Research Article

Irrelevant Words Trigger an Attentional Blink

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Abstract. It has been argued that salient distractor items displayed during rapid serial visual presentation (RSVP) trigger an attentional blink (AB) when they share features with the target item. Here we demonstrate that salient distractor words induce an AB independently of feature overlap with the target. In two experiments a color-highlighted irrelevant word preceded a target by a variable lag in an RSVP series of false font strings. Target identification was reduced at short relative to long temporal lags between the distractor word and the target, irrespective of feature sharing with the distractor word. When the target shared features with the distractor word, target accuracy was reduced across all lags. Accordingly, feature sharing between the distractor word and the target did not amplify the AB, but had an additive effect on attentional capture by the distractor word.

Keywords: attention, attentional blink, attentional capture, words

Temporal attention is often studied by the attentional blink (AB) task in which two targets are presented in close succession in a rapid serial visual presentation (RSVP) of irrelevant items (Raymond, Shapiro, & Arnell, 1992). Report of the first target (T1) leads to an impoverished identification of the second target (T2) when there are few intervening irrelevant items. If participants can ignore T1, identification performance of T2 is typically not affected by the temporal lag between T1 and T2. Therefore, the AB has been attributed to attentional demands associated with T1 processing resulting in a capacity limitation for T2 processing (e.g., Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998; Shapiro, Raymond, & Arnell, 1994).

Recently, some studies have demonstrated that an AB can also be induced when participants are asked to report only one target item preceded by a distractor item (Arnell, Killman, & Fijavz, 2007; Barnard, Scott, Taylor, May, & Knightley, 2004; Maki & Mebane, 2006). For instance, Maki and Mebane (2006) presented observers with an RSVP series consisting of false font filler strings and showed that the presentation of a to-be-ignored word or consonant string (the distractor) highlighted by color led to impaired identification of an ensuing word (the target) at short temporal lags between the distractor and the target. Crucially, this impairment caused by the attentional capture of the distractor was not observed when the distractor was a color-highlighted digit string instead of a word or consonant string. The authors concluded that attentional capture was contingent on feature overlap between the distractor and the target, whereby feature overlap means that both items consisted of letters. However, since Maki and Mebane (2006) always used a word as the target, they could not test the alternative hypothesis, namely that color-highlighted words embedded in an RSVP series trigger an AB independently of feature overlap with the target stimulus.

Privileged word processing is consistent with a number of different experimental findings. For example, semantic priming experiments demonstrate that visual word recognition is automatically triggered to a certain degree (e.g., Catena, Fuentes, & Tudela, 2002; Heil, Rolke, & Pecchinenda, 2004). Further, a large body of literature on the Stroop effect (Stroop, 1935) has shown that people often cannot avoid reading a word even though doing so strongly interferes with their assigned task (for a review, see MacLeod, 1991). Similarly, there is evidence that distractor words embedded in RSVP sequences undergo semantic processing. For instance, distractor words that are semantically related to a word target cause a substantial AB, while semantically unrelated words induce only a shallow AB (Barnard et al., 2004). Further, sexual distractor words lead to reduced target accuracy compared to neutral or negative words (Arnell et al., 2007). However, the design of these studies (Arnell et al., 2007; Barnard et al., 2004) was not suited to investigate the potential of words to automatically capture temporal attention, because participants were required to report a semantically defined target, which probably biased observers to semantically process all RSVP items, including the distractor, to be successful in identifying the target. Therefore, the rationale behind the present experiments was to test whether a salient distractor word in an RSVP series could automatically attract temporal attentional resources as measured by identification accuracy of the

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trailing target, even if there was no feature overlap between the distractor word and the target.

