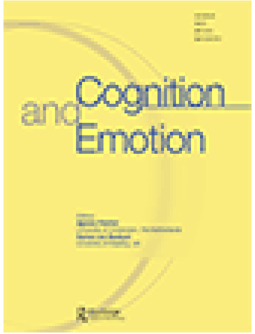

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Attentional capture by irrelevant emotional distractor faces is contingent on implicit attentional settings

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ABSTRACT
Although expressions of facial emotion hold a special status in attention relative to other complex objects, whether they summon our attention automatically and against our intentions remains a debated issue. Studies supporting the strong view that attentional capture by facial expressions of emotion is entirely automatic reported that a unique (singleton) emotional face distractor interfered with search for a target that was also unique on a different dimension. Participants could therefore search for the odd-one out face to locate the target and attentional capture by irrelevant emotional faces might be contingent on the adoption of an implicit set for singletons. Here, confirming this hypothesis, an irrelevant emotional face captured attention when the target was the unique face with a discrepant orientation, both when this orientation was unpredictable and when it remained constant. By contrast, no such capture was observed when the target could not be found by monitoring displays for a discrepant face and participants had to search for a face with a specific orientation. Our findings show that attentional capture by emotional faces is not purely stimulus driven and thereby resolve the apparent inconsistency that prevails in the literature on the automaticity of attentional capture by emotional faces.

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Emotional faces; attentional capture; bottom-up; top-down; contingent capture

Facial expressions of emotion carry a wealth of social information. For instance, smiling faces may signal friendliness and approachability, whereas fearful faces may signal a potential threat that requires immediate allocation of attention. It is therefore not surprising that a large body of research has investigated the relationship between emotional faces and attention (see Carretié, 2014; Palermo & Rhodes, 2007). Using various paradigms such as visual search tasks (e.g. Eastwood, Smilek, & Merikle, 2001), the additional-singleton visual search task (e.g. Hodsoll, Viding, & Lavie, 2011), the flanker task (e.g. Fenske & Eastwood, 2003), the dot-probe task (e.g. Mogg & Bradley, 1999), the attentional blink (AB) (e.g. Ogawa & Suzuki, 2004) and the emotional Stroop task (e.g. MacLeod & Hagan, 1992), this research has suggested that emotional faces capture attention (but see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007 for a different conclusion with regard to non-anxious participants).

Attentional capture by a distractor (i.e. by an object that is not the target one is required to respond to), comes in two forms: (a) Stimulus-driven capture in which some visual features are thought to have the intrinsic power to capture attention, even if they are totally irrelevant to the task at hand. (b) Goal-driven capture in which the visual feature may capture attention because it has some relevance in the current context. The stimuli most often used in order to demonstrate stimulus-driven capture are *singletons*. A singleton is an item that possesses a unique property in the visual field on a given dimension and that appears against a homogenous background on that dimension. Thus, for instance, a red item in a field of green items is a colour singleton. Singletons are thought to be physically salient because featural contrast is highest at their location. By extension, an angry face among emotionally neutral faces is referred to as an "emotional singleton".

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Whether involuntary allocation of attention is essentially stimulus driven or goal directed has been the focus of intense debate (see Burnham, 2007; Lamy, Leber, & Egeth, 2012; Theeuwes, 2010 for reviews). Theeuwes (e.g. 1991, 2010) showed that when observers are engaged in search for a shape singleton (i.e. for an object with a unique shape among uniformly shaped non-targets, for example, a unique green diamond among green circles) an irrelevant-colour singleton that is more salient than the target singleton (e.g. a unique red object among the green objects) interferes with search, even though observers know they have to ignore it. Theeuwes concluded that top-down guidance is not possible at the preattentive stage, because the most salient item in the display captures attention independently of the observers' goals.

Bacon and Egeth (1994) challenged this conclusion by showing that capture by an irrelevant-colour singleton occurred only when the target was consistently also a singleton. When the target was only occasionally a singleton (e.g. when on some trials, the target displays contained other unique shapes in addition to the unique target shape), search was unaffected by the presence of the uniquely coloured distractor. To account for these findings, the authors suggested that whenever the target can be found by searching for a singleton, observers adopt a "singleton-detection mode" as their default search strategy. Only when this strategy is inappropriate do observers adopt "feature-search mode" and search for the specific target-defining shape. Bacon and Egeth (1994) concluded that physically salient objects (e.g. singletons) do not capture attention automatically, because such capture depends on the search strategy employed (see also Folk & Remington, 1998; Folk, Remington, & Johnston, 1992).

Recently, the question has arisen of whether attentional capture by emotional stimuli is purely stimulus driven or instead is contingent on the observers' attentional goals (e.g. Barratt & Bundesen, 2012; Gupta, Hur, & Lavie, 2016; Hahn & Gronlund, 2007; Hodsoll et al., 2011; Horstmann & Becker, 2008; Huang, Chang, & Chen, 2011; Lien, Taylor, & Ruthruff, 2013; Schettino, Loeys, Pourtois, & Chambers, 2013; Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009; Van Dillen, Lakens, & Van Den Bos, 2011).

