, & Olivers, 2003) has shown that participants are able to ignore currently visible information, restricting their attention to new items when they arrive. For example, in one experiment Watson and Humphreys (1997) presented a set of "old" irrelevant letter stimuli (green H distractors) for 1,000 ms, followed by a "new" set of distractors (blue As) that, on target-present trials, also contained a blue H target. Performance in this preview condition was as efficient as in a half-element baseline (HEB) condition, in which only the new items were presented, and was much more efficient than when all of the items (old and new) were presented at the same time (the full-element baseline, or FEB). Thus, previewing one set of stimuli before another set allowed the old items to be discounted from future search. This increase in search efficiency when a preview of old items is given has been termed the preview benefit (Watson & Humphreys, 1997; Watson, Humphreys, & Olivers, 2003). Explanations for the preview benefit include the top-down inhibition of old items in the field (e.g., Watson & Humphreys, 1997), automatic capture of attention by the luminance changes (e.g., Donk & Theeuwes, 2001) and asynchronous grouping between the old and new stimulus sets (e.g., Jiang et al., 2002).

Irrespective of the precise underlying mechanism(s), recent work (Blagrove & Watson, 2010) has shown that the ability to ignore old items also extends to symbolic face stimuli. That is, participants were able to ignore previewed schematic faces and confine their search to a group of newly appearing faces, in order to find a particular target stimulus. However, in contrast to work with letter stimuli, when faces were used, only a partial preview benefit was obtained. Preview search efficiency now fell between the HEB and FEB conditions, rather than showing a statistical equivalence with the HEB condition as seen in previous work.

This partial preview benefit suggests that faces cannot be ignored as effectively as other types of non-facial stimuli, and

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the resulting inability to ignore faces fully could reflect the high status of facial stimuli in terms of our everyday social interactions. Faces and facial expressions are widely held to be an important source of behavioral information, vital for effective socioemotional functioning (e.g., Carey, De Schonen, & Ellis, 1992). Thus, it might be considered adaptive for these stimuli to be resistant to suppression.

Blagrove and Watson (2010) also examined the influence of the emotional valence of the stimuli, in respect of both stimuli to be ignored (i.e., old, previewed items) and search targets. Focusing here on the former, previous work has shown that negatively valenced stimuli are more likely to capture and hold onto our attention than neutral or positively valenced stimuli—a collection of valenced-based effects that may reflect the adaptive importance of detecting, locating and processing potential threat in our environment (e.g., Eastwood, Smilek, & Merikle, 2001, 2003; Fenske & Eastwood, 2003; Fox et al., 2000; Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Hampton, Purcell, Bersine, Hansen, & Hansen, 1989; Hansen & Hansen, 1988; Horstmann, Borgstedt, & Neumann, 2006; Öhman, Lundqvist, & Esteves, 2001).

Based on this, we might expect that the ability to ignore negative stimuli would be impaired relative to positive stimuli. Indeed, this was found to be the case, but only when previewed negative faces were presented for relatively short amounts of time. For example, Blagrove and Watson (2010) found that initially it took longer to ignore negative faces, but after approximately 750 ms, no difference was apparent in the ability to ignore either type of valenced face. Overall, these findings showed that (1) whilst schematic faces can be partially ignored, their behavioral relevance appears to prevent full attentional suppression, and (2) after 750 ms, there is no difference in the ability to ignore either type of emotionally valenced face.

However, it is important to note that these findings were based on stimuli that used symbolic facial representations. The visual properties of schematic faces can be highly controlled and thus they might be considered a more straightforward facial representation in this sense (e.g., Blagrove & Watson, 2010; Eastwood et al., 2001; and see Frischen, Eastwood, & Smilek, 2008, for a review). However, numerous authors have pointed out substantial issues with their use, and a debate over potential confounds has emerged recently within the literature (e.g., Becker, Horstmann, & Remington, 2011; Mak-Fan, Thompson, & Green, 2011). Such problems have been highlighted previously in work when subtle variations in facial expression have been introduced into schematic stimuli (e.g., Horstmann & Ansorge, 2009; Öhman et al., 2001; but cf. Purcell & Stewart, 2010). Moreover, when attempting to control for perceptual differences, one also runs the risk of removing or altering the properties that define the stimulus. For example, the inclusion of a simple feature, such as an eyebrow, in schematic stimuli has been suggested to induce a negative valence response, irrespective of the facial context (e.g., Larson, Aronoff, & Stearns, 2007; Schubö, Gendolla, Meinecke, & Abele, 2006; Tipples, Atkinson, & Young, 2002; see Watson, Blagrove, & Selwood, 2011, Watson, Blagrove, Evans, & Moore, 2012, for further discussion of this point).

More specifically, it is quite possible that low level perceptual features in simple schematic stimuli may introduce confounds that underlie the attentional effects seen in affective faces overall (i.e., the higher contrast of the arcs forming a facial outline and a down-turned "negative" mouth, compared with a "positive" up-turned mouth). In fact, recent work has highlighted the impact of this aspect of negative schematic faces, failing to show a processing advantage for negative faces, when this particular contrast is controlled for (e.g., Becker et al., 2011; Mak-Fan et al., 2011; and see Walley & Weiden, 1973, for an account based on lateral inhibition). Moreover, when focus rests specifically on the low-level visual salience of the face representation alone (both schematic and photorealistic stimuli), some evidence has indicated that "typical" search advantage disappears and is replaced by preferential processing of positive faces (see Calvo & Nummenmaa, 2008, 2011).

In addition to these potential issues, it is also likely that the emotional signals conveyed by more realistic, photographic representations of faces are stronger, and more ecologically valid than those able to be conveyed by the simplest schematic equivalents (e.g., Hampton et al., 1989; Hansen & Hansen, 1988; Williams, McGlone, Abbott, & Mattingley, 2008; Williams, Moss, Bradshaw, & Mattingley, 2005). Thus, realistic faces might hold additional subtle visual cues that might further influence their processing compared with schematic stimuli, and the signals presented might be perceived more directly than with symbolic face representations.

In terms of the efficiency of ignoring faces, current theory suggests that old faces can be partially ignored, but that face valence has little impact beyond a couple of hundred milliseconds or more. However, the above considerations weaken this theoretical position and suggest that the findings obtained with schematic stimuli might well not hold when we consider more realistic faces. For example, first, if realistic faces represent a "stronger" face signal to the visual system, then it might not be possible to ignore real faces at all. Second, realistic faces might well present stronger and/or a wider range of cues to their emotional expression/valence than simple symbolic representations of expression. The expressions signaled by real faces might also be more directly perceived, with less impact of potential low-level confounds. Accordingly, we might expect to find strong effects of stimulus valence when realistic stimuli are used even at the relatively long preview durations used here.

Purpose of the present study

The present study had two main aims: (1) to test the current theory that facial stimuli can be ignored in favor of new stimuli even when highly realistic photographic stimuli are used, and (2) to determine whether valence-based differences emerge when trying to ignore realistic faces. A further aim was to examine the potential interaction between the salience of visual features and valence both across positive and negative stimuli, and within the negative valence class (sad vs. threatening).

In order to provide a comprehensive test of the ability to ignore realistic faces, we present three experiments based on the preview paradigm, in which we tested facial stimuli possessing a range of emotional and visual properties. In outline, Experiment 1 provided a basic test of ignoring positively and negatively valenced facial expressions using photorealistic stimuli. Experiments 2 and 3 examined the ability to ignore potentially stronger signals of negative affect (i.e., threatening expressions) and the influence of salient visual features (specifically, an open or closed mouth) on processing. A fourth Experiment examined issues of physical salience and stimulus similarity that arose in Experiments 1–3, specifically evaluating the effects that unique features within stimulus faces may have on search via computational salience simulations and subjective ratings.

Beyond previous work, in the present experiments we also evaluated the possible difference between ignoring negatively valenced faces that are not threatening (Exp. 1), as compared with those that have some threat content (Exps. 2 and 3). This is particularly relevant, as often the emotional face stimuli used in visual attention paradigms (i.e., flanker, search, cueing tasks; see, e.g., Eastwood et al., 2001; Fox et al., 2002; Horstmann et al., 2006) can be categorized in subtly different ways across studies (e.g., by valence, emotion, threat content). This can make comparisons difficult, and can lead to the assumption that effects frequently observed in the literature (e.g., the negative face search advantage) are more generalizable than is perhaps warranted (Calvo & Nummenmaa, 2008, 2011; Juth, Lundqvist, Karlsson, & Öhman, 2005).

By using this approach, we aimed to address the questions of interest, whilst also determining the possible influence of visual features that may or may not be important for defining the emotional status of the stimuli in this and related research. In order to match the conditions of Blagrove and Watson (2010) as closely as possible, a search display contained at most two different types of face distractors, and the faces used as stimuli remained constant throughout a block of trials. In addition, from the perspective of stimulus homogeneity (i.e., Calvo & Nummenmaa, 2008, 2011), had a range of different faces been used within/across trials, any inability to ignore preview faces could have been attributable to this difference between studies. Thus, we aimed to make the present findings with realistic photographic faces as comparable as possible to the previous work on time-based selection using schematic faces.