Closely mirroring the paradigm by Maki and Mebane (2006), we presented an RSVP sequence composed of false font filler strings in which a color-highlighted word served as the distractor stimulus. To manipulate feature overlap between the distractor word and the target we varied the alphanumeric class of the target. In the digit target condition, participants were required to identify a digit target ensuing the distractor by a variable lag. According to Maki and Mebane (2006) no reduced target accuracy would be expected for the digit target condition since there was no feature overlap between the distractor and the target. In contrast, we hypothesized that the unintentional processing of the distractor word could temporarily interfere with correct digit identification. To evaluate the distinct contribution of feature overlap to attentional capture, for another group of subjects the digit target was substituted by a letter target. Thus, in this letter target condition the distractor shared target-defining features.

Additionally, we investigated if the AB was modulated by the emotional content of the distractor word. Performance differences between emotional and neutral distractor words would indicate that irrelevant distractor words were indeed semantically processed. Semantic processing of words could constitute a potential mechanism accounting for their potential to capture temporal attention. Since differential effects of sexually connotated and negatively valenced distractor words on attentional capture have been reported (Aquino & Arnell, 2007; Arnell et al., 2007), participants were presented with neutral, negative, and taboo (i.e., mainly sexually connotated) distractor words.

Experiment 1

Method

Participants

Participants were 60 volunteers from the University of Munich community who were familiar with psychological studies, but naïve to the question of this particular study. All participants were German native speakers with normal or corrected to normal vision who gave informed consent and were compensated with a small monetary payment. Thirty subjects (18 female, $M = 24.04$ years) were assigned to the digit target condition, and thirty volunteers were assigned (17 female, $M = 23.50$ years) to the letter target condition.

Stimuli

Stimuli constituting the RSVP series were filler strings of five randomly assembled black Japanese letters printed in Sardinen HR True Type Font (size: 20 points). Before the experiment started, it was ensured that none of our German participants recognized these "false fonts" as meaningful letters. Target items were flanked on each side by two randomly assigned keyboard characters ("%" and "#") printed in Arial bold font (size: 23.5 points). In the digit target condition target items were black digits between two and nine. In the letter target condition black letters (the first eight letters of the alphabet) were used as target items.

Four different pools of distractor stimuli were generated, false fonts, neutral words, negative words, and taboo words. False fonts were drawn from a list comprising 40 different strings composed of random combinations of five Japanese letters printed in Sardinen HR True Type Font (size: 20 points) similar to the filler strings, but printed in red. Words constituting the other distractor pools were obtained from the database Projekt Deutscher Wortschatz (http://wortschatz.uni-leipzig.de; Biemann, Bordag, Heyer, Quasthoff, & Wolff, 2004) and were presented in red Arial bold font (size: 23.5 points). All distractor stimuli had the same vertical size (about 0.70° of visual angle) and there were no differences between the four distractor pools regarding their horizontal size, $F(3, 116) < 1$.

Neutral words were selected from a list of 40 neutral German nouns, whereas negative and taboo were derived from lists comprising 20 German nouns, respectively. Neutral, negative, and taboo words did not differ with regard to written word frequency as given by the database Projekt Deutscher Wortschatz, $F(2, 77) < 1$. The three pools were matched with regard to the number of letters ($Mdn = 5$) and the number of syllables ($Mdn = 2$). Eighteen independent judges rated each of the distractor words on arousal and valence to differentiate between neutral and emotional (negative and taboo) words. After completing the experiment all participants rated the negative and taboo words for taboo content (from 1, *low taboo*, to 7, *high taboo*) to validate the a priori distinction between negative and taboo words. All 20 taboo words received higher values on the taboo scale than the 20 negative words (taboo words: $M = 4.12$, $SD = 0.99$; negative words: $M = 1.62$, $SD = 0.37$).