Most of these studies converged on the conclusion that emotional faces do not have the inherent (stimulus-driven) power to capture spatial attention against our will (no more than other physically salient objects, such as colour singletons or new objects appearing in our visual field, for example, Folk et al., 1992). For instance, Stein et al. (2009) used an AB paradigm (Raymond, Shapiro, & Arnell, 1992). In this paradigm, two targets are embedded in a rapid visual stream of non-targets. Identification of the second target (T2) is impaired when it appears shortly after the first target (T1) and this time-dependent impairment is referred to as the AB. An AB also occurs when the first target is replaced with a distractor and the conclusion in that case is that the distractor captured attention (e.g. Folk, Leber, & Egeth, 2002). Stein et al. (2009) showed that a fearful face produced a larger blink than a neutral face when subjects had to identify this face's emotional expression, but not when they had to judge its gender. In addition, when no task was associated with the fearful face (i.e. when it was a distractor), it produced no blink at all. These authors concluded that fearful faces do not capture attention automatically.

Schettino et al. (2013) used a temporal-order judgment task. In this task, two stimuli are flashed on the left and right at different temporal asynchronies and participants have to report which stimulus appeared first. As attention speeds processing, if one of the two stimuli benefits from spatial attention, it gains prior entry: it is perceived to appear first even if it is flashed simultaneously with the competing stimulus. Schettino et al. (2013) showed that negative emotional faces (angry/fearful) did not get prior entry when competing with neutral faces. They concluded that negative emotional faces do not capture attention more readily than neutral faces.

Only a handful of other studies have reached the opposite conclusion (e.g. Gupta et al., 2016; Hodsoll et al., 2011; Huang et al., 2011). Their findings therefore deserve special scrutiny. Gupta et al. (2016, Exp.2) had participants search for a target letter embedded in a circular display under conditions of either low or high perceptual load. On some trials, an emotional face distractor (either happy or angry) appeared in the centre of the target display. The presence of the positive distractor impaired performance irrespective of load. The authors concluded that positively valenced distractors capture attention automatically. However, as the critical emotional distractor was presented at fixation, the reported distraction effects did not index spatial capture of attention and were more likely to reflect a difficulty in disengaging attention from the emotional distractor.

Hodsoll et al. (2011; see also Hodsoll, Lavie, & Viding, 2014 and Thompson-Booth et al., 2014) used a variant of the additional-singleton paradigm developed by Theeuwes (e.g. 1991). Participants were requested to search for the male face among two female faces and report its orientation. On one third of the trials, one face, equally likely to be the target or a non-target, displayed an emotional expression (happy, angry or fearful, in three different experiments). In the remaining trials, all the faces were emotionally neutral. Capture was measured as a performance cost on emotional distractor trials relative to all-neutral trials (interference effect), and as a performance gain on emotional-target trials relative to all-neutral trials (facilitation effect). The results revealed that both negative and positive faces interfered with performance, whereas facilitation was found only for positive emotions. Hodsoll et al. (2011) concluded that all emotional faces capture attention but processing the negative emotion of angry and fearful targets delays responding to their orientation, a cost that offsets the benefit of attentional capture by these stimuli.

Hodsoll et al.'s (2011) study has two noteworthy limitations. First, emotional information was not entirely task irrelevant. Unlike in Theeuwes (1991) paradigm, the target could be the emotional face, which weakened any incentive to completely disregard emotions. Moreover, the target was more likely than chance to be the emotional face (50% instead of the 33.33% chance level).

The second limitation – and the most critical one for the present study – is that the target in Hodsoll et al.'s study was defined as the face with the unique gender, and the emotional distractor was the only emotional face in the display. Therefore, subjects may have used singleton-detection mode, in which observers adopt the strategy of searching for the odd-one out (Bacon & Egeth, 1994). If this was indeed the case, capture by the emotional face relied on observers' implicit goals and was not entirely stimulus driven after all.[1]

Hodsoll et al. (2011) rejected the possibility that participants used an odd-one out strategy, based on the results of their fifth experiment. Displays contained a neutral singleton among angry faces instead of an emotional singleton among neutral faces (Experiments 1–4). The authors reported the slowest reaction times (RTs) when the neutral singleton was a target and no interference when this singleton was a distractor relative to the no-distractor condition. However, it is well established that emotional faces are more salient than neutral faces (e.g. Amunts, Yashar, & Lamy, 2014) and it is therefore reasonable to assume that the distraction by angry non-targets overrode any small effect of the neutral face's salience.

Our main objective here was to reexamine the claim that emotional face distractors capture attention irrespective of task demands. Experiment 1 was similar to Hodsoll et al.'s (2011) study but we took two steps to ensure that the emotional face was entirely irrelevant to task demands. First, the target was defined by its known orientation and was never a singleton: each item in the display had a different orientation (henceforth, known-orientation condition).[2] Thus, participants could not find the target by searching for a singleton and instead had to maintain an attentional set for the specific feature that defined the target (i.e. they had to use feature-search mode, Bacon & Egeth, 1994). Second, the valenced emotion was always carried by a distractor, and the target was therefore always emotionally neutral. Thus, it was beneficial for observers to entirely ignore the emotional face.

