The Attentional Blink is diminished for targets that form coherent semantic categories

Helen Tibboel

Jan De Houwer

Adriaan Spruyt

Geert Crombez

Department of Experimental-Clinical and Health Psychology

Ghent University, Belgium

mailing address: Helen Tibboel

Department of Psychology

Ghent University

Henri Dunantlaan 2

B-9000 Ghent

Belgium

Email: Helen.Tibboel@UGent.be

Phone: 0032 9 264 86 18

Fax: 0032 9 264 64 89

Abstract

Studies have shown that the attentional blink (AB) effect is diminished for intrinsically salient T2 stimuli, such as arousing, familiar, personally relevant words, or stimuli with salient low-level visual features. We examined whether the AB is diminished also for stimuli that do not have special inherent properties but are made salient by the context. One such contextual factor is the coherence of the T2 stimulus set. In three experiments, we found that the AB is diminished for stimuli that form a coherent semantic category within the T2 stimulus set. Both theoretical and practical implications are discussed.

Keywords: attentional blink, coherence, attention

1. Introduction

Humans can process only a limited amount of information at once. This limitation necessitates selectivity. It is important that the information that we do attend to and select for further processing is relevant for guiding adaptive behavior. Some stimuli, such as highly arousing, very familiar, personally relevant stimuli, or stimuli with salient low-level visual features, hold important information about the state of the environment and aid us in judging which actions would be adequate to deal with the situation. It is therefore beneficial to preferentially process these stimuli. One paradigm that elegantly exposes the limits of our attentional system and that has been used to illustrate the special attentional status of salient information (e.g., Anderson, 2005), is the attentional blink paradigm (AB; Raymond, Shapiro, & Arnell, 1992). The AB effect refers to the finding that people have difficulties in identifying the second of two masked targets (T1 and T2) within a rapid serial visual presentation (RSVP) stream of distractors if T2 is presented within approximately 500 ms after T1. When the interval (lag) between the targets increases, T2 performance is no longer hampered (but see the literature on the Lag-1 sparing effect for the effects when T2 is the first stimulus to be presented after T1; e.g., Hommel & Akyurek, 2005). The common explanation for this finding is that attentional resources are not sufficient to deal with all RSVP items and that there is competition between these items in early stages of attention (e.g., Chun & Potter, 1995; Isaak, Shapiro, & Martin, 1999; Jolicoeur & Dell'Acqua, 1998; Raymond et al., 1992; Shapiro, Arnell, & Raymond, 1997; Shapiro, Raymond, & Arnell, 1994). The basic idea is thus that little attention is left to process T2 when the lag between two targets is short, causing detriments in performance. As the lag increases, attentional resources recover, thereby facilitating T2 processing.

Studies have shown that the AB is diminished for highly arousing T2 stimuli, (e.g., Anderson, 2005; Anderson & Phelps, 2001; Ihssen & Keil, 2009; Keil & Ihssen, 2004; Keil, Ihssen & Heim, 2006), familiar stimuli such as very well-learnt stimuli (Maki & Padmanabhan, 1994), and familiar faces (Jackson & Raymond, 2006). The AB is attenuated also for personally relevant information such as participants' own name (Shapiro, Caldwell, & Sorensen, 1997). Furthermore, the paradigm has been used in (sub)clinical samples, where the AB effect has proven to be smaller for spider-related stimuli in spider-phobics (Trippe, Hewig, Heydel, Hecht, & Miltner, 2007), for fearful faces in a sample of highly anxious participants (Fox, Russo, & Georgiou, 2005), for addiction-related stimuli in a sample of frequent users (Tibboel, De Houwer, & Field, 2010; Waters, Heishman, Lerman, & Pickworth, 2007). Finally, the AB is diminished when T2 has very distinct low-level visual features, such as a high visual contrast (Chua, 2005) or a salient colour (Shih & Reeves, 2007). In each of these experiments, it was found that at short lags, such salient stimuli are identified better than control stimuli (i.e., stimuli that are affectively neutral, that are not particularly relevant or familiar, or do not have specific salient visual features), thus leading to a reduced AB effect for these stimuli. These salient stimuli are therefore assumed to have a special attentional status, which allows them to gain priority access to awareness.

