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BRIEF REPORT

Attentional capture by evaluative stimuli: Gain- and loss-connoting colors boost the additional-singleton effect

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Abstract In a valence induction task, one color acquired positive valence by indicating the chance to win money (in the case of fast and correct responses), and a different color acquired negative valence by indicating the danger to lose money (in the case of slow or incorrect responses). In the additional-singleton trials of a visual search task, the task-irrelevant singleton color was either the positive one, the negative one, or one of two neutral colors. We found an additional-singleton effect (i.e., longer RTs with a singleton color than in the no-singleton control condition). This effect was significantly increased for the two valent colors (with no differences between them) relative to the two neutral colors (with no differences between them, either). This result favors the hypothesis that the general relevance of stimuli elicits attentional capture, rather than the negativity bias hypothesis.

Keywords Attentional capture · Additional singleton · Valence · Relevance · Emotion

In the field of cognition and emotion, a prevailing theme over the last two decades has been to explore the potency of evaluative stimuli to draw and/or hold attention (see, e.g., Yiend, 2010, for a review). Using stimuli with experimentally induced valences, we wanted to tackle one notorious question within the field: Are attentional effects dominantly driven by negative (or, more specific, threat-related) stimuli, or does a more general mechanism respond to goal-relevant stimuli, regardless of whether they are positive or negative? Good a priori arguments support both positions: Not noticing even a single dangerous object might have life-threatening consequences, whereas ignoring a positive opportunity typically has no dramatic result. Given the apparent functionality of a threat-detector module for survival, it thus seems a straightforward hypothesis that such a module has evolved (Öhman & Mineka, 2001). On the other hand, it can be argued that our attentional system is tuned to prioritize stimuli that are of general relevance for our goals, needs, and well-being, which is true for stimuli signaling opportunities and dangers alike (Brosch, Sander, Pourtois, & Scherer, 2008; Rothermund, Voss, & Wentura, 2008).

Although several studies have provided prima facie support for the threat-detector hypothesis (e.g., Brosch & Sharma, 2005; Buchner, Rothermund, Wentura, & Mehl, 2004; Öhman, Flykt, & Esteves, 2001; Petrova & Wentura, 2012), Brosch et al. (2008) claimed that on second sight, these studies do not speak against the relevance hypothesis. Some studies have only compared threat-related to neutral stimuli, which does not provide a means to distinguish negativity from relevance. Other studies have compared attentional capture for faces with different emotional expressions (angry vs. happy faces). In this case, Brosch and colleagues provided arguments that happy faces are not comparable in their general relevance to negative types of emotions. Thus, in their own study they compared fear-inducing and nurturance-inducing stimuli (i.e., angry faces and baby faces) and found comparable attentional effects for the two kinds of stimuli. Using the same logic, Purkis, Lester, and Field (2011) examined capture effects in a visual search task using pictures of spiders and pictures related to a popular TV series (*Dr Who*) as distractors. Participants varied with regard to whether or not they were spider-phobic and whether or not they watched the TV series. Capture effects for the stimuli of interest were indeed a function of personal relevance, regardless of whether the stimuli were threat-related or not. Using complex emotional scenes in eyetracking paradigms to explore early visual processing,

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Nummenmaa, Hyönä, and Calvo (2009) also found privileged processing of emotional (unpleasant and pleasant) scenes, but no differences between pleasant and unpleasant scenes. Finally, Wentura, Rothermund, and Bak (2000) found longer response times (RTs) for words indicating benevolent and malevolent attributes of social interaction partners in a color-naming task. In sum, then, quite substantial evidence favors the relevance hypothesis.