In order to ensure that the face carrying a unique emotion (i.e. the emotional face singleton) captured attention when the target could be found by monitoring displays for singletons, a singleton target condition was added as a control: the target was defined as the uniquely oriented item among uniformly oriented non-targets and its orientation varied unpredictably from trial to trial (henceforth, unknown-orientation singleton condition). Thus, participants had to search for a singleton to find the target. We expected the emotional face singleton distractor to capture attention in this condition and thereby to replicate Hodsoll et al.'s (2011) findings. Finally, in order to increase the ecological validity of the current study, we used veridical faces and multiple identities (see Horstmann & Bauland, 2006; Pinkham, Griffin, Baron, Sasson, & Gur, 2010).

We predicted that if, as established by most of the previous literature, attentional capture by emotional faces is goal dependent rather than stimulus driven, we should observe interference by the emotional distractor only in the unknown-orientation (singleton-detection) condition and not in the known-orientation (feature-search) condition.

Experiment 1

Method

Participants

Participants were 20 Tel-Aviv University graduate students who volunteered to participate in the experiment. All reported having normal or corrected-to-normal visual acuity. Handedness was not controlled for.

Apparatus

Displays were generated by an Intel I3 personal computer attached to a 23″ Samsung SyncMaster SA750 LCD monitor with a 120 Hz refresh rate, using 1024×768 resolution graphics mode. Responses were collected via the computer keyboard. Viewing distance was approximately 50 cm from the monitor.

Stimuli

Examples of the experimental stimuli are presented in Figure 1. The fixation display was a grey $0.2° \times 0.2°$ plus sign (+), in the centre of a black background. The stimulus display consisted of the fixation display with the addition of four faces. The faces appeared in the cells of an imaginary 2×2 matrix centred at fixation. The centre of each image was placed at 5.5 cm away from the central fixation. The faces were rotated by one of four possible angles: 45°, 90°, −45° and −90°.

The face stimuli were photographs of eight Caucasian individuals (four female and four male), selected from the MacArthur's battery of facial expressions stimuli (NimStim stimulus set http://www.macbrain.org/faces/index.htm). Each individual could display a neutral, a fearful or a happy expression. Thus, the stimulus set included a total of 24 different pictures. All pictures were grey-scaled (8 bits) and inserted behind a black overlay with a rounded central aperture subtending about 3.6° horizontally and 4.2° vertically. Mean luminance and contrast were matched between the pictures of the three different emotions of each individual.

On each trial, four individuals were randomly selected with the constraint that each display contained exactly two females and two males. On distractor-absent trials, all the faces in the display expressed a neutral emotion and on distractor-present trials, one face expressed either a fearful or a happy emotion. In the unknown-orientation singleton search condition all faces had the same orientation on a given trial, except for the target face. In the known-orientation search condition (i.e. feature search) each face had a different orientation.

Procedure

The experiment was conducted in a dark room. Participants were instructed to report the gender of the target face by pressing "3" with their right index fingers (in case the gender of the target face was male), or "z" with their left index fingers (in case the gender of the target face was female). The participants were asked to respond as quickly as possible, while maintaining high accuracy. In the unknown-orientation singleton search condition, the target was defined as the uniquely oriented face. The target orientation was randomly drawn from the four possible orientations, and the non-targets' uniform orientation was randomly drawn from the remaining three possible orientations (i.e. on a given trial, all non-targets had the same orientation). In the known-orientation search condition, the orientation of each of the four faces was different. The target orientation remained constant over a whole block of trials.

At the beginning of each block in the known-orientation search condition, a display containing two faces – a male face and a female face, displaying a neutral expression and not belonging to the experimental stimulus set – were presented side by side in the same rotation angle, which indicated the target orientation in the upcoming block. At the beginning of the unknown-orientation singleton condition, participants were informed that the target would be the face with a unique orientation among uniformly oriented non-target faces. In both conditions, participants were instructed to focus solely on identifying the target's gender and to ignore any irrelevant information.

Each trial began with a fixation display that remained on the screen for 500 ms. The stimulus display followed, and remained visible for 6000 ms or until response. Then, the screen went blank for 500 ms before the next trial began. Feedback for errors was given by a short tone. Eye movements were not monitored, but participants were explicitly requested to maintain fixation throughout each trial. Participants were allowed a short rest after each block.

Design

There were three within-subject variables: search condition (unknown-orientation singleton search vs. known-orientation search), emotional distractor presence (present vs. absent) and distractor emotion (happy vs. fearful) and two between-subjects variables: search-condition order and distractor-emotion condition order. Search conditions were blocked, such that one half of the experiment (eight blocks of trials) consisted of the unknown-orientation singleton search condition and the other half consisted of the known-orientation search condition. Distractor-emotion conditions were also blocked: within each search condition, the distractor when present expressed a happy expression in four blocks, and a fearful expression in the remaining four blocks.