One question that remains to be answered is whether T2 stimuli need to have intrinsically salient properties to be less affected by the AB, or whether they can be made salient by the context in which they are presented. The contextual variable that we examined was the (lack of) semantic coherence of the word categories. More specifically, we examined whether the AB would be reduced for neutral words (i.e., stimuli that do not have salient properties) that form a coherent category within the set of T2 stimuli that are presented during the AB task. For instance, if a substantial part of the T2 stimuli are exemplars of musical instruments, will the AB for these stimuli be smaller than the AB for other stimuli that belong to various other categories? Surprisingly, the possible impact of coherence has been overlooked in many studies examining the impact of salient T2 stimuli on the AB. Moreover, it has never been manipulated directly in AB studies. Demonstrating an impact of coherence on the AB would have both practical and theoretical implications. At the practical level, it would imply that researchers should control for coherence when they examine the modulation of the AB by specific categories of salient stimuli. For instance, experimenters who study the influence of arousal on the AB do not always mention the specific category of arousing T2 words (e.g., Ihssen & Keil, 2009), but usually they present a coherent set of either taboo words (e.g., Anderson, 2005) or aggression verbs (e.g., Experiment 3 by Keil and Ihssen, 2004). In contrast, the only common denominator for the neutral words is their non-emotional nature. That is, the neutral words are not semantically related in any apparent way. It can be argued that the semantic coherence of the arousing words adds to their salience, irrespective of their emotional nature. In this case, the special attentional status of these stimuli and the extent to which they are processed more efficiently than other stimuli cannot be attributed exclusively to their emotional properties, but might depend also on the context in which they are presented. A few studies have compared emotional words with neutral words that form a coherent category (Anderson, 2005; Keil & Ihssen, 2004; Waters et al., 2007) but testing the hypothesis that semantic coherence as such decreases AB effects requires a comparison of neutral words that form a coherent category with neutral words that do not form a coherent category. Such a comparison has not yet been performed.

Studying the effects of coherence on the AB is important also for theoretical reasons. If coherence would influence the AB in this manner, it would suggest that even very early, automatic attentional processes that determine access to awareness are flexible in the sense of that they are context-dependent and open to subtle top-down influences. Some evidence for top-down modulation of automatic attentional processes has already been reported but primarily in the context of the orienting of spatial attention (e.g., Folk, Remington, & Johnston, 1992; Vogt, De Houwer, Moors, Van Damme, & Crombez, 2010). Little is known about contextual modulation of the early attentional processes that underlie the AB. Moreover, previous studies about top-down influences on attentional processes focused on rather blatant contextual variables such as explicit task instructions (e.g., the instruction to respond to certain stimuli). In three experiments, we simply presented stimuli that belong to a coherent semantic category and compared the AB for these stimuli with the AB for comparable stimuli that do not form a coherent category.

The T2 stimuli that formed a coherent category were not emotionally arousing, nor were they more familiar, more visually salient or more personally relevant than the random T2 stimuli. In Experiment 1, we presented either music-related words (i.e., neutral words that form a coherent category) or random neutral words as T2. In Experiment 2, we presented a different kind of neutral coherent T2 category, namely words referring to numbers, and again compared them with random neutral words. In the final experiment, we examined whether the AB was diminished for two additional categories: body parts and weather phenomena. Furthermore, we manipulated the relative salience of these categories in a strictly experimental manner. Experiment 3 therefore consisted of two conditions. In both conditions, the same T2 stimuli were presented, but in each condition different filler trials were included to increase the salience of specific coherent categories: body parts in one condition, and weather phenomena in the other condition. In each of these experiments, we expected a decreased AB for words that formed a salient coherent category compared to random neutral words (i.e., better performance for the words belonging to the salient coherent category compared to random words at the short lags, but not at the long lags).

2. Experiment 1

2.1. Method

2.1.1. Participants.

Twenty-six participants (13 men) from various faculties at Ghent University participated in exchange for course credits. All participants were native Dutch-speakers.

2.1.2. Stimuli and Materials.

Thirty music-related words and 30 random neutral words served as T2 (see Appendix A). The two types of words did not differ in word length ($M = 6.37$, $SD = 1.83$, and $M = 5.83$, $SD = 1.15$ respectively, *t*s < 1) but word frequency norms (Duyck, Desmet, Verbeke, & Brysbaert, 2004) showed that music-related words were less frequent than random neutral words ($M = 33.53$, $SD = 32.66$), $t(58) = 4.10$, $p < .001$. [1]

There were 60 neutral T1 words and 79 neutral distractors (word length: $M = 5.83$, $SD = 1.22$, and $M = 12.73$, $SE = 2.07$, respectively). The distractors were adapted from stimuli used by Anderson (2005). We used relatively long distractors in order to sufficiently mask the targets. All words were Dutch.