Nevertheless, these results were gathered with rather complex natural stimuli that differed in intrinsic valence. Therefore, we wanted to corroborate the claim made by these studies by experimentally inducing extrinsic evaluative connotations to simple stimuli in a balanced design. To do so, we conducted an additional-singleton experiment using colored singleton distractors (Olivers, Meijer, & Theeuwes, 2006; Theeuwes, 1992), with different colors being randomly assigned to positive, negative, and neutral valences. In the additional-singleton paradigm, a set of stimuli—for instance, diamonds—are arranged in a circle-like structure on the screen. Within one form, the target line is presented, which is either horizontal or vertical, and has to be categorized by participants accordingly. To ensure efficient search, the target is always presented within a form singleton (e.g., one diamond among circles). In control trials, all stimuli are presented in a common color, whereas in additional-singleton trials, one distractor is presented in a deviating color. Typically, RTs are longer in additional-singleton trials than in control trials. Since target search is efficient, this effect can be interpreted as attentional capture by the additional singleton.

The basic approach for our endeavor was to associate colors with a specific meaning (i.e., positive, negative, or neutral valence) and to explore whether valence-connoting colors boost the additional-singleton effect. Participants alternately proceeded through blocks of two different tasks. In the valence induction task, participants had to categorize single stimuli in a binary-decision task. The color of the stimulus-surrounding shape determined the chance of winning points or the danger of losing points (with points finally determining a money prize). One color (positive) signaled a gain of points, in the case of a fast and correct responses; another color (negative) signaled a loss of points, in the case of slow or incorrect responses; two additional colors were either associated with negligible losses or wins (neutral color) or acted as a no-go signal (irrelevant color). We hypothesized that the presence of valent singletons would increase the additional-singleton effect relative to the control colors (relevance effect). As a manipulation check of the valence induction procedure, the colored items were presented as primes in an evaluative-priming task (Fazio, Sanbonmatsu, Powell, & Kardes, 1986).

To date, only few other studies have used versions of the additional-singleton paradigm to study the attention-grabbing effects of valent stimuli with acquired connotation. On the one hand, Notebaert, Crombez, Van Damme, De Houwer, and Theeuwes (2011) associated specific colors (in a balanced design) with aversive electrocutaneous stimulation; that is, given our research question, the comparison with an adequate positive stimulus was missing. Anderson, Laurent, and Yantis (2011; see also Anderson & Yantis, 2013; Hickey, Chelazzi, & Theeuwes, 2010, 2011), on the other hand, associated specific colors (in a balanced design) with reward. Here, in comparison to our research question, the comparison with a negative stimulus was missing. That is, until now, the attention-grabbing properties of positive and negative stimuli were not compared within a single study. The aims of our study were to fill this gap and to compare attentional-capture effects for additional singletons that had previously acquired either a negative or a positive valence.

Method

Participants

A group of 48 students (25 women, 23 men) from Saarland University took part in the experiment in exchange for €9.5 (on average, ranging from €3 to €17; see the Procedure section). The median age was 23 years (ranging from 18 to 41 years). All had normal or corrected-to-normal vision. The data of one further participant had to be discarded because of an error rate of 42% in the additional-singleton task.

Design

For the additional-singleton task, we used a 2 × 5 factorial design. The first factor was Display Size (five vs. seven stimuli), the second was Type of Distractor (negative vs. positive vs. irrelevant vs. neutral vs. no distractor), and both factors were varied within participants. The assignment of colors to the conditions was counterbalanced.

Material

We employed circles (diameter: 2.39º visual angle) and diamonds (diagonal length: 2.93º visual angle). Standard color of all items was a light grey (RGB values: 175, 175, 175). The colors for the valence manipulation were light red (255, 144, 144), light green (114, 201, 101), light blue (173, 173, 255), and yellow (180, 180, 0). Colors were matched for luminance. Background color of the monitor was white. For the evaluative priming task, we used a smiley and a grumpy schematic face as primes (*standard primes*) in addition to the color symbols. The targets in the evaluation task consisted of 12 affectively polarized German nouns (taken from Bermeitinger, Kuhlmann, & Wentura, 2012). Six of these nouns were positive ($M = 6.69$, $SD = 0.10$, on a scale from 1 [*negative*] to 7 [*positive*]), whereas the remaining six were negative (*M* = 1.89, *SD* = 0.28). For positive as well as for negative nouns, the average word length was 5.5 letters (*SD* = 0.5, ranging from 5 to 6).