Apparatus and Procedure

Participants viewed the stimuli on 19″ CRT monitors in a dimly lit room at a free viewing distance of ~ 55 cm. RSVP series consisted of 16 items (about 1.80°–3.80° × 0.70° of visual angle) that were presented on a gray background. Each trial started with a 1-s presentation of a black fixation cross in the middle of the screen which disappeared for a period of 300 ms to indicate the beginning of the stimulus presentation, followed by the sequential presentation of 16 stimuli, that is, the distractor, the target, and 14 filler strings (see Figure 1). Each item in the sequence was presented for 83 ms and was immediately followed by the trailing item. The distractor appeared equally often in serial positions 2–5. There were five lags between the distractor and the target, Lag 2 (two intervening items, stimulus onset asynchrony [SOA] 167 ms), Lags 3, 4, 6, and 8 (seven intervening items, SOA 583 ms). At the end of the sequence, subjects were prompted to type the target. Participants were informed that their responses should be made as accurately as possible, without speed pressure. Feedback

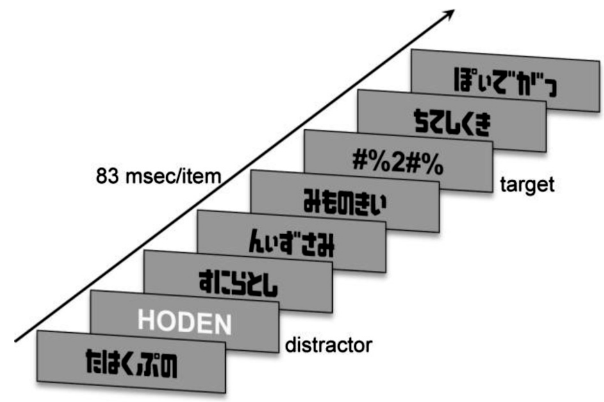

Figure 1. Schematic of an example trial. The distractor was always red (indicated by printing it in white). In Experiment 1, the distractor could be either a false font string, a neutral word, a negative word, or a taboo word. In Experiment 2, false fonts, neutral words, and digit strings were displayed as distractors. In the example depicted here the distractor is a taboo word (HODEN = testicle). Depending on the experiment and the condition the target was a digit between 2 and 9 or a letter (A, B, C, D, E, F, G, or H). The target was flanked by two keyboard characters on each side. The RSVP consisted of black false font strings.

was given immediately after each response had been executed.

Before the testing session started, participants conducted a practice block containing 20 trials that were excluded from the analysis. Within each testing session, there were five blocks consisting of 120 trials each. The five different distractor-target lags and the distractor's four possible serial positions occurred with equal probability. The false font condition and the neutral word condition occurred in one third of the trials, respectively, while the negative word condition and the taboo word condition were presented in one sixth of the trials. Hence, false fonts, neutral words, and emotion-laden words occurred with equal probability. The identities of the distractor and the target stimuli were selected at random without replacement from their respective pool for each trial. Thus, each word appeared one time per block.

Results

Target accuracy data were submitted to an ANOVA with the between-subjects factor target condition (digit and letter) and the within-subjects factors distractor type (false fonts, neutral words, negative words, and taboo words) and lag (2, 3, 4, 6, and 8). Performance was significantly higher for digit targets compared to letter targets, $F(1, 58) = 9.22$, $p < .005$, $\eta_p^2 = .14$. Further, there were significant main effects of distractor type, $F(3, 174) = 71.92$, $p < .0001$, $\eta_p^2 = .55$, and lag, $F(4, 232) = 28.79$, $p < .0001$, $\eta_p^2 = .33$, as well as interactions between distractor type and lag, $F(12, 696) = 7.02$, $p < .0001$, $\eta_p^2 = .11$, and between target condition and distractor type, $F(3, 174) = 11.86$, $p < .0001$, $\eta_p^2 = .17$. The three-way interaction between target condition, distractor type, and lag did not reach significance, $F(12, 696) < 1$.

We followed up on the interaction between distractor type and lag by performing separate ANOVAs for each distractor type. From Figure 2 it is obvious that target identification accuracy increased with lag for neutral words, $F(4, 236) = 17.76$, $p < .0001$, $\eta_p^2 = .23$, negative words, $F(4, 236) = 17.81$, $p < .0001$, $\eta_p^2 = .23$, and taboo words, $F(4, 236) = 13.06$, $p < .0001$, $\eta_p^2 = .18$. By contrast, for false fonts there was a slight drop in accuracy at long lags that reached significance, $F(4, 236) = 3.29$, $p < .05$, $\eta_p^2 = .05$. These results indicate that whereas false font distractors failed to induce an AB, all word distractors triggered a robust AB. Importantly, this AB, that is, the deterioration of target accuracy at short compared to long lags, was independent of target type, as evidenced by the absence of an interaction between target condition and lag, $F(4, 232) = 1.29$, n.s., $\eta_p^2 = .02$.