Experiment 1: Preview search with negative and positive previewed photographic faces

Experiment 1 examined preview search with positively or negatively valenced photographic face previews and targets (i.e., previewed faces were of one valence, and target faces, the opposite valence). For the first twelve participants, previews consisted of negative face distractors, with a positive face target. For the second half of the participant set, this was reversed. This experiment determined whether realistic faces could be ignored, using a photographic representation of the simple negative–positive emotional valence distinction used previously in Blagrove and Watson (2010; e.g., "happy" positive face target vs. "sad" negative face preview). In particular, it tested the influence of photorealistic valence signals and provided a test of the general negative-face search advantage theory.

Method

Participants

A group of 24 students at the University of Warwick (18 female, 6 male) participated in this study, either for payment or course credit. Participants in Experiment 1 were between 18 and 20 years old (M = 18.7 years), and all but one were right-handed. All participants self-reported normal or corrected to normal vision. Half of the participants were allocated to the positive preview condition and half to the negative preview condition.

Stimuli and apparatus

A Gateway GP6 400 computer was used to present all displays and to record participant responses in this and the subsequent experiments. Stimuli were displayed on a 17-in. Gateway VX 700 monitor with 800 × 600 pixel resolution and 75-Hz refresh rate, positioned at eye level at a viewing distance of approximately 60 cm. The facial stimuli were modified versions of the Pictures of Facial Affect (PoFA; Ekman & Friesen, 1976) and are shown in Fig. 1 (positive face, PoFA code 001; negative face, code 002; neutral face, code 006). These stimuli were selected to provide a test of time-based selection with photographic facial stimuli that matched the affect and visual properties of the schematic stimuli that had been used previously (Blagrove & Watson, 2010) as closely as possible.

All stimuli were presented in grayscale against a light gray background (RGB values = 200, 200, 200). For 12 of the participants in Experiment 1, the target was a positive face presented among neutral faces, and the preview distractors had a negative expression. For the other 12 participants, targets were a negative face presented amongst neutral faces, and the preview distractors had a positive expression. All

Face stimulus

Valence	Positive	Neutral	Negative	Negative	Negative
Threat	Non-threat	Non-threat	Non-threat	Threat	Threat
PoFA code	001	006	002	005	003

Fig. 1 Examples of photographic facial stimuli, by valence, threat, and PoFA code

photographic faces were cropped in order to remove hair from the image, leaving an ellipse with dimensions of 16 × 22 mm approximately.

Search displays were generated by randomly positioning items within an invisible 6 × 6 matrix, with an interelement display spacing of 75 pixels (approximately 29 mm). Stimulus positions were then jittered by up to ± 7 pixels on both the 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, depending on the participants' condition assignment) taking the place of one of the neutral distractors. The target was displayed equally often to the left and the right of midline. Targets were not presented in the center two columns of the matrix (i.e., they were only presented in columns 1, 2, 5, and 6), to ensure that they could be easily distinguished from the midline of the display (and therefore, that response times [RTs] would not be influenced by difficulty in differentiating between the sides of the screen). The 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 a small proportion of trials (referred to as *catch trials*), no target face was presented.

Design and procedure

The experiment was conducted in a dimly lit, sound-attenuated room and took approximately one hour to complete. A 3 (Condition: HEB, FEB, preview) × 4 (display size) × 2 (preview type: ignore positive or negative faces) mixed design was used, with preview type as the only between participants factor. For 12 participants, the target was a positive face, the preview set consisted of negative faces and the search distractor set comprised neutral faces. Valence of the target and preview set were reversed for the other 12 participants (see Fig. 1 for examples of the facial stimuli).

A trial in the HEB and FEB conditions consisted of a blank screen (1,000 ms), followed by a dark gray central fixation dot (2 × 2 mm) for 1,000 ms, followed by the search display. The preview condition was similar, except that half of the distractors were presented for 1,000 ms before the search display, which contained the target, when one was present (see Fig. 2). Participants were asked to locate the target and to indicate whether it was to the left or the right of the display center by pressing the "Z" or the "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 contained the target (when present).

In all conditions, the search display remained on screen until the participant responded or for 6,000 ms, after which the next trial began automatically. Errors were signaled by a short tone (1000 Hz, 500 ms). Each search condition was run in a separate block of 160 experimental trials, with a further 16 catch trials, in which no target was present. Each participant completed one block of trials per search condition, with a practice block of 20 trials preceding each condition. Trial order was randomized within a block, and the order of search conditions was fully counterbalanced.

Results

Reaction time data

All RTs <150 ms were discarded (eight out of 11,520) and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. The overall mean correct RTs and search slopes are shown in Fig. 3.

As in previous research on the preview benefit, search slopes were plotted and calculated using the same display sizes from the FEB condition for both the preview and HEB conditions. This provided values for the HEB that would be expected if observers were able to fully ignore the old items in the preview condition, and allowed for comparison of the preview condition with both baseline conditions (i.e., HEB and FEB). A 3 (condition: HEB, FEB, preview) × 4 (display size) × 2 (preview type: positive or negative) mixed analysis of variance (ANOVA) was first performed, to determine the existence of overall search performance differences across the preview and baseline conditions and any differential influence of distractor/target valence.

Additional follow-up mixed ANOVAs (comparing the preview condition with the FEB and the preview condition with the HEB individually) were then conducted in order 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 that in the FEB, but not in the HEB. In contrast,

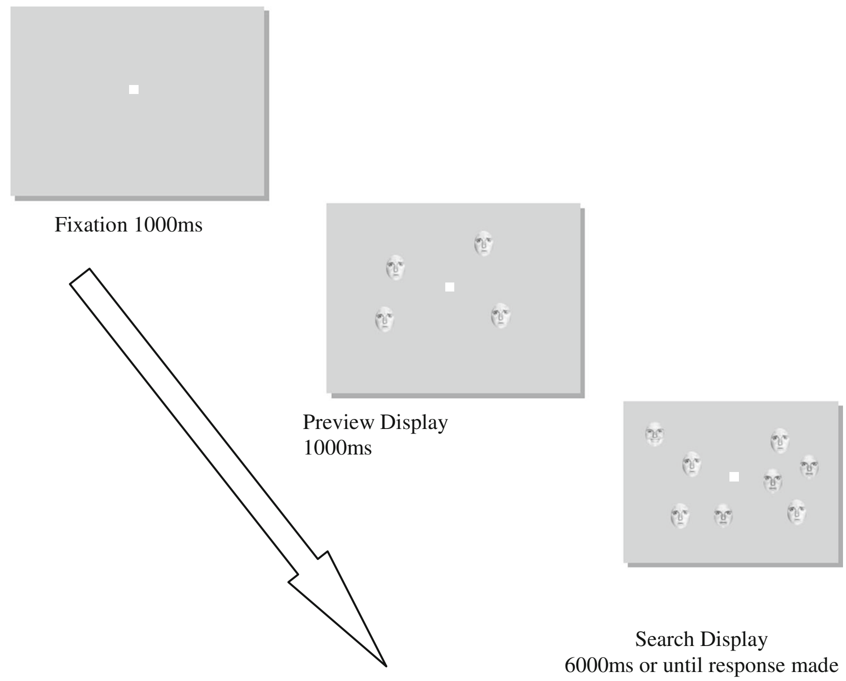


Fig. 2 Example preview search trial with a positive face target and negative preview in the display size 8 condition from Experiment 1

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). For clarity, the patterns of results for the most relevant findings are described below, with full details of the ANOVA results presented in Table 1. As an additional check to test whether a preview benefit occurred, we also analyzed the HEB versus preview and the FEB versus preview conditions separately (within preview type). For brevity, we will report only the Condition × Display Size interactions for these comparisons.

HEB, FEB, and preview conditions Overall, RTs increased with display size, were longest in the FEB and *ignore positive* preview conditions (i.e., with negative targets), and were shortest in the HEB and *ignore negative* preview conditions (i.e., with positive targets). However, of most interest, the effects of display size differed across conditions: Search was most efficient in the HEB and least efficient in the FEB condition. In addition, search was more efficient for finding a positive target (i.e., with negative previews) than for finding a negative target (i.e., with positive previews).