Procedure

At the beginning, participants received €10 with the obligation to invest the money as part of the stakes in a game-like situation. Participants were seated individually (separated by partition walls) in front of a computer screen in a dimly lit room. Viewing distance was approximately 60 cm. Instructions were given on the CRT screen. First, participants worked through blocks of the valence induction task (called *game task*). Second, blocks of the additional-singleton task alternated with further blocks of the valence-induction task. Finally, an evaluative priming task was administered.

Valence induction task Participants were informed that they could win or lose €1 in each block of the game task, depending on the final game score. In each given trial, a single colored frame (either a circle or a diamond) was presented until a response was registered. The frame included a target line that had to be categorized as either horizontal or vertical as quickly as possible. A fast and correct response was a success trial; slow and/or incorrect trials were failure trials. To ensure equal amounts of successful (gain) and unsuccessful (loss) trials, we used the moving median of the last trials as a criterion for fast/slow responses (Rothermund, 2003).[1] The color of the frame determined the consequences of success or failure. The positive color was associated with a gain of 20 points for success trials, but with no consequences for failure trials. The negative color was associated with a loss of 20 points for failure trials, but with no consequences for success trials. A third color (neutral color) was associated with negligible gains and losses of 1 point in the case of success or failure. A fourth (irrelevant) color was introduced as a no-go signal. That is, we instructed participants to press no key when this color appeared. Pressing a key caused the message: "Please do not respond to items of this color." Due to the occasional presence of a no-go color, color became a task-relevant feature, which should facilitate associations between color and valence. Each block started with a score of zero and comprised 48 trials. Each trial ended by a feedback screen, displayed for one second. Changes in the score were explicitly shown (i.e., "Good +20!" in case of a successful trial with positive color; "Bad –20!" in the case of an unsuccessful trial with negative color; "+1" or "–1" in case of the neutral color). If the score did not change, the feedback display contained only the current score that was shown throughout the whole block in the bottom part of the screen. Participants won €1 for each block that was completed with a final score of zero or above. If the score was below zero, they lost €1.

The experiment started with three blocks of the game task. Between two blocks of the additional-singleton task (see below), a further block of the game task was administered. Thus, for the entire experiment, participants had a chance of winning or losing up to €7. Taking into account the €10 compensation paid at the start of the study, they left the lab with a net amount of money that ranged between €3 and €17 (*M* = €9.5; see the Participants section).

Additional-singleton task In each trial, either five or seven items appeared on the screen in a circle-like structure. In each trial, one circle or diamond was accompanied either by four or six diamonds or by four or six circles, respectively. Within this form singleton, the target line (horizontal or vertical) was presented. Distractors were filled with randomly chosen tilted lines. The task was to classify the target line as either horizontal or vertical. In half of the trials, one distractor was presented in one of the four colors (i.e., the additional singleton). Participants were instructed to ignore the color singletons. The exact sequence of events within each trial was as follows. First, a fixation cross appeared for 2,600 ms. At 600 ms prior to offset, the fixation cross increased in size to warn the participant. It disappeared upon presentation of the search array. The search array stayed on the screen until response, after which the next trial followed immediately.

One block included 64 trials: eight trials for each combination of set size, form singleton, and target line. Four of the eight trials had no color singleton; the remaining four trials of the set had a color singleton with red, green, blue, and yellow appearing once. The location of the form singleton was randomly drawn. The location of the color singleton was drawn randomly from the remaining locations.

Overall, five blocks of the search task were administered. As we already noted, between two successive blocks of the search task a further block of the game task was inserted in order to refresh the valence assignment of the colors. Before the first experimental block, participants worked through 64 practice trials. During the practice trials, feedback was provided in case of an error (i.e., the message "wrong!" was presented for 2,000 ms).