To further investigate the interaction between target condition and distractor type *t* tests were computed to compare both target conditions for each distractor type separately. While performance for false fonts did not differ between target conditions, $t(58) = 1.60$, n.s., letter targets were identified less accurately than digit targets when preceded by neutral, negative, or taboo words, smallest $t(58) = 2.90$.

Given the hypothesis that a deteriorated performance for emotional as compared to neutral distractors could indicate semantic processing of word distractors, we further explored the main effect of distractor type. Bonferroni corrected *t* tests (*p* values are reported as Bonferroni corrected by the number of tests) revealed that false fonts led to higher identification accuracy than the three word distractor conditions, smallest $t(59) = 8.56$. Critically, performance for taboo words was lower than for neutral words, $t(59) = 3.52$, $p_6 < .005$, and tended to be lower than for negative words, $t(59) = 2.26$, $p_6 = .16$.

To further assess if taboo words influenced the AB we performed another three-way ANOVA including only the three word distractor types, lag, and target condition as factors. Importantly, there was neither an interaction between distractor type and lag, $F(8, 464) < 1$, nor any other significant interactions. Thus, taboo words only lowered performance across all lags, but did not exhibit an effect on the AB.

Discussion

The present experiment was conducted to test if a task-irrelevant color-highlighted word in an RSVP series triggers an AB even if there is no feature overlap with the target stimulus. We found that identification accuracy for both digit and letter targets dropped with decreasing lags between the distractor word and the target. Importantly, this was not the case when a color-highlighted false font string was displayed instead of the word. Thus, salient words induced an AB even when they did not share target-defining features. These results pose a serious challenge to the perspective that