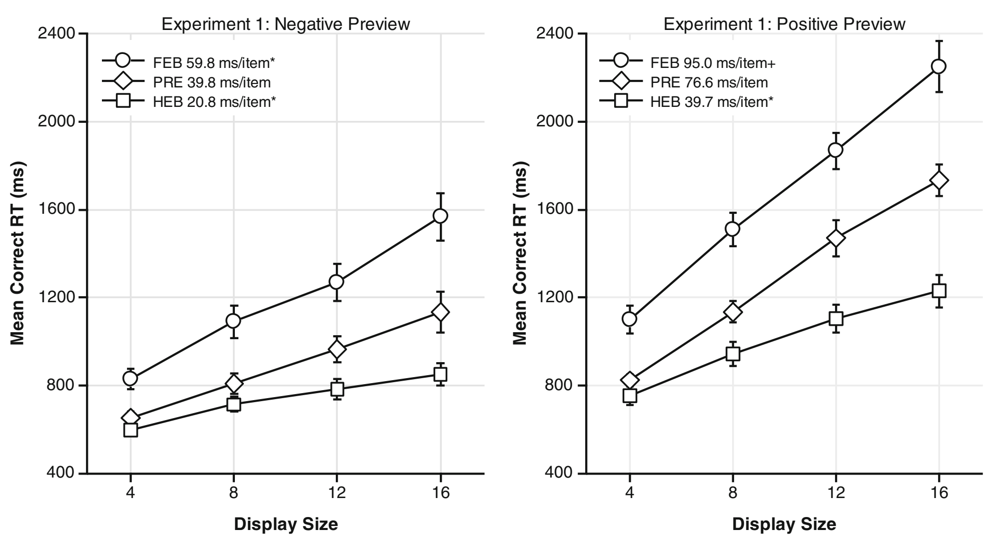


Fig. 3 Mean correct response times (RTs) and search slopes for ignoring negative (sad) previewed faces (left) and positive (happy) previewed faces (right), as a function of condition and display size for Experiment 1. *Preview search efficiency differed significantly from this baseline. +Preview search efficiency was marginally different from this baseline. Error bars indicate ± 1 standard error

Table 1 ANOVA results for Experiment 1, by comparison, search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), and display size (DS; within-subjects factors) and preview type (PT; between-subjects factor)

	df	*F*	η_p^2	Significance
HEB–FEB–Preview				
Condition	2, 44	87.60	.799	.001
Condition × PT	2, 44	3.41	.134	.042
DS	3, 66	370.54	.944	.001
DS × PT	3, 66	28.22	.562	.001
Condition × DS	3, 66	108.77	.83	.001
Condition × DS × PT	6, 132	1.53	.065	.172
PT	1, 22	30.53	.581	.001
FEB–Preview				
Condition	1, 22	42.39	.66	.001
Condition × PT	1, 22	0.78	.03	.39
DS	3, 66	357.86	.94	.001
DS × PT	3, 66	25.66	.54	.001
Condition × DS	3, 66	8.2	.27	.001
Condition × DS × PT	3, 66	0.01	.001	.99
PT	1, 22	33.29	.60	.001
HEB–Preview				
Condition	1, 22	35.24	.62	.001
Condition × PT	1, 22	3.13	.12	.09
DS	3, 66	192.29	.90	.001
DS × PT	3, 66	19.24	.47	.001
Condition × DS	3, 66	25.3	.54	.001
Condition × DS × PT	3, 66	2.65	.11	.06
PT	1, 22	31.6	.59	.001

Preview versus FEB Search was overall faster and more efficient in the preview condition than in the FEB baseline. We found no evidence that this differed depending on whether participants were ignoring positive or negative previewed distractors. In addition, search was overall faster and more efficient for finding a positive target.

Preview versus HEB The main findings of interest were that responses were faster overall and search was more efficient in the HEB condition than in the preview condition, regardless of target or distractor valence. In addition, responses were faster overall and search was more efficient for finding a positive target than for finding a negative target.

Within preview type comparisons As a further test to determine whether a preview benefit had occurred in the two preview type conditions, we carried out separate within-subjects ANOVAs for the negative and positive preview conditions. For the ignore negative preview condition, this revealed a significant Condition × Display Size interaction for both the FEB–preview and HEB–preview comparisons, $F(3, 33) = 10.78$, $p < .001$, $\eta_p^2 = .495$, and $F(3, 33) = 11.33$, $p < .001$, $\eta_p^2 = .507$, respectively. For the ignore positive preview condition, the Condition × Display Size interaction approached significance for the FEB–preview comparison, $F(3, 33) = 2.38$, $p = .088$, $\eta_p^2 = .178$,[1] and was highly significant for the HEB–preview comparison, $F(3, 33) = 14.92$, $p < .001$, $\eta_p^2 = .576$. Thus, when analyzing at the condition level, we observed a robust but partial preview benefit for ignoring negative faces, but only a marginal benefit (in a nondirectional test) for ignoring positive faces.[2]

Error data

The mean percentage errors for this experiment are shown in Table 2. Overall, error rates were low on both search trials (ignore negative distractors, 0.82 %; ignore positive distractors, 1.48 %), and catch trials (ignore negative distractors, 3.65 %; ignore positive distractors, 2.60 %) and were not analyzed further.

Discussion

The main aim of Experiment 1 was to determine whether realistic faces can be ignored, and whether negative faces can be ignored as easily as positive faces. Consistent with Blagrove and Watson's (2010) finding with schematic face stimuli, we obtained a robust but partial preview benefit for ignoring realistic negative valenced faces. That is, search efficiency in the preview condition fell between the two baselines. A full preview benefit would have been indicated by equivalent search efficiency in the preview and HEB. A total lack of preview benefit would have been shown by equivalent search in the FEB and preview condition. However, two surprising results emerged.

First, in contrast to Blagrove and Watson (2010), an arguably weak/marginal preview benefit was obtained when ignoring positive faces. On the basis of the theory reviewed in the introduction, we would have expected the opposite. Second, when comparing search performance for negative and positive face targets, we found an unexpected search advantage for the positive face target (but cf. Calvo & Nummenmaa, 2008, 2011; Juth et al., 2005). Although this result has been documented previously, it is inconsistent with the search advantage seen for previewed schematic faces (Blagrove & Watson, 2010). One reason for this might be that the negative

[1] Note that this is according to a nondirectional test. On the basis of previous work, we would expect that the slope in the preview condition would be shallower than that of the FEB. With such a directional prediction, the p value would be significant at the .05 level.

[2] We note that this preview difference did not emerge in the omnibus ANOVA, most likely because of increased noise introduced by inclusion of the between-subjects factor.

Table 2 Mean percentage error rates for Experiment 1, by search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), preview valence, and display size

	Display Size				
HEB:	2	4	6	8	Mean
FEB:	4	8	12	16	
Search Trials					
Ignoring Negative					
HEB	1.04	0.63	1.04	0.42	0.78
FEB	0.21	0.42	0.42	2.29	0.83
Preview	1.25	0.00	1.46	0.63	0.83
Ignoring Positive					
HEB	0.83	0.63	0.42	0.63	0.63
FEB	1.46	1.88	2.08	3.33	2.19
Preview	0.63	1.04	1.88	2.92	1.61
Catch Trials					
Ignoring Negative					
HEB	12.50	2.08	0.00	2.08	4.17
FEB	8.33	2.08	0.00	2.08	3.13
Preview	8.33	4.17	2.08	0.00	3.65
Ignoring Positive					
HEB	12.50	0.00	0.00	0.00	3.13
FEB	2.08	0.00	2.08	0.00	1.04
Preview	12.50	0.00	2.08	0.00	3.65

faces (here, displaying a sad expression) may not have presented a sufficiently strong threat signal for a negative face search advantage (e.g., Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001) to emerge. However, this seems unlikely because the negative targets produced less efficient search than the positive targets. If the threat signal had simply been weak in our negative stimuli, then we might have expected no difference in search efficiency between the positive and negative facial targets.

There are two likely explanations for this finding. First, it is possible that a salient feature (the open mouth) within the positive face acted to draw attention, making the positive face stand out of the display. Second, observers might have been able to use the open mouth region, unique to the positive face, to help top-down processes guide attention to the target more easily (Wolfe, 1994). In this sense, the open mouth might not have captured attention by way of bottom-up salience, but rather provided a visually distinct cue to allow attention to be guided to it.

Related to this, it is possible that stimulus similarity also played a role in driving this finding. According to attentional engagement theory (AET; Duncan & Humphreys, 1989), search efficiency improves with (1) the increasing extent to which a target item matches an internal target template, (2) the increasing extent to which the target differs visually from the distractors (the target–distractor [T-D] similarity), and (3) the increasing extent to which the distractors are similar to each other (the distractor–distractor [D-D] similarity). With the stimuli used in Experiment 1, it is likely that the D-D similarity was greater when searching for the positive target (e.g., when both distractors had closed mouths), than when searching for the negative target (e.g., when one distractor had a closed mouth and one an open mouth). Likewise, the biggest visual difference between the target and the distractors is likely to have occurred in the positive (open mouth) target condition. We return to these considerations in Experiment 4.

In terms of time-based selection, why might we have obtained a robust preview benefit for ignoring negative faces, yet only a weak benefit for ignoring positive ones? On the basis of some previous work, we would expect that ignoring negative faces would be equivalent to or more difficult (e.g., Blagrove & Watson, 2010; Eastwood et al., 2003; Fenske & Eastwood, 2003; Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Horstmann et al., 2006) than ignoring positive faces. One possibility is that the negative face target was detected so efficiently that there was simply no room left for improvement by presenting one set of distractors first. However again, this is unlikely because search slopes for detecting the negative target were steep (approximately 95 ms/item, in the FEB), rendering the search for the negative target very inefficient (Wolfe, 1998).

Another possibility is that the preview benefit might be limited in the amount of time that the suppression of old items can be sustained for, once search begins. For example, Emrich, Ruppel, Al-Aidroos, Pratt, and Ferber (2008) found that in preview conditions, saccades can only be prioritized for up to approximately four new elements, after which all items (i.e., both old and new) are treated equivalently (but cf. Watson & Inglis, 2007). Related to this, Watson and Kunar (2012) recently found that when all new items had to be responded to, prioritization was limited to approximately six to seven new elements. More importantly, this capacity was reduced if a delay was introduced between the onset of the new items and when participants were allowed to start selecting the new elements (see also Watson, Compton, & Bailey, 2011).