Evaluative priming task Participants classified target words according to their valence using two keys ("m" for positive, "c" for negative). Each word was preceded by a briefly presented first stimulus (the prime, consisting of either a colored shape or a smiley or grumpy face) that should be ignored. The sequence of each trial was as follows: First, a fixation stimulus (+) was presented for 500 ms. Then the prime was shown for 100 ms. The prime was followed by a blank screen for 100 ms (i.e., SOA = 200 ms). Then, the target appeared until a response was given. Participants were

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[1] Actually, we used the formula $Md' = Md - (W*10) + 10$, with *Md* being the moving median of the last six trials and *W* the money hitherto won or lost.

instructed to respond as fast as possible without making lots of errors. The intertrial interval was 800 ms.

The task comprised two blocks with 72 trials each, each starting with two warm-up filler trials. Before the experiment, participants worked through 12 practice trials. Participants could take a rest after the first block. Within each block, each target word appeared six times, once following each of the four colors (positive, negative, neutral, irrelevant), the smiley face, and the grumpy face.

Results

Unless otherwise noted, all effects referred to as statistically significant throughout the text are associated with p values below .05, two-tailed.

Additional-singleton task

Mean RTs were derived from correct responses only. The average error rate across participants was 7.8%. RTs that were 1.5 interquartile ranges above the third quartile of the individual RT distribution (see Tukey, 1977) or were below 200 ms were discarded as well (4.2%).

Mean RTs are depicted in Fig. 1. The irrelevant and neutral conditions yielded almost identical values (all Fs < 1 for a 2 [irrelevant vs. neutral] × 2 [display size] analysis of variance). We therefore collapsed these data into a new *control* condition. A 4 (singleton: no singleton vs. control vs. positive vs. negative) × 2 (display size: five vs. seven) repeated measures multivariate analysis of variance (MANOVA), with RTs as the dependent variable, yielded only a main effect of singleton type, $F(3, 45) = 59.29$, $p < .001$, Pillai–Bartlett = .798 (both other Fs < 1).

We used orthogonal contrasts to test more specific hypotheses. The first contrast showed that the difference between the no-singleton condition and all other conditions combined was significant, $F(1, 47) = 184.20$, $p < .001$, $\eta_p^2 = .797$, confirming an additional-singleton effect of $M = 72$ ms ($SD = 38$ ms, $dz = 1.96$). The means of the remaining conditions still differed significantly, $F(2, 46) = 9.47$, $p < .001$, Pillai–Bartlett = .292, confirming that the different colors had differential influences on the size of the singleton effect. The second contrast showed that the difference between the control colors and the two emotional colors combined was significant, $F(1, 47) = 18.79$, $p < .001$, $\eta_p^2 = .286$, indicating an effect of emotional relevance, $M = 22$ ms ($SD = 35$ ms, $dz = 0.63$). The final contrast showed that the difference between the negative and positive colors was not significant, $F(1, 47) = 2.29$, $p = .14$, $\eta_p^2 = .046$ ($M = 14$ ms, $SD = 62$ ms, $dz = 0.22$).

Because of the importance of the comparison of the positive and negative conditions, we added two analyses. First, we explored the difference between the positive and negative conditions meticulously. The difference variable (collapsed across display sizes) had one outlying value (according to Tukey, 1977). Without this value, the positive and negative conditions were even more balanced, $t(46) = 1.14$, $p = .26$ ($M = 9$ ms, $SD = 54$ ms, $dz = 0.17$). We also conducted a nonparametric test, which yielded $z = 1.07$, $p = .284$, for the positive–negative comparison. Second, additional tests revealed that both the positive and negative conditions elicited significantly slower RTs than did the control condition, $t(47) = 3.92$, $p < .001$, $dz = 0.57$, for positive, $t(47) = 2.47$, $p = .017$, $dz = 0.36$, for negative.

Error rates were between 6.9% and 8.7% for the conditions of the design. A 4 (singleton) × 2 (display size) MANOVA yielded no significant results, all Fs < 1.02, n.s., except $F(1, 47) = 1.93$, $p = .17$, $\eta_p^2 = .040$, for the contrast of no-singleton versus singleton conditions. Numerically, the difference corresponded to an additional-singleton effect, $M = 0.7\%$ ms ($SD = 3.3\%$, $dz = 0.20$).