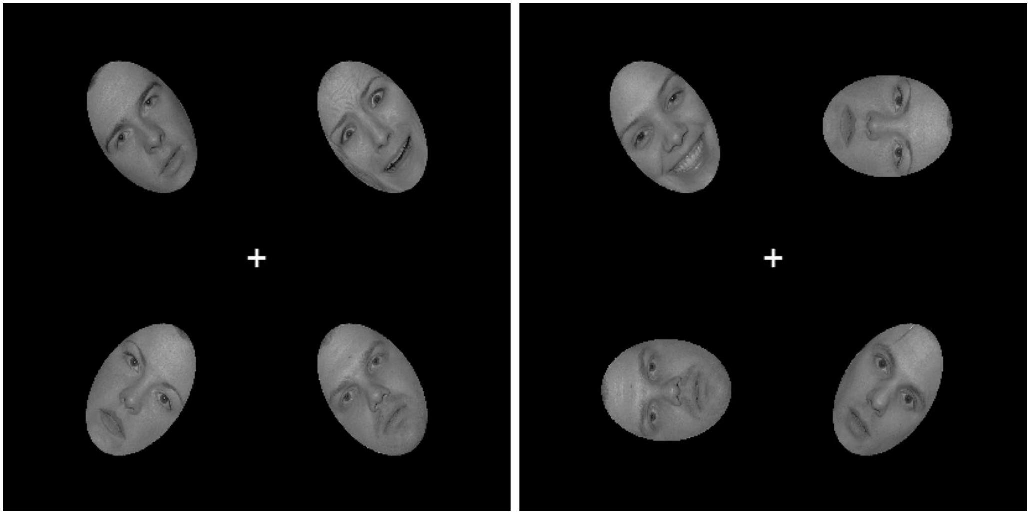

Figure 1. Sample displays in Experiment 1 (not to scale). The left-hand display corresponds to the unknown-orientation singleton search distractor-present (fearful) condition. The right-hand display corresponds to the known-orientation search distractor-present (happy) condition.

Emotional distractor presence was mixed within each block of trials: for each combination of search and distractor-emotion conditions, the distractor was equally likely to be present or absent. Search and distractor-emotion conditions orders were counterbalanced between participants. For each participant, distractor-emotion order was the same in each search condition.

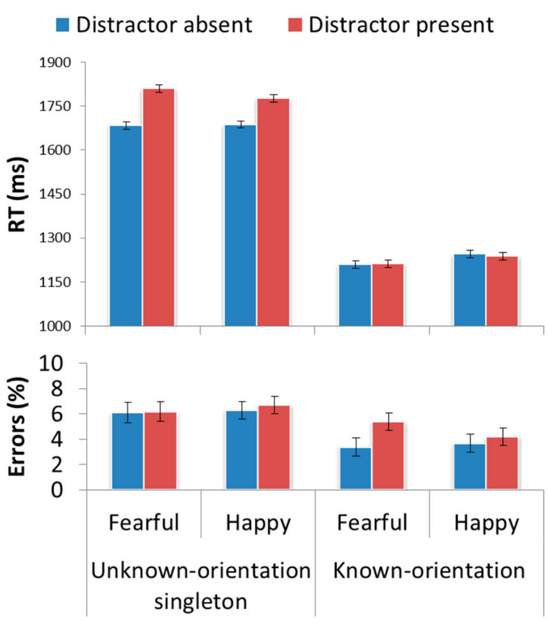

Figure 2. Gender identification performance as a function of search condition (unknown-orientation singleton search vs. known-orientation search), distractor emotion (happy vs. fearful) and emotional distractor presence (present vs. absent) in Experiment 1. *Upper panel*: Mean RTs in milliseconds. *Lower panel:* percentage (%) of errors. Error bars indicate within-subject standard errors (Loftus & Masson, 1994).

The experiment consisted of 16 experimental blocks of 32 trials each, that is, 512 experimental trials in total. Each search condition was preceded by a short practice block of 10 trials.

Results and discussion

The data from one participant were excluded because his overall accuracy was lower than the group's mean by more than three standard deviations (M = 71.9% vs. M = 93.6%, SD = 5.7%). All RT analyses were conducted on correct trials. RTs faster than 150 ms or exceeding the mean of their cell by more than 2.5 standard deviations (fewer than 1.1% of all correct trials) were removed from analysis. Preliminary analyses revealed a significant interaction between distractor emotion (fearful vs. happy) and emotion order (fearful first vs. happy first), $F(1, 17) = 12.24$, $p = .003$, $\eta^2 = .42$, which reflects effects of practice and is irrelevant to the issues at hand. The data were therefore collapsed across conditions of distractor-emotion condition order.

A repeated measures analysis of variance (ANOVA) was conducted with search condition (unknown-orientation singleton vs. known-orientation), distractor emotion (happy vs. fearful) and emotional distractor presence (present vs. absent) as within-subject factors and search-condition order (unknown-orientation singleton search first vs. known-orientation search first) as a between-subjects variable. Mean RT on correct trials and accuracy data across conditions of search order are depicted in Figure 2 and are presented separately for each condition of search order in Appendix 1.