Thus, it is possible that the ability to ignore old items decreases over time and we might therefore expect a weaker preview benefit (or ultimately, none at all) when new-item targets are particularly difficult to find (e.g., with negative face targets in Exp. 1). Note that search slopes obtained in Experiment 1 for negative face targets were approximately double those seen in previous work with geometric stimuli (e.g., Watson & Humphreys, 1997), and those in which a robust partial preview benefit for ignoring positive schematic faces (Blagrove & Watson, 2010) was demonstrated. The combination of relatively *difficult-to-ignore* preview stimuli (i.e., faces) and a *difficult-to-find* new item target might have led overall to a weakened (i.e., marginally significant) preview benefit when ignoring positive faces.

To assess these possibilities in Experiment 2, we replicated Experiment 1, but used negatively valenced faces that also displayed open mouths. Thus, in terms of the uniqueness of the mouth region, the negative and positive facial stimuli were now better matched.

In respect of positive or negative valence-based search differences, two results are possible. First, by equating the visual features of the mouth region across the positive and negative facial targets, we might obtain the "typical" search advantage for negative face targets. This prediction assumes that the presence of a visually unique feature simply adds to any emotionally driven attentional guidance. Alternatively, any potential valenced-based search differences might be washed out due to the ability of the distinct mouth region to guide attention efficiently. Also, better equating the visual features across mouth regions will make T-D and D-D grouping more similar across valence conditions. All these considerations predict that search efficiency should become more similar for the detection of both negatively and positively valenced targets in comparison with Experiment 1 (and, now potentially, a negative search advantage might occur).

In terms of the preview benefit, making the mouth region more equivalent in negative stimuli should also increase search rates for that target. That is, equating the search rates for positive and negative targets should eliminate any potential preview benefit differences that might be attributable to the uniqueness of the mouth region alone. It follows that, if the marginal preview benefit obtained when searching for negative targets (Exp. 1) was due to search being particularly slow, then increasing search efficiency should strengthen the preview benefit in that condition.

However, by matching the perceptual properties, the threat signal in the negative faces might also have been increased (i.e., to a more threatening, open-mouthed facial display; see Tipples, 2007, for a discussion of the open mouth feature, Calvo & Nummenmaa, 2008, for discussion of the role of facial feature salience and Öhman et al., 2001; Williams, McGlone, Abbott, & Mattingley, 2008; Williams et al., 2005, for details of differential effects of negative valence and threat). In other words, the use of negative faces with open mouth displays may also increase the relative strength of facial affect between valences, with negative faces increasing in threat content in this experiment.

To assess this possibility, we conducted a rating study to measure the perceived emotional valence and threat content of the faces used. The rating study also allowed us to confirm that differences between our negative and positive stimuli could be perceived by participants (note that stimulus valence rating was not obtained in Blagrove & Watson, 2010). Ratings were obtained for all facial stimuli used in Experiment 1, and for the negative face used in Experiment 2; referred to as the negative (threat–open mouth) face. We also collected ratings for an additional stimulus that we used in Experiment 3—the negative (threat–closed mouth) face, to address the possible influence of the visually salient open mouth feature.

Stimulus rating task

A group of 45 (age range, 18–56 years) participants rated the five photographic facial stimuli used in Experiments 1–3 (see Table 3 for the stimuli). The ratings were obtained using a procedure based on that developed by Lundqvist, Esteves, and Öhman (1999; see also Lundqvist, Esteves, & Öhman, 2004; Lundqvist & Öhman, 2005; Watson & Blagrove, 2012), in which each participant rated each stimulus on five 7-point scales labeled: good–bad, kind–cruel, friendly–unfriendly, pleasant–unpleasant, and threatening–not threatening. The first four scales were designed to obtain valence measures, and the final scale to obtain a rating of threat content for each stimulus. The stimuli were presented on individual sheets of paper (stimulus order randomized), with the five rating scales to the right of each stimulus picture. The stimuli were presented in grayscale on a gray background, and were of approximately the same size as those presented in the computerized search tasks.

Results and discussion

Valence measures Rating responses for each scale were scored from –3 (i.e., reflecting *negative valence*) to +3 (i.e., reflecting *positive valence*). The valence for each stimulus was then calculated by averaging the results over the four valence scales associated with that stimulus, for each participant individually. The overall means and standard deviations are presented in Table 3. A one-way within-subjects ANOVA revealed that the valence ratings differed across stimuli, $F(4, 44) = 193.03$, $p < .0001$, $\eta_p^2 = .814$. Bonferroni-corrected comparisons showed significant differences between all faces (all ts > 11.03, all ps < .05), except for comparisons of the neutral versus negative faces (Exp. 1) and the negative (threat–open mouth, to be used in Exp. 2) versus negative (threat–closed mouth, to be used in Exp. 3) faces. This confirmed the basic difference in perceived valence between the positive and negative faces used in Experiment 1. It also showed that the new stimuli to be used in Experiments 2 and 3 were perceived as being more negatively valenced than those of Experiment 1.

Threat measure These rating responses were scored from –3 (i.e., reflecting *threat*) to +3 (i.e., reflecting *non-threat*), and the average threat values are presented in Table 3. A one-way within-subjects ANOVA revealed that the threat ratings differed across stimuli, $F(4, 44) = 87.19$, $p < .0001$, $\eta_p^2 = .665$. Bonferroni-corrected comparisons showed significant differences between

Table 3 Mean valence, threat ratings, and gray-level pixel values (standard deviations in parentheses) for the stimuli used in Experiments 1–3

	Experiments 1, 2 and 3		Experiment 1	Experiment 2	Experiment 3
	Positive	Neutral	Negative (Non-threat)	Negative (Threat- open mouth)	Negative (Threat- closed mouth)
Stimulus face					
Valence	2.29	0.17	0.11	-2.05	-1.89
	(0.79)	(0.89)	(0.87)	(0.84)	(0.79)
Threat	2.36	1.00	2.16	-1.38	-1.56
	(0.88)	(1.48)	(1.13)	(1.95)	(1.39)
Mean pixel level	201.42	193.39	201.37	202.79	207.09
	(31.929)	(34.79)	(34.851)	(32.256)	(31.576)

all faces (all ts > 4.74, all ps < .05), except for comparisons of the positive versus negative faces and the negative (threat–open mouth) and negative (threat–closed mouth) faces. These findings suggested that the new stimuli to be used in Experiments 2 and 3 were not only perceived as being more negatively valenced than those in Experiment 1, but were also perceived as being more threatening. More generally, the results further suggested that the theoretical concepts of emotional valence and threat should not be conflated when evaluating the affective content of the facial stimuli (see Frischen et al., 2008, for an overview of this issue).

Experiment 2: Preview search with negative (threat–open mouth) and positive previewed photographic faces

Experiment 2 was similar to Experiment 1, except that the negative and positive stimuli were more closely matched for visual features around the mouth region (i.e., both contained open mouths; see Fig. 1). In addition, the negative face was perceived as being more negatively valenced and more threatening than that used in Experiment 1. Accordingly, we might expect these characteristics to maximize the chance of finding any valenced-based differences in the ability to ignore previewed faces, and increase the possibility of obtaining a general negative face search advantage.

Method

Participants

A group of 24 students at the University of Warwick (16 female, eight male) participated in this study, either for payment or course credit. Participants in Experiment 2 were between 18 and 20 years old (M = 18.8 years), and all but two were right handed. All participants self-reported normal or corrected to normal visual acuity. Half of the participants took part in the ignore negative preview condition and the other half in the ignore positive preview condition.

Stimuli and apparatus

The stimuli and apparatus were identical to those in Experiment 1, except that target stimuli were either positive faces or negative faces (see Fig. 1 for the stimuli; PoFA codes: positive face, 001; negative face with open mouth, 005; neutral face, 006); as in Experiment 1, previews consisted of either negative faces or positive faces.

Design and procedure

The design and procedure were identical to those in Experiment 1.

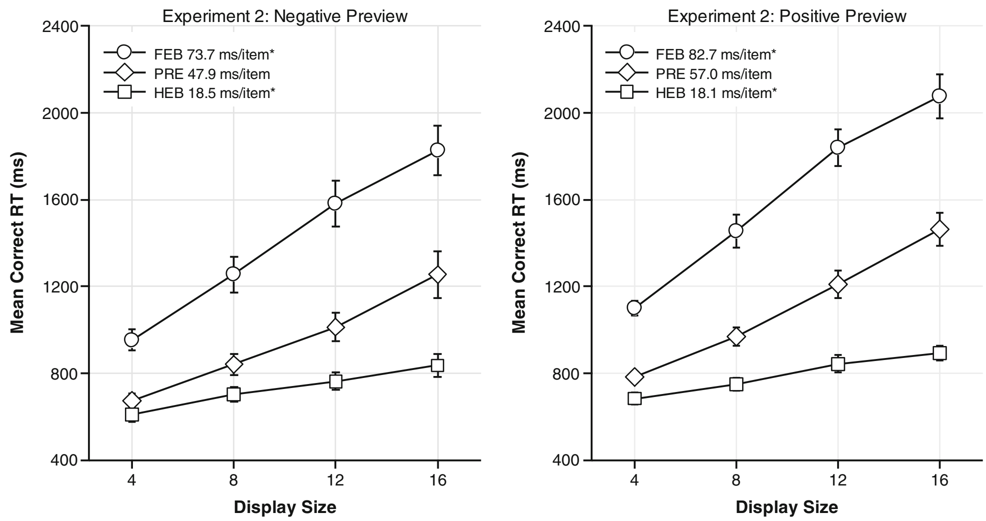
Results

Reaction time data

RTs <150 ms were discarded (seven out of 11,520) and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. The overall mean correct RTs and search slopes are shown in Fig. 4. The data were analyzed using the same strategy as in Experiment 1; full ANOVA details are given in Table 4.