Evaluative priming

Mean RTs were derived from correct responses only. The data of one participant were discarded because of an error rate above 40%. The average error rate across participants was 6.1%. RTs that were 1.5 interquartile ranges above the third quartile of the individual RT distribution (see Tukey, 1977) or that were below 200 ms were discarded (4.9%). Mean RTs and error rates are shown in Table 1.

Priming effects were defined by the difference in mean RTs for incongruent prime–target pairings (i.e., positive prime–negative target, negative prime–positive target) minus the mean RT for congruent prime–target pairings (i.e., positive–positive, negative–negative) in order to disentangle priming effects from the main effects of prime type and target type (see, e.g., Wentura & Degner, 2010). The priming effect was $M = 22$ ms ($SD = 25$ ms) for the standard primes, $t(46) = 5.74$, $p < .001$, and $M = 14$ ms ($SD = 28$ ms) for the positive/negative colors, $t(46) = 3.51$, $p = .001$. Additionally, Table 1 includes the simple differences between the RT to negative targets minus the RT to positive targets for each of the different types of primes. The fact that these differences are all positive is indicative of a main effect of target valence, as is usually found in evaluative-priming tasks (see, e.g., Wentura & Degner, 2010). However, we can see that the differences for the positive and negative colors mimics the ones for the standard positive and negative primes (smiley and grumpy faces), respectively. The simple difference for the positive *color* is significantly larger than the difference for the *standard* negative prime, $t(46) = 4.79$, $p < .001$, and does not significantly deviate from the difference for the *standard* positive prime, $t(46) = 1.43$, $p = .16$. Likewise, the simple difference for the negative *color* is significantly lower than the

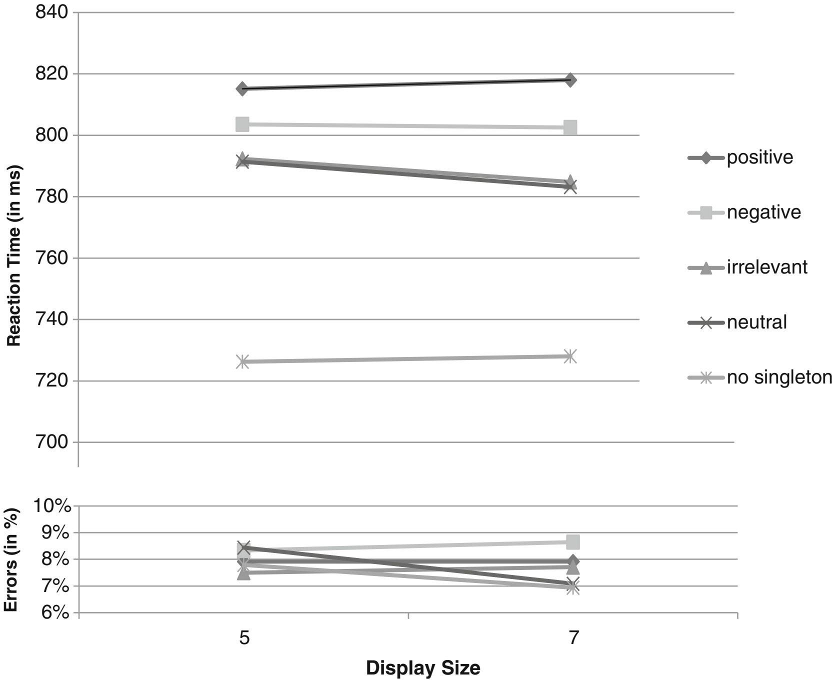

Fig. 1 Mean response times and errors as a function of display size and type of additional singleton

difference for the *standard* positive prime, $t(46) = 4.92$, $p < .001$, and does not significantly deviate from the difference for the *standard* negative prime, $t(46) = 0.34$, n.s. The neutral/irrelevant colors have simple differences that lie between the differences for positive and negative primes, and are not significantly different from one another, $t(46) = 0.11$, n.s.

For error rates, we found a significant priming effect for the standard primes, $M = 3.8\%$ ($SD = 6.9\%$), $t(46) = 3.72$, $p < .001$, but not for the colors, $M = 1.4\%$ ($SD = 9.6\%$), $t(46) = 1.01$, n.s.