Reaction times

The main effect of search condition was significant, $F(1, 17) = 114.21$, $p < .0001$, $\eta^2 = .87$, with faster RTs in known-orientation search than in unknown-orientation singleton search, and so was the main effect of the emotional distractor's presence, $F(1, 17) = 15.17$, $p = .001$, $\eta^2 = .47$, with slower RTs when this distractor was present than when it was absent. The interaction between the two factors was significant, $F(1, 17) = 5.51$, $p = .031$, $\eta^2 = .24$. The four-way interaction between search-condition order, search, distractor emotion and distractor presence was significant, $F(1, 17) = 9.47$, $p = .007$, $\eta^2 = .36$. In order to explicate this interaction separate ANOVAs were conducted for each search condition. During unknown-orientation singleton search, the presence of an emotional distractor interfered with performance, $F(1, 17) = 10.35$, $p = .005$, $\eta^2 = .38$, irrespective of search-condition order or distractor emotion, all ps > .25. Notably, both fearful and happy distractors slowed performance, $F(1, 17) = 13.36$, $p = .002$, $\eta^2 = .44$, and $F(1, 17) = 5.73$, $p = .029$, $\eta^2 = .25$, respectively. During known-orientation search, the three-way interaction between search-condition order, distractor emotion and distractor presence approached significance, $F(1, 17) = 3.47$, $p = .08$, $\eta^2 = .17$, indicating that when the known-orientation search was performed after the unknown-orientation singleton search, there was a numerical trend towards interference by the fearful distractor, $F(1, 8) = 1.71$, $p = .22$, $\eta^2 = .18$ and an opposite trend in the remaining conditions, all Fs < 1. Thus, emotional distractors did not interfere with performance in any of the known-orientation search conditions (see Figure 2).

Mean RTs were much faster in the known-orientation than in the unknown-orientation singleton search condition, $M = 1226$ ms, $SD = 166$ ms vs. $M = 1739$ ms, $SD = 298$ ms, respectively.[3] As effects are known to increase with increasing RTs, this difference might account for the larger distractor interference observed in the latter relative to the former condition. In order to examine this possibility, we conducted the previous ANOVA using only the 50% slowest trials of each subject in the known-orientation search condition and the 50% fastest trials of each subject in the unknown-orientation singleton search condition. For this subset of trials, mean RTs were actually faster in the unknown-orientation singleton condition, $M = 1296$ ms, $SD = 229$ ms, than in the known-orientation search condition, $M = 1544$, $SD = 268$ ms, $F(1, 17) = 7.53$, $p = .021$, $\eta^2 = .31$. Our findings were fully replicated. Namely, interference by the emotional distractor was significant in the unknown-orientation singleton search condition, $F(1, 17) = 8.29$, $p = 0.01$, $\eta^2 = .33$ but not in the known-orientation search condition $F < 1$.

Accuracy

The main effect of search condition was significant, $F(1,17) = 10.95$, $p = .004$, $\eta^2 = .39$, with higher accuracy during known-orientation search, $M = .95$, $SD = .037$, than during unknown-orientation singleton search, $M = .93$, $SD = .035$. No other effect was significant, all ps > .16.

The results of Experiment 1 fully supported our predictions. An emotional distractor face (either fearful or happy) captured attention when participants searched for an orientation singleton, the orientation of which changed randomly from trial to trial, whereas such capture did not occur when participants searched for a face that was defined by its known orientation and could not be located by searching for a singleton. These findings did not result from the overall slower performance in the singleton- relative to the known-orientation search condition, as they were replicated when only the fastest trials in the former condition and the slowest trials in the latter condition were entered in the data analyses. We conclude that capture by an irrelevant emotional face is not strictly stimulus driven and is contingent on the adoption of singleton-detection mode.

It is noteworthy that the order in which the search conditions were administered did not modulate distractor interference during unknown-orientation singleton search but had some impact during known-orientation search. Specifically, whereas fearful distractors could be successfully ignored when the known-orientation search condition was administered first, with a trend towards *faster* RTs when the fearful distractor was present, RTs tended to be *slower* when participants had searched for a singleton in the first half of the experiment. This pattern of results (although unreliable) is in line with earlier findings showing that irrelevant singletons interfere more with search performance after observers have been actively looking for a singleton (Leber & Egeth, 2006).

Experiment 2

In the unknown-orientation singleton condition of Experiment 1, the target feature (i.e. orientation) varied randomly from trial to trial, whereas in Hodsoll et al.'s (2011) study, the target feature remained constant throughout the experiment (henceforth, known-orientation singleton condition). Bacon and Egeth (1994) showed that even when the feature of the singleton target is known (e.g. when observers search for the unique circle among diamonds), an irrelevant singleton (e.g. the unique red item among green items) captures attention. They concluded that observers adopt singleton-detection mode whenever the target can be detected by monitoring displays for singletons (see Lamy, Bar-Anan, Egeth, & Carmel, 2006; Lamy, Carmel, Egeth, & Leber, 2006; Lamy, Bar-Anan, & Egeth, 2008 for a discussion of the mechanisms underlying singleton-detection mode). Accordingly, it is reasonable to assume that observers adopted singleton-detection mode in both our unknown-orientation singleton condition and in Hodsoll et al.'s (2011) study. It was nevertheless important to show that with our stimuli and set-up, we could replicate Hodsoll et al.'s (2011) findings, namely, attentional capture by an irrelevant emotional face in known-orientation singleton search. This was the objective of Experiment 2.