HEB, FEB, and preview conditions Overall, RTs increased with display size, were longest in the FEB and shortest in the

Fig. 4 Mean correct response times (RTs) and search slopes for ignoring negative (threat–open mouth) previewed faces (left) and positive (happy) previewed faces (right), as a function of condition and display size for Experiment 2. *Preview search efficiency differed significantly from this baseline. Error bars indicate ± 1 standard error



HEB condition. However, of most interest, search efficiency differed across the conditions, being most efficient in the HEB and least efficient in the FEB condition. We found no significant influence of preview type (or target type) on overall search slopes across the conditions.

Table 4 ANOVA results for Experiment 2, by comparison, search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), and display size (DS; within-subjects factors) and preview type (PT; between-subjects factor)

	df	*F*	η_p^2	Significance
HEB–FEB–Preview				
Condition	2, 44	151.69	.872	.001
Condition × PT	2, 44	1.49	.064	.236
DS	3, 66	265.23	.923	.001
DS × PT	3, 66	1.13	.049	.344
Condition × DS	6, 132	55.54	.716	.001
Condition × DS × PT	6, 132	0.525	.023	.788
PT	1, 22	5.13	.189	.034
Preview–FEB				
Condition	1, 22	98.75	.82	.001
Condition × PT	1, 22	0.29	.01	.60
DS	3, 66	248.75	.92	.001
DS × PT	3, 66	1.32	.06	.28
Condition × DS	3, 66	15.78	.42	.001
Condition × DS × PT	3, 66	0.06	.003	.98
PT	1, 22	5.04	.20	.03
Preview–HEB				
Condition	1, 22	102.69	.82	.001
Condition × PT	1, 22	3.37	.13	.08
DS	3, 66	131.11	.86	.001
DS × PT	3, 66	0.69	.03	.56
Condition × DS	3, 66	53.62	.71	.001
Condition × DS × PT	3, 66	1.04	.05	.38
PT	1, 22	3.77	.15	.07

Preview versus FEB Search was faster overall and more efficient in the preview condition than in the FEB baseline; this preview benefit was statistically equivalent when ignoring either positive or negative distractors. However, responses were faster overall when searching for a negative target.

Preview versus HEB Responses were faster overall in the HEB condition, RTs increased with display size, and search was less efficient in the preview than in the HEB condition. The valence of the preview display had no significant influence on this pattern of findings.

Within-preview-type comparisons For ignoring negative faces, we observed a significant Condition × Display Size interaction for both the FEB–preview and HEB–preview comparisons, $F(3, 33) = 8.68$, $p < .001$, $\eta_p^2 = .441$, and $F(3, 33) = 20.96$, $p < .001$, $\eta_p^2 = .656$. The same was true for ignoring positive faces: FEB–preview, $F(3, 33) = 7.32$, $p < .005$, $\eta_p^2 = .40$; HEB–preview, $F(3, 33) = 33.16$, $p < .001$, $\eta_p^2 = .751$.

Error data

Mean percentage errors are shown in Table 5. Overall, error rates were low on both search trials (ignore negative, 1.04 %; ignore positive, 1.06 %) and catch trials (ignore negative, 3.30 %; ignore positive, 1.74 %). These data were not analyzed further.

Discussion

Experiment 2 examined preview performance for ignoring negative and positive faces, when these were better matched

Table 5 Mean percentage error rates for Experiment 2, by search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), preview valence, and display size

	Display Size				
HEB: FEB:	2 4	4 8	6 12	8 16	Mean
Search Trials					
Ignoring Negative					
HEB	0.42	0.42	0.21	0.21	0.31
FEB	1.67	1.25	0.63	2.71	1.56
Preview	0.83	0.83	1.46	1.88	1.25
Ignoring Positive					
HEB	0.83	0.00	0.42	0.21	0.36
FEB	0.21	1.88	1.25	2.71	1.51
Preview	1.25	0.42	1.67	1.88	1.30
Catch Trials					
Ignoring Negative					
HEB	12.50	8.33	0.00	2.08	5.73
FEB	0.00	2.08	0.00	2.08	1.04
Preview	6.25	4.17	2.08	0.00	3.13
Ignoring Positive					
HEB	8.33	0.00	0.00	0.00	2.08
FEB	4.17	2.08	0.00	0.00	1.56
Preview	2.08	0.00	2.08	2.08	1.56

for the visual features present in the mouth region. In addition here, the negative stimulus used was perceived as being more negative and more threatening than that used in Experiment 1. The main finding was a robust, albeit partial, preview benefit for ignoring both positive and negative photorealistic faces. Compared with Experiment 1, having an open mouth feature present in the negative face greatly improved search efficiency; this was approximately 70 ms/item obtained in Experiment 1, and 50 ms/item in Experiment 2. This finding is consistent with the idea that the exceptionally slow search rate for the negative target in Experiment 1 was likely to have caused weakening of the representations used to separate the old items from the new, causing the preview benefit to decay over time (Emrich et al., 2008; Jiang & Wang, 2004; Watson & Kunar, 2012).

The second main finding was that no evidence emerged for a valenced-based difference for ignoring previewed faces. This suggests that, at least in some circumstances, photorealistic faces can be partially ignored, but that stimulus valence has little effect. Furthermore, this remains true even in conditions with clear and substantial differences in facial affective content, indicated by the ratings of the negative and positive faces on both valence and threat scales.

The third finding was that, even though the negative face was rated as being more negatively valenced and threatening than that used in Experiment 1, we found no search advantage for finding negative face targets compared with positive targets. This held despite the fact that negative and positive faces were better matched in terms of possessing a visually unique feature, and again, runs contrary to the search advantage that might have been expected for negatively valenced faces.

One possible account for this lack of effect is that participants might have attentionally set themselves (Folk & Anderson, 2010; Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994; see also Horstmann & Becker, 2008) to search for a target defined by a unique feature within the new set. This would be in contrast to them including the target's valence (e.g., a face's negative affect) or threat content in their search template. If the search task could be completed effectively using this strategy, then there might be little difference between searching for a positive or a negative target—as was the case here. Consistent with this account, Watson and Blagrove (2012) recently showed no difference between the rates of enumerating positive or negative targets, when the task could be performed in a way that did not require a negative–positive valence-based discrimination. To test this possibility, in Experiment 3 we used a facial stimulus that was equally negative and threatening as the one used in Experiment 2 (see Table 3) but that did not possess a visually salient/unique feature (i.e., an open mouth; see Fig. 1).

Experiment 3: Preview search with negative (threat–closed mouth) and positive previewed photographic faces

Experiment 3 was similar to Experiment 2, but used a negative (threat–closed mouth) face. As we described above, this was equally negatively valenced and threatening as that used in Experiment 2, but without possessing a visually unique mouth region.

Method

Participants

A group of 24 students at the University of Warwick (14 female, ten male) participated in this study, either for payment or course credit. Participants in Experiment 3 were between 18 and 27 years old (M = 20 years), and all were right handed. Half completed the negative preview condition and half the positive preview condition. All participants self-reported normal or corrected to normal vision.

Stimuli and apparatus

The stimuli and apparatus were identical to those in Experiment 1 above, except that the target stimuli were either positive faces (PoFA code 001) or negative faces with closed-mouth displays (PoFA code 003); the previews consisted of either negative or positive faces.

Design and procedure

The design and procedure were the same as in Experiments 1 and 2.

Results

Reaction time data

RTs <150 ms (seven out of 11,520 trials) were discarded and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. The overall mean correct RTs and search slopes are shown in Fig. 5. The data were analyzed using the same strategy that had been used in Experiment 1; the full ANOVA details are given in Table 6.

HEB, FEB, and preview conditions Overall, RTs increased with display size, and were longest in the FEB and shortest in the HEB condition. However, of most interest, search efficiency differed across the conditions, being most efficient in the HEB and least efficient in the FEB condition. Overall, negatively valenced targets were found more efficiently than positively valenced targets.

Preview versus FEB Search was faster overall and more efficient in the preview condition than in the FEB baseline. However, the preview benefits did not differ when ignoring either positive or negative distractors. Negatively valenced targets were found more efficiently than positively valenced targets.

Preview versus HEB Responses were faster overall in the HEB condition, RTs increased with display size, and search was less efficient in the preview than in the HEB condition. The valence of the preview display had no significant influence on this pattern of findings. Again, negatively valenced targets were found more efficiently than positively valenced targets.

Within preview type comparisons For ignoring negative faces, we observed a significant Condition × Display Size interaction for both the FEB–preview and HEB–preview comparisons, $F(3, 33) = 5.37, p < .005, \eta_p^2 = .328$, and $F(3, 33) = 11.83, p < .001, \eta_p^2 = .518$, respectively. For ignoring positive faces, the Condition × Display Size interaction failed to reach significance for the FEB–preview comparison ($F < 1$), but was significant for the HEB–preview comparison, $F(3, 33) = 9.18, p < .001, \eta_p^2 = .455$.