2.1.3. Procedure.

Participants were tested in a spacious room in which four computers were set up, separated by partitions. Three or four participants were tested during each session. They were seated in front of a 19 inch CRT-monitor with a refresh rate of 85 Hz, at a distance of approximately 45 cm. After giving informed consent, they performed the experiment. For stimulus presentation and response registration, we used the E-Prime software package (Schneider, Eschman, & Zuccolotto, 2002a, 2002b).

Each trial started with the presentation of a red fixation cross that remained on the screen for 1000 ms. This was followed by the RSVP stream, consisting of 13 distractor words in white, and T1 and T2 in green. All these stimuli were presented for 94 ms (equaling 8 screen refreshes), in 16 point bold Courier New font, against a black background. Participants were instructed to monitor the stream and to report the green words. At the end of each trial, participants were prompted to type in their responses. They were encouraged to guess when necessary. There was no response deadline.

T1 was randomly selected from the list of neutral T1 words. T2 was randomly selected from the list of random neutral T2 words on half of the trials, and from the list of music-related T2 words on the other half of the trials. T1 could appear at the third, fourth, or fifth position in the stream, and T2 could appear 2, 4, or 6 lags after T1, reflecting a stimulus onset asynchrony (SOA) of 188, 376, and 564 ms respectively. Each of the 18 trial types (2 T2 categories * 3 lags * 3 T1 positions) was repeated ten times, yielding a total of 180 experimental trials. Trials were presented in a random order. At the beginning of the experiment, there was a practice block consisting of 18 trials in which all targets were different neutral words.

2.1.4. Data analysis.

The percentage of accurate responses was calculated for each of the experimental conditions for T1 and for T2. For our analysis of T2 data, only trials with a correct T1 identification were taken into account (T2|T1-correct). [2] We performed a repeated measures ANOVA with two within-subjects factors: T2 type (coherent or random), and lag (2, 4, or 6). Relevant summary data can be found in Table 1.

2.2. Results

We excluded data of one participant from our analyses because the proportion of correct T1 identifications was below .50 (i.e., M = .46). As we analyzed T2 data only for trials in which T1 was identified correctly, for this participant not many trials were left to estimate the value of each cell in the design. The identification of T1 did not differ between conditions, all Fs < 1.75. Overall, T1 detection was accurate, M = .80, SE = .02. Prior inspection of the data revealed that two T2 stimuli were identified poorly overall. For accordion (“accordeon”), M = .13, and double bass (“contrabas”), M = .09, accuracy was more than two standard deviations below the overall mean accuracy for music-related words, $M = .62$, $SD = .21$. We therefore excluded these items from further analysis.

Most importantly, the crucial interaction between T2 type and lag approached significance, $F(2, 23) = 2.75$, $p = .07$. At Lag 2, participants were better at identifying music-related words than random neutral words, $t(49) = 3.45$, $p < .005$, while there was no such difference at Lag 4, $t < 1$. At Lag 6, performance tended to be worse for music-related words, $t(49) = 1.88$, $p = .07$.

In addition, there was a main effect for lag, $F\ (2, 23) = 142.99$, $p < .001$, reflecting better performance as lag increased. Paired samples t-tests show that performance at Lag 4 was significantly better than performance at Lag 2, $t(24) = 12.13$, $p < .001$, and performance at Lag 6 was in turn significantly better than performance at Lag 4, $t(24) = 5.55$, $p < .001$, and Lag 2, $t(24) = 13.56$, $p < .001$. There were no other effects, Fs < 1.

2.3. Discussion

Our results showed that the AB effect was weaker for music-related words (i.e., words that formed a coherent category) compared to random neutral words. Even though these results are promising, there are several limitations to our study. First, the crucial interaction did not reach conventional levels of significance (i.e., $p = .07$). Second, the modulation of the AB was due not only to better performance for music-related words than for random neutral words at Lag 2, but it was driven also by the tendency for performance to be worse for the music-related words than for the random neutral words at Lag 6. Possibly, this is because the music-related words were less frequent than the random words. This may have increased the error rates on trials in which music-related words were presented, and may have decreased the number of music-related guesses on trials in which participants were unsure about their answer. Even though the AB effect (i.e., the difference between performance on the short compared to the long lag) was stronger for the random neutral words than for the music-related words, this would lead to better performance for random neutral words in conditions where we would expect no difference (i.e., at Lag 6). Third, Experiment 1 was limited in that we used only music-related words as a coherent category. Hence, we do not know whether we can generalize our findings to other coherent categories. For these reasons, we performed a second study in which, instead of music-related words, we presented words belonging to a different neutral coherent category, namely numbers.