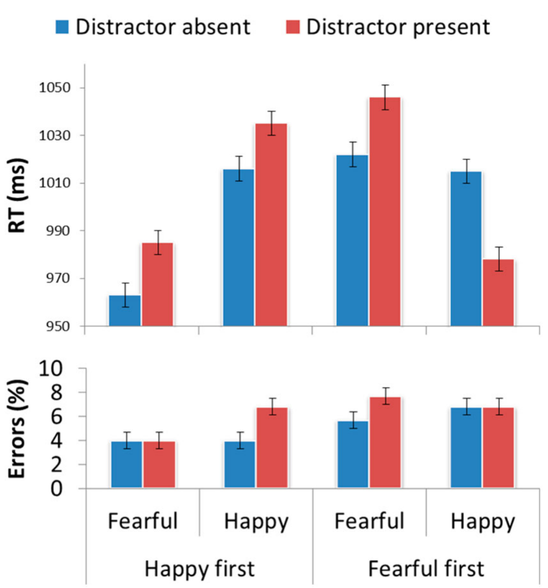

Figure 3. Gender identification performance as a function of distractor emotion (happy vs. fearful), emotional distractor presence (present vs. absent) and distractor-emotion order (happy first vs. fearful first) in Experiment 2 (known-orientation singleton task). *Upper panel*: Mean RTs in milliseconds. *Lower panel:* percentage (%) of errors. Error bars indicate within-subject standard errors (Loftus & Masson, 1994).

Method

Participants

Participants were 16 Tel-Aviv University graduate students who volunteered to participate in the experiment. All reported having normal or corrected-to-normal visual acuity. Handedness was not controlled for.

Apparatus, stimuli, procedure & design

The apparatus, stimuli, procedure and design of Experiment 2 were similar to those of Experiment 1, except for the following changes. Instead of searching for the face with the pre-specified orientation among heterogeneously oriented faces (known-orientation search) or for an orientation singleton that varied from trial to trial (unknown-orientation singleton search) participants searched for a singleton, the orientation of which was constant and thus known in advance (known-orientation singleton condition). Targets had two possible orientations: 45° or −45°, and non-targets had three possible orientations: −45°, 90° or −90° (in case the target orientation was 45°), or 45°, 90° or −90° (in case the target orientation was −45°). For each participant the orientations of the target and non-targets remained constant throughout the experiment (i.e. each participant saw only one combination of the target and non-targets' orientations). Thus, the design included two within-subject variables, distractor emotion (fearful vs. happy) and emotional distractor presence (present vs. absent), and three between-subjects variables: emotion-condition order, target orientation and non-targets' orientation, counterbalanced between participants. The experiment began with 16 practice trials, followed by 384 experimental trials, divided into four blocks of 96 trials each.

Results and discussion

All RT analyses were conducted on correct-response trials (94.8% of all trials) and excluding RT outliers (1.6% of all correct trials). Mean RTs on correct trials and accuracy data are depicted in Figure 3. Preliminary analyses revealed no significant effect of the target and non-targets' orientations, and the data were therefore collapsed across orientation conditions.

An ANOVA was conducted with distractor emotion (happy vs. fearful) and emotional distractor presence (present vs. absent) as within-subject factors, and emotion-condition order (happy first vs. fearful first) as a between-subjects factor.

Reaction times

No main effect was significant (all $ps > .36$). The two-way interaction between distractor emotion and emotional distractor presence was significant, $F(1, 14) = 9.67$, $p = .008$, $\eta^2 = .41$. It was modulated by a significant three-way interaction between distractor emotion, emotional distractor presence and emotion-condition order, $F(1, 14) = 8.17$, $p = .012$, $\eta^2 = .37$. To clarify this interaction, we conducted separate follow-up ANOVAs for the fearful and happy distractors conditions. In the fearful-distractor condition, the main effect of emotional distractor presence was significant, $F(1, 14) = 8.33$, $p = .012$, $\eta^2 = .37$, with slower responses when the fearful distractor was present, and did not interact emotion-condition order, $F < 1$. In the happy-distractor condition, the interaction between emotional distractor presence and emotion-condition order was significant, $F(1, 14) = 8.21$, $p = .012$, $\eta^2 = .37$, indicating that the presence of a happy distractor did not interfere with performance when the happy-distractor condition was presented first, $F(1,7) = 1.68$, $p = .23$, $\eta^2 = .19$, and significantly facilitated performance when the happy-distractor condition was presented after the fearful-distractor condition, $F(1,7) = 8.33$, $p = .023$, $\eta^2 = .54$).