Error data

Mean percentage errors are shown in Table 7. Overall, error rates were low on both search trials (ignore negative, 0.82 %; ignore positive, 1.27 %) and catch trials (ignore negative, 2.08 %; ignore positive, 6.60 %). These data were not analyzed further.

Discussion

In Experiment 3, we examined performance when negative faces possessed strong valence and threat content, but did not

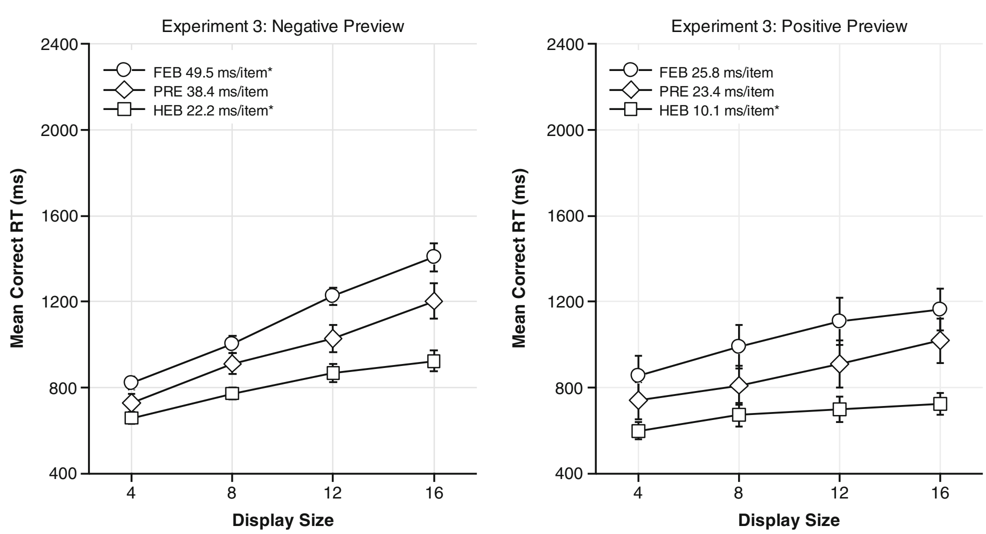


Fig. 5 Mean correct response times (RTs) and search slopes for ignoring negative (threat–closed mouth) previewed faces (left) and positive (happy) previewed faces (right), as a function of condition and display size for Experiment 3. *Preview search efficiency differed significantly from this baseline. Error bars indicate ± 1 standard error

Table 6 ANOVA results for Experiment 3, by comparison, search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), and display size (DS; within-subjects factors) and preview type (PT; between-subjects factor)

	df	*F*	η_p^2	Significance
HEB–FEB–Preview				
Condition	2, 22	37.58	.631	.001
Condition × PT	2, 44	0.200	.009	.820
DS	3, 66	236.88	.915	.001
DS × PT	3, 66	21.27	.492	.001
Condition × DS	6, 132	15.25	.409	.001
Condition × DS × PT	6, 132	1.72	.072	.122
PT	1, 22	1.53	.065	.229
FEB–Preview				
Condition	1, 22	13.39	.38	.005
Condition × PT	1, 22	0.03	.001	.87
DS	3, 66	211.79	.91	.001
DS × PT	3, 66	16.93	.44	.001
Condition × DS	3, 66	2.74	.11	.05
Condition × DS × PT	3, 66	1.59	.07	.20
PT	1, 22	0.82	.04	.38
HEB–Preview				
Condition	1, 22	19.96	.48	.001
Condition × PT	1, 22	0.17	.01	.68
DS	3, 66	129.01	.85	.001
DS × PT	3, 66	10.90	.33	.001
Condition × DS	3, 66	20.17	.48	.001
Condition × DS × PT	3, 66	0.92	.04	.44
PT	1, 22	2.03	.09	.17

possess a visually unique mouth region (i.e., the mouth was closed). In terms of overall search efficiency, unlike Experiments 1 and 2, we now obtained a strong negative target search advantage (e.g., Eastwood et al., 2001; Fox et al., 2000), for the negative face target. Here, search slopes were approximately twice as efficient as for the positive target, despite the fact that the negative face target no longer possessed the visually unique mouth region. This supports our hypothesis that a sufficiently strong visual feature might reduce the potential impact of valence in terms of attentional search and guidance (see also Watson & Blagrove, 2012).

In terms of ignoring negative faces, as in Experiment 2, we obtained a robust, but partial, preview benefit, with preview search efficiency falling between the HEB and FEB. This demonstrates that photorealistic faces, exhibiting strong negative emotional signals (threat or sadness), can be successfully ignored in order to prioritize new stimuli—even when they do not possess a unique visual feature within the display context.

However, although the findings for ignoring negatively valenced faces are consistent with and extend prior work based on schematic stimuli (Blagrove & Watson, 2010), the same is not true for ignoring positive stimuli. Specifically, when participants had to ignore positive stimuli, preview slopes were significantly steeper than in the HEB and did not differ from those of the FEB. This finding appears somewhat puzzling. On the basis of previous findings, which show that negative faces are more likely to attract and hold attention (e.g., Blagrove & Watson, 2010; Eastwood et al., 2001, 2003; Fenske & Eastwood, 2003; Fox et al., 2000; Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Horstmann et al., 2006), we might have expected that ignoring negatively valenced faces would have been more difficult than ignoring positive faces. However, here we obtained the reverse pattern, which we will consider further in the General Discussion section.

Experiment 4: The influence of stimulus similarity and bottom-up salience

Throughout Experiments 1–3, we attempted to manipulate/equate the extent to which stimuli differed in terms of possessing unique, potentially salient visual features. In Experiment 4, we examine whether visual salience and similarity might account for the pattern of results that we have obtained.

Table 7 Mean percentage error rates for Experiment 3, by search condition (half-element baseline [HEB] vs. full-element baseline [FEB]), preview valence, and display size

	Display Size				
HEB: FEB:	2 4	4 8	6 12	8 16	Mean
Search Trials					
Ignoring Negative					
HEB	0.83	0.63	0.42	0.21	0.52
FEB	0.42	0.63	0.63	1.67	0.83
Preview	1.46	0.83	0.63	1.46	1.09
Ignoring Positive					
HEB	1.04	0.83	0.21	1.46	0.89
FEB	1.04	2.50	0.83	1.46	1.46
Preview	0.63	1.25	1.46	2.50	1.46
Catch Trials					
Ignoring Negative					
HEB	8.33	2.08	0.00	2.08	3.13
FEB	2.08	2.08	0.00	0.00	1.04
Preview	6.25	2.08	0.00	0.00	2.08
Ignoring Positive					
HEB	10.42	6.25	4.17	8.33	7.29
FEB	10.42	4.17	0.00	6.25	5.21
Preview	4.17	6.25	10.42	8.33	7.29

First, we consider potential overall luminance / variance differences between stimuli, followed by use of a neurologically inspired computational model (Itti, 2004; Itti & Koch, 2000) to determine whether bottom-up salience can account for the results. Finally, we consider the influence of perceived salience and similarity between the stimuli.

Overall stimulus luminance

We calculated a basic overall measure of the stimulus properties. For each of the five faces used, we calculated the mean and standard deviation of the gray-level pixel values present within each face image (range: 0 = black, and 255 = white). As is shown in Table 3, the overall luminance values were similar, as were the standard deviations of pixel values. Thus, it is unlikely that any gross difference in stimulus luminance or overall luminance variance within each face could account for the results. For example, in Experiment 1 (i.e., a positive face search advantage) the positive target was of equal overall luminance to the negative face (average pixel gray level of 201.42 vs. 201.37).

Computationally derived salience

To consider the influence of bottom-up salience, we used the ezVision component of the iLab Neuromorphic Vision C++ Toolkit[3] (Itti, 2004; Itti & Koch, 2000). This software implements a sophisticated model of early visual processing and simulates movements of attention on the basis of bottom-up stimulus salience. We generated image bitmaps of 40 random search displays from the FEB conditions of each experiment, for the two extreme display sizes (4 and 16). This represented the typically most difficult search condition in each experiment, and the hardest and easiest searches presented within this condition. These images were then fed into the ezVision package, and we recorded how many simulated shifts of attention were required to reach the target item (or that the target was not found), and how long (in simulated milliseconds) the target took to locate. The results are shown in Table 8.

Table 8 Mean simulated ezVision times for attention to fall on target items, as a function of experiment/target valence and display size

	Display Size		RT Slope
	4	16	
E1 positive target	226.4 (72.8) [40]	676.7 (289.3) [28]	37.5
E1 negative target	140.2 (43.0) [40]	324.1 (196.3) [39]	15.3
E2 positive target	168.5 (54.5) [40]	545.0 (405.9) [31]	31.4
E2 negative target	184.8 (95.1) [40]	596.2 (321.1) [33]	34.3
E3 positive target	172.4 (66.3) [39]	597.7 (288.7) [30]	35.4
E3 negative target	211.3 (72.3) [39]	889.7 (1,106.8) [29]	56.5

Standard deviations are shown in parentheses. Numbers of successful target detections (out of 40 trials) are shown in square brackets.