3. Experiment 2

3.1. Method

3.1.1. Participants.

Nineteen native Dutch-speaking students (two men) from various faculties at Ghent University participated in exchange for course credits.

3.1.2. Stimuli and Materials.

For the AB task, we used the same distractors as in the previous experiment, and we used 30 of the T1 stimuli that were used in the previous experiment (mean word length: M = 5.80, SD = 0.19). There were 10 neutral T2 words that did not form a coherent category (mean word length: M = 4.70, SD = 0.95; mean word frequency per million: M = 267.20, SD = 151.22) and 10 T2 words that referred to numbers (mean word length: M = 4.30, SD = 0.82; mean word frequency per million: M = 256.41, SD = 304.23). Importantly, word length and word frequency did not differ for the two types of stimuli, ts < 1.01. T2 stimuli can be found in Appendix B.

3.1.3. Procedure.

The procedure was very similar to Experiment 1, but there were some exceptions. First, T1 could appear only at the third or fifth position in the RSVP stream, and T2 would follow at Lag 2 or Lag 8. Second, there were two blocks in which the 20 different T2 words were presented once at each of the two lags, at both trials in which T1 appeared at the third or at the fifth position. This yielded 80 trials per block, and thus a total of 160 trials. The practice block now consisted of 12 trials.

3.1.4. Data analysis.

We treated the data as we did in Experiment 1. We subjected the data to a repeated measures ANOVA with two within subjects factors: lag (2 or 8), and T2 type (coherent or random). The relevant descriptives can be found in Table 2.

3.2. Results

The identification of T1 did not differ between conditions, all *F*s < 1.19. Overall, T1 identification was very accurate, $M = .91$, $SE = .04$.

Most importantly, our analyses of T2 data yielded a significant interaction between T2 type and lag, $F(1, 18) = 24.50$, $p < .001$. At Lag 2, participants were significantly better at identifying T2 stimuli that formed a coherent category, $t(18) = 5.57$, $p < .001$, while there was no difference at Lag 8, $t = 1.47$. In addition, there was a significant main effect for lag, $F(1, 18) = 42.50$, $p < .001$, and a significant main effect for T2 type, $F(1, 18) = 29.79$, $p < .001$.

3.3. Discussion

Our second experiment clearly shows that the AB was smaller for T2 stimuli that formed a coherent category. Words referring to numbers were affected less by the AB than random neutral words. Contrary to Experiment 1, T2 stimuli that formed a coherent category were perfectly matched for length and frequency. However, we still cannot rule out with certainty that it is not coherence but some intrinsic property that made the numbers salient and diminished the AB. For instance, several theorists (e.g., Dehaene, Piazza, Pinel, & Cohen, 2003) suggest that the human brain has evolved to attend to numerosity. It is thus possible that numbers are encoded more efficiently because of highly developed neural circuitry that deals with number processing, and not because numbers form a coherent category.

We therefore decided to conduct a final experiment in which we used two approaches to obtain further evidence for the hypothesis that coherence in itself can modulate the AB. First, we tested the generality of our findings by using two coherent categories that were not used in the previous experiments (i.e., body parts and weather phenomena). If we observed a reduced AB for these categories as well, it would render the hypothesis that the effects observed in Experiment 2 were due to some inherent property of the stimuli of the coherent category highly unlikely. Second, we tried to manipulate coherence experimentally, that is, independent from the stimuli that form the coherent category. Experiment 3 thus consisted of two conditions in which the same T2 stimuli were presented: four words referring to body parts, four words referring to weather phenomena, and eight random words. Note that there were two different categories of words: weather phenomena and body parts. However, in each condition there were also additional filler trials in which filler T2 stimuli were presented that also belonged to one of these categories (i.e., body parts in one condition, and weather phenomena in the other condition). We hoped that adding filler T2 from a specific category would make one of the two coherent categories stand out even more. We will refer to the coherent category for which filler trials were added as “salient coherent” and to the other category as “control coherent”. Importantly, the data from the filler trials were not analysed. The advantage of this design is that coherence was thus manipulated without changing the identity of the stimuli that were used for the analyses. If we observe an even smaller AB for the stimuli belonging to the salient coherent category than for the stimuli belonging to the control coherent category, this could not be due to specific properties of these stimuli, because exactly the same stimuli were presented in both conditions. This would thus allow us to exclude the possibility that the reduction in AB observed in the previous experiments is due to inherent properties of the stimuli.