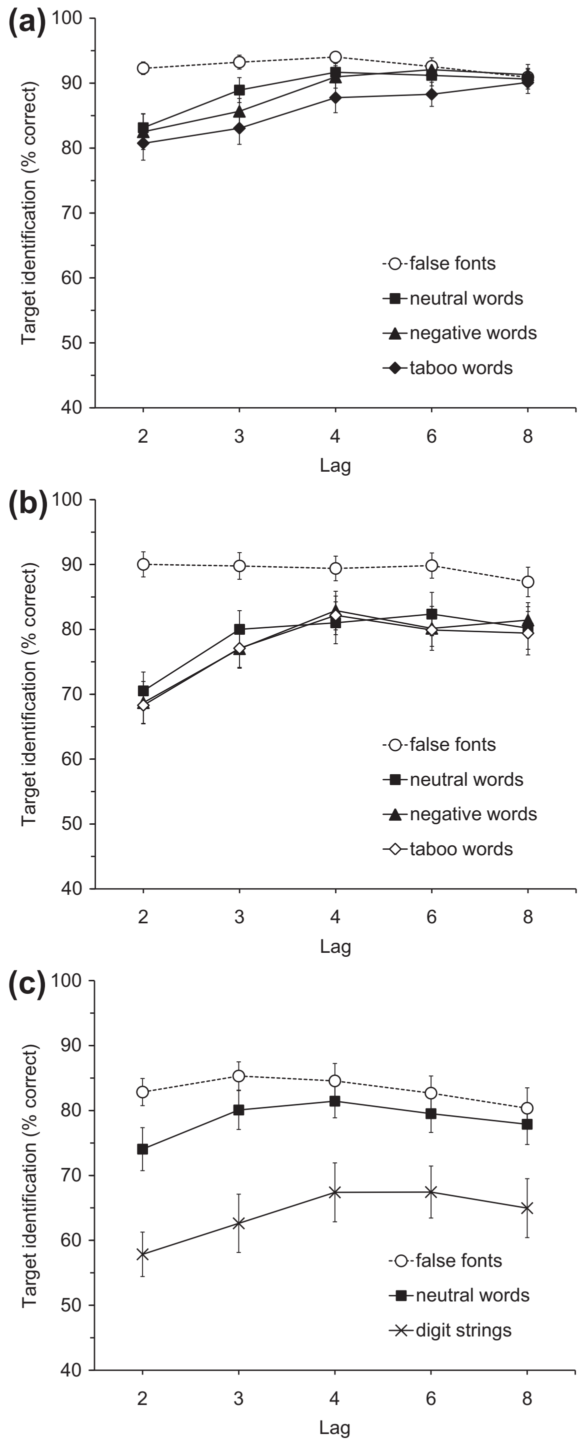

Figure 2. Mean percentage of accurate target report depicted as a function of distractor type and distractor-target lag. Error bars represent standard errors of the mean values. (a) Results for the digit target condition from Experiment 1, (b) results for the letter target condition from Experiment 1, and (c) results from Experiment 2.

an AB can only be triggered by distractor stimuli that share features with the target (Maki & Mebane, 2006).

Interestingly, feature sharing between the distractor and the target led to a generally lowered target identification accuracy across all lags. Thus, feature overlap had a purely additive effect on attentional capture. Since the AB is considered to refer to a reduced target accuracy at short as compared to long distractor-target lags, this implies that feature overlap between the target and the color-highlighted word distractor does not induce a stronger AB, but only a generally lowered target accuracy.

In addition, similar to the results obtained by Arnell et al. (2007) accuracy further deteriorated when the target was preceded by taboo words as compared to neutral words. Thus, participants apparently read and semantically processed the task-irrelevant words. However, this slight decrement in target accuracy due to taboo distractor words was not specific to short distractor-target lags, but was observed across all lags. As such, taboo words did not influence the AB specifically. Furthermore, this suggests that semantic processing of irrelevant words is probably not causing their potential to trigger an AB.

In summary, the data have demonstrated that the performance difference between short and long distractor-target lags is not affected by feature overlap. Thus, one might conclude that the AB observed in Experiment 1 was only triggered by the mere presentation of color-highlighted words. In this light, Experiment 2 examined if nonword distractors were capable of inducing an AB when they shared features with the target. Subjects searched for a digit target that could be preceded by color-highlighted digit strings, neutral words, or false fonts. Assuming that only salient word distractors had the potential to trigger an AB, we expected to observe no lag effect for digit strings. Alternatively, the Maki and Mebane (2006) account would predict a much stronger lag effect for digit strings than for neutral words.

Experiment 2

Method

Participants

Twenty-five (20 female, $M = 22.96$ years) volunteers from the University of Bielefeld community participated in this experiment for pay. In contrast to Experiment 1, subjects were generally unfamiliar with psychological experiments.

Stimuli and Procedure

Experiment 2 mirrored the digit target condition of Experiment 1 regarding all stimulus and design parameters, with the exception of the distractor conditions. Participants were required to report a digit between two and nine flanked on each side by two randomly sampled keyboard characters ("%" and "#"). The negative and taboo word conditions were replaced by a digit string condition in which a string of four or five digits between two and nine served as the distractor. The digits included in the distractor string were sampled randomly with the restriction that the target digit could not appear in the distractor string. Thus, a neutral word condition and a digit string condition were employed in Experiment 2. The visual angle and the number of distractor items employed in the digit string condition were matched to the word condition.

After ensuring that participants did not recognize the "false fonts" as meaningful Japanese letters, subjects received 20 practice trials that were excluded from the analysis and subsequently conducted five blocks containing 120 trials each. Within each block the three distractor types (false fonts, words, and digit strings), the five different distractor-target lags, and the distractor's four serial positions occurred with equal probability. For each trial, the identities of the distractor and target items were selected randomly without replacement.