Let us first consider the simulation data from Experiment 2. The attentional simulation results showed little difference in the efficiency of searching for either a positive or a negative target; this matched the participant data obtained from Experiment 2 earlier. Considering the simulation data from Experiment 1, the results showed that search was faster overall and more efficient when searching for a negative rather than a positive target. The simulation also successfully "found" the negative target more often than the positive target at the largest display size. However, this pattern was opposite from the one found in the participant data in Experiment 1, in which search showed a positive rather than a negative advantage. Moreover, the simulation data for Experiment 3 were likewise in the opposite direction from those obtained in the participant data. Here, the simulation data showed more efficient search for the positive target, whereas the participant data showed the reverse. Taken together, the findings suggest that a simple bottom-up visual-salience explanation cannot account for the differences in search efficiency (i.e., finding a positive or a negative face target) obtained across Experiments 1–3.

Perceived salience and similarity

One possible reason for the difference in results between the participant and simulation data is that actual perceived salience might have differed from the computationally derived salience. Potentially, this might be similar to the way in which psychophysical isoluminance can differ from physical isoluminance (see, e.g., Jordan, Sherman, & Tonkin, 2007).

Another possibility is that, in the context above, the perceived target–distractor (T-D) and distractor–distractor (D-D) similarity might be crucial for determining search efficiency. According to attentional engagement theory (AET; Duncan & Humphreys, 1989), visual search efficiency increases as a function of the extent to which (1) the target item matches an internal target template, (2) the target differs from the distractors (T-D similarity), and (3) the distractors are similar to each other (D-D similarity). According to AET, the more homogeneous the distractors are, the easier they are to group and reject as a whole unit. The more similar the target is to the distractors, the more difficult it is to isolate, and the slower search becomes.

To investigate these two possibilities, we ran a rating study with two main conditions. In the *distinctiveness condition*, we presented participants with search displays from the three experiments and asked them to rate how much the target item "stood out" and "was distinctive" from the displays. In the *similarity condition*, we presented pairs of face stimuli and

[3] Available at http://ilab.usc.edu/toolkit/.

asked participants to rate how *visually* similar the two faces were to each other.

Method

Participants

A group of 20 students from the University of Warwick (eight female, 12 male) between 18 and 22 years old ($M = 20.3$) took part for payment of £2.00.

Stimuli and apparatus

In the salience rating condition, participants were presented with search displays from the FEB conditions using the six facial targets (positive or negative target valence × three experiments). In the similarity rating condition, participants were shown two faces presented side by side.

Design and procedure

Participants completed seven blocks of trials in total: six for the distinctiveness rating task and one for the similarity rating task.

Distinctiveness rating task In the distinctiveness rating condition, each trial consisted of a blank screen (500 ms), followed by a fixation dot (1,000 ms), followed by the search display. The experimenter then pressed the space key, which placed a black outline rectangle around the target (to enable detection, without the need for active search). After approximately 3 s, the experimenter pressed the space key again to extinguish the rectangle. The participant then rated how much they thought the target "stood out" of the display on a 1 (*not at all distinctive*) to 7 (*extremely distinctive*) scale.

As a response reminder, the scale was present below the computer monitor throughout the task. This procedure removed the need for participants to search the display for the target item before they considered how much it stood out, thus avoiding participants' ratings being influenced by subjective evaluations of search ease/ difficulty. After verbally reporting their rating, the experimenter pressed the space key to begin the next trial.

This task consisted of six blocks of eight trials. Each block contained search displays from the positive and negative target FEB conditions of Experiments 1–3. Within each block, equal numbers of trials were presented for each combination of the four display sizes (4, 8, 12, and 16 items) and target locations (left or right). Block order was randomized across participants.

Similarity rating task Each trial consisted of a blank screen (500 ms), followed by a fixation dot (1,000 ms), followed by a pair of face stimuli presented side by side (3.8 cm apart) in the center of the display. Participants were asked to rate how *visually* similar they thought the two stimuli were to each other, and indicated their responses by pressing the keys "1" (*not at all similar*) to "7" (*extremely similar*) on the computer keyboard. After each response, the next trial began. The similarity between the face stimuli was assessed for the following comparisons: (1) positive versus negative, (2) positive versus neutral, (3) negative versus neutral, (4) positive versus negative (open mouth), (5) negative (open mouth) versus neutral, (6) positive versus negative (closed mouth), and (7) negative (closed mouth) versus neutral (see Table 9). Each pairwise comparison was repeated twice in a single block of 14 trials.

For half of the participants, the similarity rating block was presented before the six distinctiveness rating blocks, and for the other half, this order was reversed.

Results and discussion

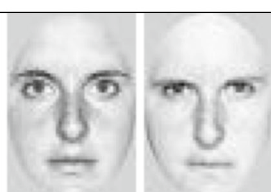
Distinctiveness ratings

Average ratings for how much the target was distinctive from the display in each of the search conditions are shown at the far right of Table 9, with values ranging from 4.34 to 5.55. A 6 (search condition) × 4 (display size) within-subjects ANOVA showed that perceived target distinctiveness differed overall across the conditions, $F(5, 95) = 6.54$, $p < .001$, $\eta_p^2 = .256$, and decreased as display size increased, $F(3, 57) = 16.80$, $p < .001$, $\eta_p^2 = .469$. The Condition × Display Size interaction was not reliable, $F(15, 285) = 1.091$, $p = .364$, $\eta_p^2 = .054$. Next, we collapsed the data across display sizes and compared the positive and negative target conditions for each experiment individually via planned comparisons.

This showed that the positive target was perceived as being more distinctive than the negative target for the stimuli presented in Experiment 1, $t(19) = 4.202$, $p < .001$, $d = 0.939$, and Experiment 2, $t(19) = 2.446$, $p < .05$, $d = 0.546$. However, for the stimuli in Experiment 3, we found no reliable difference between the perceived distinctiveness of the positive and negative targets, $t(19) = 1.706$, $p = .104$, $d = 0.381$. Considering the stimuli from Experiment 1, these ratings are consistent with the participant data. That is, the positive target (which was found efficiently) was rated as standing out from displays more than the negative target (which was less easily found). Note that these self-reported distinctiveness ratings contradict the results from the bottom-up salience simulation, which suggested that the negative target was visually more salient than the positive target.

However, the data are less clear for Experiments 2 and 3. For Experiment 2, the positive target was again rated as standing out more from the distractors than the negative target.

Table 9 Mean stimulus similarity (by target–distractor [T-D], distractor–distractor [D-D], and T-D/D-D similarity) and distinctiveness (by target) ratings

Target	Distractor 1 and 2	Stimulus similarity ratings T - D1	T - D2	D - D	D-D/ T-D	Dist. rating
Experiment 1: Ignore Negative						
		3.25	2.20	4.25	1.693	5.55
Experiment 1: Ignore Positive						
		4.25	2.20	3.25	1.070	4.34
Experiment 2: Ignore Negative						
		3.25	3.48	2.73	0.850	5.03
Experiment 2: Ignore Positive						
		2.73	3.48	3.25	1.171	4.39
Experiment 3: Ignore Negative						
		3.25	2.80	4.18	1.545	5.03
Experiment 3: Ignore Positive						
		4.18	2.80	3.25	0.994	4.53

However, neither the simulation nor the participant data indicated that the positive target was detected more efficiently than the negative target. For the stimuli from Experiment 3, no reliable difference was found between the distinctiveness ratings for the negative and positive targets (although we observed a numerical trend for the positive face to stand out more). That said, the search data showed that negative targets were detected more efficiently overall.

Similarity ratings

The similarity ratings for each target–distractor and distractor–distractor combination for the stimuli from Experiments 1–3 are also shown in Table 9. Search efficiency has been shown to depend on both target–distractor and distractor–distractor similarity (Duncan & Humphreys, 1989). Therefore, we generated a basic combined predicted search efficiency (PSE) measure by dividing the average distractor–distractor similarity by the target–distractor similarity for each participant, across the conditions from Experiments 1–3. The resulting average PSE values ranged from 0.85 to 1.69 (see Table 9). A one-way within-subjects ANOVA on the PSE values showed a significant main effect of search condition, $F(5, 95) = 6.19$, $p < .001$, $\eta_p^2 = .246$. Within-experiment comparisons revealed that predicted search was more efficient for the positive target in Experiment 1, $t(19) = 2.497$, $p < .05$, $d = 0.558$, and in Experiment 3, $t(19) = 2.107$, $p < .05$, $d = 0.471$. For Experiment 2, search was predicted to be more efficient for the negative target, $t(19) = 2.356$, $p < .05$, $d = 0.527$. Thus, these search efficiency predictions are consistent with participants' search performance for Experiment 1, but not for Experiments 2 and 3.

Overall, the findings show that the detection of a valenced face target does not appear to be accounted for fully by simple bottom-up salience differences, perceived visual distinctiveness, or perceived visual similarity between the target and distractor stimuli. Instead, visual and valence signals appear to interact in order to produce the resultant search behavior.

General discussion

The main aim of this study was to examine the efficiency of ignoring photorealistic faces, the extent to which facial valence might influence this ability and whether visual and affective signals interact. This was achieved by conducting a number of experiments in which a range of faces, differing across visual, valence, and threat dimensions, were tested. Within each experiment, we examined (1) the extent to which face stimuli could be ignored overall (i.e., the existence of a preview benefit), (2) the influence of stimulus valence on the ability to ignore old stimuli, and (3) the overall efficiency of detecting a negative or positive target face.