4. Experiment 3

4.1. Method

4.1.1. Participants.

Sixty-four students from various faculties at Ghent University participated in exchange for course credits. Thirty-two participants (two men) were assigned to the body parts condition, the other participants (five men) were assigned to the weather phenomena condition. All participants were native Dutch-speakers.

4.1.2. Stimuli and Materials.

We used the same distractors as in the previous experiments. There were 30 neutral T1 stimuli (mean word length: $M = 5.70$, $SD = 1.18$). In both groups, there were four T2 stimuli that referred to body parts (mean word length: $M = 4.00$, $SD = 0.00$; mean word frequency: $M = 50.25$, $SD = 31.42$), four stimuli that referred to weather phenomena (mean word length: $M = 4.50$, $SD = 1.29$; mean word frequency: $M = 47.00$, $SD = 6.58$), and eight random words (mean word length: $M = 5.00$, $SD = 1.04$; mean word frequency: $M = 41.50$, $SD = 30.41$). There were no differences in word length and word frequency between the different types of T2 stimuli, ts < 1.39.

In the body parts condition, there were 8 additional filler T2 stimuli referring to body parts (mean word length: $M = 4.75$, $SD = 1.49$; mean word frequency: $M = 50.25$, $SD = 53.23$) and in the weather phenomena condition there were 8 additional filler T2 stimuli referring to weather phenomena (mean word length: $M = 5.25$, $SD = 1.04$; mean word frequency: $M = 27.37$, $SD = 34.18$). There was no difference in word frequency and word length between the different types of filler T2 stimuli, ts < 1.03. All T2 stimuli can be found in Appendix C.

4.1.3. Procedure.

The procedure was almost the same as in Experiment 2, but there were some exceptions. First, we used a 19 inch CRT-monitor with a refresh rate of 100 Hz, and all RSVP items were presented for 100 ms (i.e., 10 screen refreshes). Second, there was a practice block that consisted of 16 trials in which neutral words were presented. After this, the experiment started with a block that served only to create a context in which one category became salient. The data for this block were not analysed because different filler trials were presented in the two conditions. This block consisted of 32 trials in which only filler T2 stimuli (body parts in the body parts group, weather phenomena in the weather phenomena group) were presented. Each of the eight filler T2 stimuli occurred once at each of the two lags and for each of the two T1 positions.

Then the experiment proceeded with a block in which all types of trials (filler and non-filler) were presented randomly. Again, there were 32 trials in which filler T2 stimuli were presented (body parts in the body parts group, weather phenomena in the weather phenomena group; each of the eight fillers was presented once at each of the two lags and for each of the two T1 positions). The data obtained from these trials were again discarded. The rest of the trials contained T2 stimuli that were presented in both conditions and were thus used for our analyses. Each of the four body parts, the four weather phenomena, and the eight random words was presented twice at each lag for each T1 position, resulting in 128 trials (32 body parts trials, 32 weather phenomenon trials, and 64 random neutral trials), and thus a total of 160 trials (including the 32 filler trials) for the second block. Hence, across blocks, the task consisted of 192 trials. Note that in the body parts condition, half of all trials contained a T2 referring to body parts (i.e., one sixth of trials contained a non-filler body part T2, and one third of trials contained a filler body part T2), whereas the other half of trials did not (i.e., one sixth of trials contained a T2 referring to weather phenomena and one third of trials contained a random T2). Likewise, in the weather phenomena condition, half of the trials contained a T2 referring to weather phenomena.

4.1.4. Data analysis.

We prepared the data the same way as in the previous experiments. As we mentioned above, the data for filler trials were discarded. In contrast to the first two experiments, there were now three types of T2 stimuli: words that belonged to the salient coherent category (i.e., body parts in the body parts condition and weather phenomena in the weather phenomena condition), words that belonged to the control category (i.e., body parts in the weather phenomena condition and weather phenomena in the body parts condition), and random words.

We subjected the data to a repeated measures ANOVA with two within subjects factors: lag (2 or 8), and T2 type (salient coherent category, control category, or random), and one between-subjects factor: condition (body parts or weather phenomena). The relevant data can be found in Table 3.