Results

A repeated measures ANOVA with the variables distractor type (false fonts, words, and digit strings) and lag revealed main effects of distractor type, $F(2, 48) = 61.47$, $p < .0001$, $\eta_p^2 = .72$, and lag, $F(4, 96) = 6.89$, $p = .001$, $\eta_p^2 = .22$, which were qualified by a significant interaction between distractor type and lag, $F(8, 192) = 2.38$, $p < .05$, $\eta_p^2 = .09$.

To examine the interaction between distractor type and lag in more detail, separate ANOVAs were calculated for each distractor type. The main effect lag was significant for words, $F(4, 96) = 4.69$, $p = .005$, $\eta_p^2 = .16$, and for digit strings, $F(4, 96) = 4.36$, $p < .01$, $\eta_p^2 = .15$, but was not significant for false fonts, $F(4, 96) = 2.40$, $p = .071$, $\eta_p^2 = .09$. Thus, we observed a word-induced and an overlap-induced AB.

Importantly, when considering solely words and digit strings, there were only main effects of distractor type, $F(1, 24) = 59.05$, $p < .0001$, $\eta_p^2 = .71$, and lag, $F(4, 96) = 9.03$, $p < .0001$, $\eta_p^2 = .27$, but no interaction between distractor type and lag, $F(4, 96) < 1$. Hence, while performance was generally lower for digit strings as compared to words, both distractor types induced a similarly strong AB (see Figure 2).

Discussion

The successful induction of an AB by salient words replicated the results yielded by Experiment 1. A comparable difference in target accuracy between short and long lags was observed for color-highlighted digit strings that shared features with the target. Word- and overlap-induced ABs did not differ in size. However, a generally deteriorated performance was observed for the overlap-induced condition that was independent of the AB.

These results qualify the conclusions by Maki and Mebane (2006). In line with these authors a salient nonword distractor that shared features with the target item induced an AB. This overlap-induced AB supports the idea that attentional capture is contingent on feature overlap between the distractor and the target. However, similar to Experiment 1 a color-highlighted word led to target deficits at short lags, although the target was from a different alphanumeric class. Again, this word-induced AB argues for a capturing potential of words independent of feature sharing between distractors and targets.

General Discussion

In the present experiments we asked if a distractor word inserted in an RSVP sequence has to share features with a target item to trigger an AB. The results demonstrate that feature sharing between a color-highlighted distractor word and a target is not necessary for temporal attentional capture. The mere presentation of a distractor word interfered with the identification of a digit target at short temporal lags. However, feature overlap between the distractor and the target had an additive effect on attentional capture, as evidenced by a stronger deterioration of target accuracy across all lags when the distractor word shared features with a letter target (Experiment 1) or when a digit string distractor preceded a digit target (Experiment 2).

In all experiments colored false font strings did not capture temporal attention. The observation that a simple color singleton does not capture attention is in line with research on attentional capture in visual search demonstrating that attentional capture by irrelevant singletons does not occur when subjects have to search for a target that is not defined as being a singleton (Bacon & Egeth, 1994; Lamy & Tsal, 1999). Folk, Leber, and Egeth (2002) extended this finding to the domain of temporal attention. In their study, participants had to search for a color-defined letter target which was preceded by colored keyboard characters appearing in the periphery of a central RSVP series. Attentional capture only occurred when the singleton shared the target-defining feature, that is, the color. However, this study investigated intradimensional capture. Thus, only color was manipulated and no words were used as distractors and therefore this study does not allow to decide on the question of attentional capture by words in general. While Folk et al. (2002) demonstrated that the AB was caused by an involuntary shift of attention away from the central RSVP series, Maki and Mebane (2006) showed that a colored distractor word within the RSVP sequence could also induce an AB when participants had to report a word target. However, since the target was always a word in this study the design was not suited to investigate if a salient word might capture attention independently of feature overlap with the target.