Overall search efficiency for negatively and positively valenced target faces

In terms of overall search efficiency, in Experiment 1, searching for a positively valenced face was more efficient than searching for a negative one. In Experiment 2, no difference emerged between positive and negative targets, and in Experiment 3, we obtained a negative face search advantage. From an everyday perspective, the negative face target was clearly "more negative" than the positive target in all three experiments, and this was confirmed by a rating study that evaluated the valence content of all five faces. Yet, in some conditions, this target was found more easily than the positive face targets; in others, it was found less easily.

This difference is likely to reflect the influence of simple visual differences between target and distractor items, over and above differences in stimulus valence. For example, in Experiment 1, the positive face also possessed a unique mouth region (i.e., an open mouth smile) compared with the neutral and negative faces. It is likely that this feature assisted in target detection. Consistent with this, when the negative face possessed a similar open mouth feature, search efficiency for this target increased, and became equivalent to that for the positive face. Finally, in Experiment 3, we obtained a strong negative face search advantage; the negative face target did not contain a unique mouth region (i.e., the stimulus included a closed mouth, similar to the negative face used in Exp. 1), but still it was rated as being highly negative and threatening.

From a theoretical perspective, these findings clearly indicate that visual properties can influence the absolute search rate of emotionally valenced faces, over and above any influence of the signaled valence itself. This finding makes sense when considered alongside a *sensory bias* perspective (see Horstmann & Bauland, 2006, for further discussion of this point). According to this view, the visual properties of adaptively important facial expressions may have co-evolved with the ability to process them efficiently. Thus, the perceptual features of affective faces would not necessarily be expected to be disentangled from either their visual processing or their behavioral relevance. However, our findings also show that bottom-up visual salience, the extent to which a stimulus is perceived to visually stand out from a display, and perceived similarity based grouping between stimuli cannot alone explain the ease of detecting a valenced face among other face distractors. Instead, it would seem that search efficiency is influenced by a combination of purely visual- and valence-based properties.

The efficiency of ignoring negatively valenced photographic faces

In terms of preview search efficiency, we obtained a robust, but partial preview benefit for ignoring negative face previews across all three experiments. It is likely that realistic faces provide a stronger and more direct facial signal than symbolic facial representations and so, might be particularly difficult to ignore (i.e., due to their special status as an important social stimulus; see, e.g., Carey et al., 1992). This might be especially relevant for negatively valenced faces, given that negative facial stimuli can be particularly effective at capturing, guiding and holding attention (e.g., Blagrove & Watson, 2010; Eastwood et al., 2001, 2003; Fenske & Eastwood, 2003; Fox et al., 2000; Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Horstmann et al., 2006). If so this would lead to a very weak or abolished preview benefit.

However, clearly this was not the case here. All three experiments showed that negatively valenced faces could be partially ignored. Moreover, this ability generalized over both non-threatening and threatening expressions (i.e., either with or without an open mouth display). Thus, being able to partially deprioritize faces for attention generalizes to realistic faces, and in *at least* two ways of considering negatively valenced expressions; negative affect (e.g., sadness) and threat.

The efficiency of ignoring positively valenced faces

In contrast to ignoring negatively valenced faces, the data for ignoring positively valenced faces was less straightforward to interpret. In Experiment 2, we found a robust, partial preview benefit, similar to that found for ignoring negatively valenced faces. However, in Experiment 1, we obtained only a weak, marginally significant preview benefit, and in Experiment 3, no reliable preview benefit emerged at all. Based on our previous predictions, this pattern of data is the opposite of what we expected to find. Contrary to the weight of evidence in the literature, and our expectations that ignoring negative stimuli might be more difficult or unreliable than ignoring positive stimuli, we found the reverse.

How might we account for this apparently puzzling set of findings? The most likely explanation can be found in considering the overall search rates across the different experiments and emotional valences tested. In other words, the underlying attentional mechanisms involved may have a substantial impact in addition to the facial affect per se. Taking the results of Experiment 1 first, recent work has shown that the ability to prioritize new stimuli might decrease over time after the new items have been added. For example, Emrich et al. (2008) found that, in a preview search task, the ability to fixate the new stimuli was limited to approximately four new items. Similarly, Watson and Kunar (2012) found that the capacity to select and respond to new stimuli was reduced when a delay was introduced between the onset of the new items and when participants were allowed to start selecting the new stimuli.

If the ability to prioritize new items decreases over time, then we might expect to find weaker preview benefits in search tasks that are particularly slow and inefficient. This follows because, with a slow search task, the representations separating the old from the new items would decay more before the target had been found. This could be due to either interference with an inhibitory template suppressing the old items (Watson & Humphreys, 1997), decay of signals associated with the new items (Jiang & Wang, 2004; see also Sligte, Scholte, & Lamme, 2008), or a combination of both.

Given that previewed facial stimuli appear to be only weakly suppressed (i.e., driving only a partial preview benefit), such stimuli may be particularly susceptible to any decay of old/new representations associated with a slow search task. Consistent with this account, across the set of experiments, search rates were slowest overall in Experiment 1. Hence, weak suppression of previewed faces, along with decaying old/new representations may account for why we obtained only a weak/marginally significant preview benefit in Experiment 1. More generally, this finding suggests that time-based selection might be reduced (or even abolished) in conditions in which search is particularly difficult.

However, consider now the lack of a preview benefit for ignoring positive faces in Experiment 3. Here, we obtained search rates that were the fastest across all three experiments, thus, an account that is based on difficulty/delay of search cannot explain the absence of a preview benefit. Indeed, according to the decay account, we might have expected a stronger preview benefit, because these representations would have less opportunity to decay before the target could be found. Two possible explanations could account for this finding. The first is based on the notion that ignoring old items is a time consuming and effortful process (Watson & Humphreys, 1997). For example, competing tasks consume resources necessary for ignoring the old items, and result in a reduced preview benefit (e.g., Humphreys, Watson, & Jolicœur, 2002). Furthermore, the ability to ignore old items appears to be under the control of the observer. In other words, there appears to be a top-down intentional goal required for this type of attentional processing to be effective. Watson and Humphreys (2000) measured responses to probe dots presented at new or old item locations under a "preview-style" search task. When the majority of trials were search trials (and, hence, incentive to ignore the old items was strong), detecting a probe dot was impaired when it fell at the location of an old item, compared with a new item location. However, when all trials were probe trials (and there was no incentive to ignore old items), we observed no difference in probe dot detection accuracy between old and new item locations (see also Olivers & Humphreys, 2002). This suggests that observers can choose intentionally whether to prioritize new items over old. It is possible that, when search for a target is already quite efficient (as in Exp. 3), then participants may adopt a strategy of avoiding engaging in an effortful process (i.e., suppressing the old items) because the overall benefit is considered too small.

A second account is based on findings from a study by Gibson and Jiang (2001), who examined the preview benefit with high salience targets. The overall finding was that when the search target was not particularly salient, then a full preview benefit was obtained. However, the preview benefit was weakened when the new item target was highly salient among the new item distractors. They suggested that the size of the preview benefit might depend critically on the context of the search task. Specifically, the preview benefit might be weaker when the target information is highly salient. Consistent with this possibility, Experiment 3 (threat–closed mouth) produced the most efficient search across all three experiments. It is therefore possible that the weakened ability to ignore face stimuli generally, due to their behavioral importance, coupled with a reduced preview benefit for highly detectable stimulus was sufficient to abolish the preview benefit in this condition.

This particular finding also addresses a further theoretical issue. Previous work with schematic stimuli (Blagrove & Watson, 2010) has consistently found a robust, but partial, preview benefit for ignoring face stimuli, whether positively or negatively valenced. However, the search rates obtained by Blagrove and Watson were relatively steep, as compared to those obtained in Experiment 3 (e.g., approximately 37 to 42 ms/item for the HEB conditions, as compared with 22 ms/item in Experiment 3). Thus it is possible, as detailed above, that relatively slow searches might reduce the preview benefit, if the mechanisms responsible for separating old items from the new decay over time. It follows then that a full preview benefit might be obtained in conditions in which search was more efficient (i.e., faster), even with face stimuli. However, Experiment 3 suggests that this is highly unlikely.

Overall implications

The main aim of this study was to examine time-based selection of realistic facial stimuli, given the current debate regarding more symbolic facial representations. The results showed that negative valenced photorealistic faces could be partially ignored, as can schematic faces (Blagrove & Watson, 2010). However, for ignoring positive stimuli, the results ranged from no preview benefit at all, to a weak benefit, to a robust but partial benefit. In particular, ignoring positive faces was only successful in "medium difficulty" search conditions. If the search task became too difficult (e.g., in Exp. 1: ignore positive faces) or too easy (e.g., Exp. 3: ignore negative faces), then the preview benefit was greatly weakened or abolished. This suggests that the context of the search task (see also Frischen et al., 2008), seen in terms of either overall attention or the specific impact of the constituent stimuli, can also have a strong influence on the success of time-based selection. Thus, the influence of valence-based differences on overall search rates might be more important, when determining whether a preview benefit will occur, than the valence of the facial stimuli themselves *or* their role in the experimental paradigm (i.e., previewed or new items). It follows, then, that the ability to ignore previewed faces depends on a combination of the speed of search and the interaction between the visual properties and valence of the stimuli.

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