4.2. Results

We excluded the data of three participants (one in the body parts condition, two in the weather phenomena condition) because their T1 accuracy was lower than 50%. T1 identification did not differ across conditions, Fs < 3.10. Overall, T1 was identified well, M = .88, SD = .08.

The analysis of T2 data revealed an interaction between T2 type and lag, $F(2, 57) = 4.16$, $p < .05$. Contrasts show that the AB was significantly weaker for T2 stimuli that belonged to the salient coherent category than for random words, $F(1, 58) = 11.22$, $p < .005$. The modulation of the AB was marginally significant when comparing the control category with random words, $F(1, 58) = 3.64$, $p = .06$, and not significant when comparing the salient coherent category with the control category, $F < 1$. At Lag 2, performance was significantly better for both the salient coherent category, $t(59) = 4.97$, $p < .001$, and the control category, $t(59) = 2.85$, $p < .01$, compared to random words, while there was no difference in performance between the salient and the control category, $t < 1.57$. At Lag 8, performance was still significantly better for the salient coherent category compared to random words, $t(59) = 2.85$, $p < .01$. None of the other differences were significant, ts < 1.39.

There was also a main effect for lag, $F(1, 58) = 129.51$, $p < .001$, reflecting better performance at Lag 8. Furthermore, we found a main effect for T2 type, $F(2, 57) = 11.52$, $p < .001$. Finally, there was a tendency towards a significant interaction between T2 type, condition, and lag, $F(2, 57) = 2.44$, $p = .10$. There were no other effects, Fs < 1. Even though the three-way interaction only approached significance, we performed separate repeated measures ANOVAs with T2 type (salient coherent, control, or random) and lag (2 or 8) as within-subjects factors for both conditions to examine whether the interaction between T2 type and lag was significant in both conditions.

4.2.1. Body parts condition.

The analyses yielded a significant interaction between T2 type and lag, $F(2, 29) = 3.40$, $p < .05$. Simple contrasts show that the interaction was marginally significant when comparing the salient coherent category (i.e., body parts) with random words, $F(1, 30) = 3.26$, $p = .08$, and significant when comparing the control category (i.e., weather phenomena) with random words, $F(1, 30) = 6.74$, $p < .05$. There was no significant interaction when comparing the salient and the control category, $F < 1$.

T-tests reveal that at Lag 2, performance was better for the salient coherent category (i.e., body parts), $t(30) = 3.29$, $p < .005$, and for the control category (i.e., weather phenomena), $t(30) = 3.34$, $p < .005$, compared to random words. At Lag 8, performance was still better for the salient coherent category than random words, $t(30) = 3.01$, $p < .01$. Other ts < 1.73. There was also a significant main effect for lag, $F(1, 30) = 50.42$, $p < .001$, showing better performance at Lag 8.

Finally, there was a significant main effect for T2 type, $F(2, 29) = 7.93$, $p < .005$. Performance was better for the salient coherent category, $t(30) = 3.75$, $p < .005$, and for the control category, $t(30) = 3.01$, $p < .01$, compared to random words, while there was no difference between performance for the salient and the control category, $t < 1$.

4.2.2. Weather phenomena condition.

The ANOVA yielded an interaction between T2 type and lag that approached significance, $F(2, 27) = 3.17$, $p = .05$. Contrasts reveal that the interaction was significant when the salient coherent category was compared with random words, $F(1, 28) = 8.38$, $p < .01$, but not when the control category was compared with random words, $F < 1$. The interaction that compared the salient coherent category with the control category did not reach conventional levels of significance, $F(1, 28) = 2.95$, $p = .10$, but there was a trend in this direction.

T-tests show that this was driven mainly by the fact that at Lag 2, the salient coherent category (i.e., weather phenomena) was identified better than random words, $t(28) = 3.75$, $p < .005$, and slightly better than the control category (i.e., body parts), $t(28) = 1.92$, $p = .07$. There was no difference between the control category and random words at Lag 2, nor were there any differences at Lag 8, *t*s < 1.08. There was also a main effect for lag, $F(1, 28) = 90.64$, $p < .001$, revealing better performance at Lag 8. Finally, there was a significant main effect for T2 type, $F(2, 27) = 4.52$, $p < .05$. Performance for the salient coherent category was better than performance for random words, $t(28) = 3.23$, $p < .005$, and tended to be better than performance for the control category, $t(28) = 1.64$, $p = .11$. There was no difference in performance between the control category and random words, $t < 1.19$.