Accuracy

The accuracy data generally mimicked the RT data. The three-way interaction between distractor emotion, emotional distractor presence and emotion-condition order was significant, $F(1, 14) = 5.76$, $p = .\ 031$, $\eta^2 = .29$. Follow-up analyses revealed that when the happy-distractor condition was administered first, the happy distractor's presence interfered with performance, $F(1, 7) = 5.69$, $p = .049$, $\eta^2 = .45$ but had no effect when this condition came after the fearful-distractor condition. $F < 1$, whereas with fearful distractors, there was no significant accuracy effect, all $ps >$,21.

The results of Experiment 2 essentially replicated Hodsoll et al.'s (2011) main findings with our own stimuli and design. We showed that when participants searched for a known-orientation singleton target, an emotional face distractor singleton captured attention. Such interference was observed for the fearful-distractor condition (irrespective of whether it was run as the first or the second condition). For happy faces, the interference was observed on accuracy data with only a numerical trend in the same direction on the RT data, and only when the happy-distractor condition was run as the first condition. The opposite effect was obtained when the happy condition was conducted as the second condition. As the distractor's emotion was run as a between-subjects variable in Hodsoll et al.'s study, there is no discrepancy between our results (in the happy-first and fearful-first conditions) and theirs.

We suggest two possible accounts for the facilitation observed when happy distractors followed fearful distractors: (a) the salience of emotional singletons might be modulated by the context in which they are encountered: namely, a happy face may be less salient when it follows exposure to a fearful face, presumably because the latter is intrinsically more salient. (b) In our study the target was never the emotional face, which ensured that participants would attempt to fully ignore the irrelevant emotional expression. Emotion may therefore have been suppressed (see Lamy et al., 2006; Sawaki & Luck, 2010 for evidence of such suppression) and suppression may be more readily applied to threatening than to positive emotional faces. Further research is required to further test these speculations.

General discussion

The question of whether emotional faces in general, and threatening faces in particular, have the intrinsic power to capture attention is central to our understanding of emotion processing (e.g. LeDoux, 1996). The idea that emotional faces capture attention automatically is intuitively appealing because we seem to be biologically prepared to perceive and respond to facial expressions in a unique manner, suggesting that despite their featural complexity, facial expressions are endowed with the same attentional status as basic features such as colour or shape (Ekman, 1993). However, previous research investigating the determinants of attentional capture has shown that even the most salient basic properties (e.g. colour singletons and "abrupt onsets", that is, new objects suddenly appearing in our visual field) do not capture our attention automatically: they summon our attention only if they match our explicit or implicit task goals (e.g. Folk et al., 1992).

Most studies in the current literature concur to show that in a similar way, emotional faces do not capture attention automatically (e.g. Barratt & Bundesen, 2012; Hahn & Gronlund, 2007; Hodsoll et al., 2011; Horstmann & Becker, 2008; Lien et al., 2013; Schettino et al., 2013; Stein et al., 2009; Van Dillen et al., 2011). These studies have typically focused on the relevance of *emotion* to the task at hand in order to challenge the notion that emotional stimuli mandatorily summon our attention. For instance, using a variant of Folk et al.'s (1992) spatial cueing paradigm, Lien et al. (2013) examined whether a target is responded to faster when it appears at the location just occupied by a fearful face distractor than when it appears elsewhere. They found no such effect when the target was defined by its known colour (and the fearful face distractor was therefore task irrelevant). By contrast, spatial capture was observed when the fearful face distractor was task relevant, namely, when the target was also defined by its fearful emotion.

However, a few studies demonstrated that even when emotion is utterly irrelevant to the task at hand, an emotional face elicits spatial shifts of attention against our will (Hodsoll et al., 2011, 2014; Thompson-Booth et al., 2014). These findings suggest that facial expressions of emotion have stronger intrinsic power to capture attention than do salient basic features. Here, we relied on the vast literature on the role of implicit attentional sets in attentional capture (e.g. Bacon & Egeth, 1994; Gibson & Kelsey, 1998) to resolve the apparent inconsistency between the two lines of findings.

We examined the hypothesis that in the few studies that demonstrated attentional capture by nominally task-irrelevant emotional distractors, observers adopted a set for singletons – that is, they searched for the object that differed from all the others on some property. We showed that when the target was reliably a singleton (with either an unpredictable orientation as in Experiment 1 or a predictable orientation as in Experiment 2), a face with a discrepant unique emotion captured attention. However, when the target could not be found by monitoring displays for singletons, the emotional singleton did not capture attention. Taken together, our findings suggest that attentional capture by emotional faces is not purely mandatory.

It is important to underscore that this conclusion does not entail that facial expressions of emotion are not special stimuli. It is likely that any other stimulus category with the same level of featural complexity as emotional faces would not capture attention in any of the conditions of the present experiments. Here, we showed that facial expressions of emotion behave like basic features, in that a face that differs from other faces in the emotion that it carries (i.e. an emotional face singleton) is salient in a similar way as an object that differs from surrounding objects by its unique colour (i.e. a colour singleton).