Here we demonstrate that color-highlighted words induced an AB although they did not share target-defining features as defined by Maki and Mebane (2006). It has been argued that visual word recognition is largely obligatory and ballistic, in the sense that it is automatically triggered by the presentation of a word stimulus and activates semantics independently of the observer's intention (e.g., Brown, Gore, & Carr, 2002; Heil et al., 2004). We hypothesized that unintentional semantic processing of salient distractor words might lead to temporal attentional capture. Evidence that semantic word processing can interfere with the assigned task can be derived from the well-known Stroop paradigm, whereby participants are slow to name the ink color of a word that spells an incongruent color name (for a review, see MacLeod, 1991). In Experiment 1 participants apparently processed the distractor's semantics since target accuracy was decreased for taboo words as compared to neutral words. However, the strength of the AB was not influenced by the emotional content of the distractor word. This implicates that the AB induced by irrelevant salient words is probably not caused by the fact that words convey a semantic content.

Similarly, feature overlap between the distractor word and a letter target did not influence the AB specifically. When subjects had to report a letter instead of a digit target, distractor-induced interference was stronger across all lags. This is in line with the results obtained by Maki and Mebane (2006) who found longlasting interference effects from distractor words on word identification. It appears that feature sharing between the distractor word and the target has a purely additive effect on attentional capture, that is, it does not specifically lead to deteriorated performance at short lags between the distractor and the target, but to worse performance across all lags.

Based on the data obtained in Experiment 1 it might be concluded that feature overlap is entirely superfluous to trigger an AB, and that presenting a color-highlighted distractor word is the only necessary requirement to observe a performance difference between short and long distractor-target lags. However, in contrast to that plausible prediction Experiment 2 demonstrated that feature overlap between a salient nonword distractor and a target triggered an AB. Thus, as proposed by Maki and Mebane (2006), feature overlap induces an AB. Crucially, feature overlap is not necessary to observe the AB phenomenon when the critical distractor is a color-highlighted word. Interestingly, in Experiment 2 there was only little recovery from the AB in the digit string distractor condition. Even at long lags performance was low as compared to the word and false font distractor conditions.

One could argue that the capturing potential of salient words was already evident by the fact that Maki and Mebane (2006) reported a stronger AB when word targets were preceded by word distractors than by consonant string distractors. However, this observation can be readily explained by more feature overlap between word distractors and word targets, since words have features such as vowels that consonant strings have not. To investigate the potency of salient distractor words to induce an AB over and above feature sharing with a target, it is key to manipulate the nature of the target stimulus.

Future studies should further examine why salient, but completely task-irrelevant, words trigger an AB. Results from studies investigating the effect of irrelevant words on the deployment of spatial attention suggest that words as overlearned communicative signals attract attentional resources in a relatively automatic manner (Hommel, Pratt, Colzato, & Godijn, 2001). Here we extend these findings to the domain of temporal attention. In line with Hommel et al. (2001) it seems feasible that observers reflexively orient attention to communicative symbols such as salient words.

Alternatively, an extension of the idea put forward by Maki and Mebane (2006) might explain the present results.[1] It could be that an exact feature overlap between the target and distractor may not be necessary, but some similarity between the target-distractor categories, for example, belonging to an alphanumeric class, would be sufficient to produce an AB (Ghorashi, Zuvic, Visser, & Di Lollo, 2003; Visser, Bishof, & Di Lollo, 2004). Along this line, salient false font distractors did not induce an AB because they were highly dissimilar from the target category. Further, one could assume that digits are less imperative for automatic processing. This might explain the observation that salient digit string distractors did not induce an AB for word targets (Maki & Mebane, 2006), whereas in the present Experiment 1 color-highlighted words triggered an AB for digit targets.

In conclusion, this study showed that the mere presentation of salient distractor words triggers an AB, independently of feature overlap between the distractor words and the target. Feature overlap did not increase the magnitude of the AB specifically, but induced a lower target accuracy across all lags between the distractor word and the target.

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[1] We would like to thank an anonymous reviewer for pointing to this possibility.

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