4.3. Discussion

The results of Experiment 3 provide further support for the hypothesis that the AB is reduced for coherent categories. We replicated the effect of coherence yet again with two categories that were not used in the previous experiments (i.e., body parts and weather phenomena). This attests to the generality of the effect and raises doubts about whether all of our effects could have been due to inherent features of the stimuli that formed the coherent categories. It is difficult to see why a reduced AB was found for the presented music-related words (Experiment 1), numbers (Experiment 2), body parts (Experiment 3), and weather phenomena (Experiment 3) other than because each group of stimuli formed a coherent category.

However, the approach to manipulate coherence experimentally by presenting filler trials did not produce clear results. On the one hand, the AB was reduced for body parts only when additional body parts were presented on filler trials (i.e., the body parts condition) but not when filler trials contained weather phenomena. This is in line with the idea that the reduced AB for body parts in the body parts condition was not due to intrinsic properties of the stimuli. If intrinsic properties would have been crucial, the reduced AB for body parts should have been found also in the weather phenomena condition. On the other hand, the AB effect was reduced for weather phenomena regardless of the nature of the filler items. Although this could indicate that some intrinsic property of the weather phenomena was responsible for the reduced AB effect, it is also possible that our manipulation of the salience of the weather phenomena was not successful. It is, for instance, possible that weather phenomena were salient even when the filler items were names of body parts. This is not unlikely given that even in the body parts condition, each of the four crucial names of weather phenomena was presented eight times. This high number of repetitions was unavoidable given that we needed a sufficient number of observations to estimate the AB effect. As such, the mere test of the AB effect for stimuli from a particular category could in some cases already endow the category with coherence, thus canceling out any attempt to manipulate coherence experimentally. Hence, even in future studies, it might turn out to be very difficult to manipulate the salience of a category by adding filler trials. The fact that we found a diminished AB for weather phenomena in both conditions could be related to the baseline salience of this category. We did find some evidence that the weather phenomena were quite salient in both conditions, whereas the body parts were mainly salient in the body parts condition. At the end of the experiment, participants filled in a brief questionnaire containing the question whether there was one word category that stood out during the task. In the body parts condition 26% of participants mentioned both categories, whereas in the weather phenomena condition, only 10% of participants mentioned both categories.

5. General discussion

The results of our experiments show that the AB was diminished for T2 stimuli that were affectively neutral and did not stand out in any other way except for the fact that they formed coherent categories within the T2 stimulus set. In Experiment 1, AB effects were slightly weaker for music-related words compared to random neutral words. The results from Experiment 2 show that the attenuation of the AB by coherent T2 categories is not limited to music-related words, but generalizes to words referring to numbers. Experiment 3 extends these findings by showing that the AB is smaller also for body parts and weather phenomena. Experiment 3 also showed that the effect for body parts was limited to a situation in which these stimuli were made salient by presenting additional names of body parts on filler trials. This observation argues against the possibility that the reduced AB effect for body parts was due to some inherent feature of those stimuli. Unexpectedly, the manipulation of filler trials did not influence the extent to which the AB was reduced for names of weather phenomena. One explanation for the latter result is that these stimuli were salient even when filler items referred to body parts either due to the repeated presentation of the names of the four crucial weather phenomena, or because of an inherent property of those stimuli. However, it is unclear what this property might be. Moreover, the fact that our experiments have shown a reduced AB effect for four different coherent categories raises doubts about the possibility that each of these effects is due to some inherent feature of the stimuli that belong to that category. In sum, our data support the conclusion that the AB is reduced for neutral stimuli that form a coherent category.

This conclusion has important implications. First, it means that researchers who want to examine the special attentional status of specific categories of stimuli should use control stimuli that form an equally coherent category as the salient stimuli. Furthermore, it is possible that in previous studies specific stimulus properties (i.e., arousal, familiarity) were confounded with coherence. For instance, the fact that Liu and colleagues (2008) found a smaller AB for addiction-related compared to neutral stimuli in a sample of abstinent opiate dependent patients (AODPs) may have been due to the fact that the addiction-related stimuli formed one coherent category, whereas the neutral stimuli did not. We thus need to be careful in interpreting results from studies in which specific categories of salient stimuli are compared with random control stimuli. Differential effects for salient stimuli may not necessarily be due to intrinsic properties, but could at least partly be due to contextual effects.