Our study focused on facial expressions of emotion. Can our conclusions be extended to other types of valenced stimuli? Several studies showed that inconspicuous stimuli that have been associated with reward or punishment in a training phase and have thereby acquired positive or negative valence, respectively, capture attention when they are presented as distractors during subsequent visual search (e.g. Anderson, Laurent, & Yantis, 2011; Anderson & Yantis, 2013; Hickey, Chelazzi, & Theeuwes, 2010; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011; Wentura, Müller, & Rothermund, 2014). This line of research presents two critical methodological advantages for the study of attention capture by valenced stimuli. First, while valence and physical salience may be confounded in facial expressions of emotion, because these may have intrinsic physical salience (e.g. Horstmann, 2007), this is not the case with conditioned stimuli: their valence is entirely independent of their physical salience, because rewarded and unrewarded stimuli are counterbalanced.

Second, although participants searched for a singleton target in all studies of attentional capture by rewarded stimuli, the claim that attentional capture was contingent on the adoption of singleton-detection mode in these studies is less straightforward than for the studies reviewed here that used facial expressions of emotion as stimuli. Indeed, in the former studies, the rewarded distractor was not physically a singleton. For instance, in Anderson et al.'s (2011) study, observers searched for a unique target shape (e.g. a diamond among circles) and each item in the display had a different colour. One of nontarget circles' colours had been rewarded in the training phase and was found to capture attention. In order to claim that such capture was goal dependent, one would have to postulate that the notion of singleton can be extended from physical to abstract dimensions, such that the only rewarded object among nonrewarded objects is also a singleton. This conjecture is not warranted, and in order to test it, it will particularly useful to determine in future research whether rewarded distractors capture attention also during search for a target that is not a singleton.

On a final note, let us point out that the counter-intuitive conclusion that purely stimulus-driven capture by either salient basic features or biologically significant stimuli such as facial expressions of emotion does not occur should be qualified. The remarkable resistance to stimulus-driven capture observed in most experiments may be overestimated because of the specific conditions prevailing in these experiments – as well as in ours: the to-be-ignored distractors appear repeatedly and are typically drawn from a very limited stimulus set. Such predictability and regularity does not always characterise our natural environment and more unpredictable events are likely to be endowed with more power to capture our attention. Recent studies investigating automatic attentional capture by rare or surprising events support this conjecture (e.g. Becker & Horstmann, 2011; Folk & Remington, 2015; Liao & Yeh, 2011 but see Noesen, Lien, & Ruthruff, 2014). For instance, Folk and Remington (2015) showed that an abruptly onset irrelevant object does not capture attention when it appears on every trial but does so when it appears rarely (on only 20% of the trials). Intriguingly, irrelevant-colour singletons, even if rare, did not capture attention. It would be useful to test in future research whether emotional expressions are capable of summoning our attention in a purely stimulus-driven fashion when they occur only occasionally.

Notes

1. Similar observations apply to Huang et al.'s (2011) study. Participants were instructed to search an array of faces for a target face indicated by a dot and to respond to the dot's position. One face displayed an emotion while the other faces were neutral. The authors reported that performance was improved when the angry face was the target and impaired when it was a distractor. Thus, as in Hodsoll et al.'s (2011) study, participants could use singleton-detection mode to locate the target. In addition, the target also sometimes coincided with the emotional face.
2. As there are only two possible face genders (male and female), it was not possible to assign a different gender to each face in a four-item display in order to induce observers to search for a specific known gender and to prevent them from searching for the face with the unique gender. We therefore used orientation as the target-defining feature, unlike Hodsoll et al. (2011) who used gender.
3. The finding that unknown-orientation singleton search was considerably slower than known-orientation search is inconsistent with Bacon and Egeth's (1994) suggestion that searching for a singleton may be less cognitively demanding than searching for a specific feature (see Bravo & Nakayama, 1992; Lamy, Carmel, Egeth, & Leber, 2006; Lamy, Bar-Anan, Egeth, & Carmel, 2006, for similar findings and for a discussion of the notion of "default singleton detection mode").

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Appendix 1. Mean RT on correct trials and mean accuracy on the gender identification task as a function of search condition (unknown-orientation singleton search vs. known-orientation search), distractor emotion (happy vs. fearful), emotional distractor presence (present vs. absent) and condition of search order (unknown-orientation singleton first vs. known-orientation first) in Experiment 1.

		Unknown-orientation singleton				Known-orientation			
		Fearful		Happy		Fearful		Happy	
		Absent	Present	Absent	Present	Absent	Present	Absent	Present
Unknown-orientation singleton first	RTs	1766(359)	1863(359)	1718(374)	1822(382)	1186(142)	1225(180)	1199(147)	1180(76)
	%	93.6(4.0)	93.6(3.9)	92.7(5.9)	93.8(6.6)	96.7(3.6)	95.0(3.9)	97.7(2.1)	97.0(1.8)
Known-orientation first	RTs	1607(157)	1759(205)	1660(248)	1735(280)	1232(197)	1201(220)	1291(182)	1286(187)
	%	94.2(2.2)	93.9(3.2)	94.5(4.1)	93.0(4.7)	96.6(2.9)	94.2(4.1)	95.0(4.3)	94.7(5.2)