Discussion

Our search task showed a standard additional-singleton effect; that is, RTs were longer if one of the distractors carried a task-irrelevant salient color. The effect was found in a setting with flat search slopes, indicating that the singleton captured attention. Importantly, the evaluatively connoting colors yielded stronger interference effects than did the neutral colors. Two features of this result are remarkable. First, we observed a clear difference between the neutral and valent colors. This difference cannot be explained by the mere frequency of presentation of colors in the valence induction task, since presentation rates were completely balanced. Second, gain- and loss-connoting colors made no difference, although we could show (using the evaluative-priming paradigm) that they had acquired positive and negative valences of comparable strengths. Thus, in a setting in which positive and negative valences were assigned to neutral color stimuli in a completely balanced design, we found no differences between the attentional-capture effects of the two valences. This corroborates the hypothesis of a general relevance principle that governs attentional processes (Brosch et al., 2008).

Table 1 Mean response times (RTs, in milliseconds) as a function of target and prime valence (errors as percentages, in parentheses), as well as priming effects (PE, in milliseconds; standard errors are in brackets) for the RTs

	Color				Schematic Face	
Target	Positive	Negative	Neutral	Irrelevant	Positive	Negative
Positive	448 (5.6)	464 (4.4)	454 (5.5)	463 (6.7)	442 (2.5)	469 (4.2)
Negative	484 (10.1)	472 (6.0)	469 (6.7)	477 (7.4)	489 (10.0)	473 (4.2)
Δ	36	7	15	14	47	5
PE	14 [4]				22 [4]	

Δ denotes the difference in the RT for negative targets minus the RT for positive targets (discrepancies are due to rounding); PEs are calculated as the RT for incongruent prime–target pairs minus the RT for congruent pairs.

The “add-on” effect of evaluative connotations might be due to capture or to attentional maintenance (Fox, Russo, & Dutton, 2002), or to a mixture of both. In the first case, it might be that the probability of attentional capture by color singletons is increased for valent colors. Thus, more trials indicating attentional capture by the additional singleton distractor would enter into the calculation of the mean for trials comprising valent as compared to neutral color distractors. In the second, attentional-maintenance case, this probability is assumed to be constant across colors. However, if attention is captured by a color singleton, the evaluative connotation causes additional attentional dwelling. It is beyond the scope of the present article to decide between these possibilities, but we can speculate on the basis of comparable studies. Olivers et al. (2006)—who found that (color) features held in working memory during visual search increased the additional-singleton effect if the singleton matched this feature—performed an additional eyetracking experiment to disentangle the two possible mechanisms. They found clear evidence for an increased probability of attentional capture if the singleton had the matching feature, rather than evidence for an increase in attentional dwell time.

However, even if we take this as an argument for the hypothesis of a boost in attentional capture by valent stimuli, we should remind ourselves of the boundary conditions. Notebaert et al. (2011) studied the attention-grabbing effect of threat-conditioned color stimuli in the visual search paradigm. One color (CS+) out of a set of colors was a signal for a painful, aversive electrocutaneous stimulus (US). In the visual search task, three, five, or seven circles of *different* colors were presented (thus, no salient color singleton was present). The results were clear cut: RTs were significantly slower than baseline (i.e., CS+ color not present) if the CS+ was a distractor, but significantly faster than baseline if the CS+ was the target. However, since slopes in the latter case were far beyond those associated with efficient search, the authors concluded that the CS+ did not capture attention, but merely prioritized the allocation of attention.

Nevertheless, our aim was to provide the best possible test for the equivalence of the attention-grabbing effects of positive and negative stimuli. The results were clear: no difference at all. Future work might show that this balance was due to situational factors that prioritized attention to positive stimuli in specific situations, but attention to negative stimuli in other situations. Rothermund and colleagues (2008; see also Rothermund, 2003; Wentura, Voss, & Rothermund, 2009) opted instead for a flexible mechanism of prioritization that would act in the service of emotional regulation. It will be up to further work to test this idea with the present paradigm.

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