Second, our results imply also that T2 stimuli that do not have any intrinsically salient features can be made salient by presenting them in a context in which other exemplars from the same category are presented. Stimuli can thus gain special attentional properties without extensive familiarization as was the case in previous studies (Jackson & Raymond, 2008; Maki & Padmanabhan, 1994; Shapiro et al., 1997) and without specific emotional (e.g., Anderson, 2005; Anderson & Phelps, 2001; Ihssen & Keil, 2009; Keil & Ihssen, 2004; Keil et al., 2004) or visual (e.g., Chua, 2005; Shih & Reeves, 2007) properties. Rather, the mere semantic coherence of a category seems to increase the salience of exemplars belonging to that category. This suggests that early attentional processes are remarkably flexible in adjusting to the broader experimental context and can accommodate attentional settings online.

This leads to questions regarding the underlying mechanism that drives the modulation of the AB by coherence. First, our findings may be explained by accessibility. The frequent presentation of category exemplars could have made the coherent category more accessible. This may have lowered the threshold for identifying category exemplars and thereby decreased the AB. This explanation is similar to the view of Shapiro et al. (1997), who assumed that similar processes are at play for extremely familiar stimuli like one's name. To our knowledge, accessibility of T2 stimuli has not yet been manipulated, apart from several studies that have examined priming effects in RSVP tasks (e.g., Davenport & Potter, 2005; Maki, Frigen, & Paulson, 1997; Potter, Dell'Acqua, Pesciarelli, Job, & Peressotti, 2005). However, while main effects of priming are usually found, priming does not seem to modulate the AB (i.e., targets that were primed were identified better overall, but were not affected less by the AB). Before we conclude that priming is not a likely explanation for our findings, we must note that there are important procedural differences between our study and these previous studies (Davenport & Potter, 2005; Maki et al., 1997; Potter et al., 2005). The latter made use of quick sequence priming, in which the prime was followed by a semantically related target after a brief period of time. In our study, priming more closely resembled category priming, in which repeated exposure to exemplars of a specific category (e.g., hostile behavior) influences subsequent judgments of subsequent neutral or ambiguous stimuli (e.g., a person is judged to be more hostile by participants who were primed with hostility than by participants who were not) (e.g., Bassili, 2001). Although we did not examine how category priming affects participants' judgments but rather their capacity to attend to exemplars of the category, the underlying process may be similar: the repeated presentation of category exemplars may have increased the accessibility of the category and thereby attenuated the AB.

A related explanation is that because half of the trials contained words that form a coherent category, category membership may have become task-relevant and affected participants' attentional set. Several studies have shown that task demands specify attentional control settings and thereby influence what captures our attention (e.g., Folk et al., 1992). To examine the influence of task-relevance is difficult in a design like ours, because T2 always needs to be reported and its identity is thus per definition task-relevant. However, it is possible to manipulate the extent to which category-membership is task-relevant. In a task in which participants are not required to identify T2, but instead have to judge whether the word is a verb or a noun, we may expect that the semantic category to which the stimulus belongs is less task-relevant and therefore does not modulate the AB. In the context of the emotional modulation of the AB, a similar manipulation has been implemented by Stein, Zwickel, Ritter, Kitzmantel, and Schneider (2009). They found that when they presented fearful faces as T1, this increased the AB effect only when the emotional expression of the face needed to be indicated. When participants were required to judge T1 faces' gender, no such effect was found. To our knowledge, however, such manipulations have not yet been performed in studies examining the modulation of the AB by salient T2 stimuli. The question whether task-relevance modulates the AB thus remains to be explored. The impact of accessibility and task relevance does not need to occur outside of conscious awareness. Possibly, participants may have noticed that half of the trials contained a word that belonged to a specific coherent category. This may have made it easier to recognize exemplars of this category. Further research is needed to examine whether participants need to be aware of the fact that a subset of the T2 stimuli form a clear coherent category, whereas the remaining T2 stimuli do not.

One could also question whether the modulation of the AB is indeed an attentional effect. It is possible that the diminished AB that was observed both in our studies and in previous studies in which salient T2 stimuli were presented (e.g., Anderson, 2005; Anderson

& Phelps, 2001; Fox et al., 2005; Ihssen & Keil, 2009; Jackson & Raymond, 2006; Keil & Ihssen, 2004; Keil et al., 2006, Maki & Padmanabhan, 1994; Shapiro et al., 1997; Tibboel et al., 2010; Trippe et al., 2007; Waters et al., 2007) was (at least partly) caused by a response bias. Participants may have adopted a strategy to report words that belonged to the salient category, which implies that there would be more correct guesses for the coherent category than for the random words. This benefit would be most apparent at Lag 2, as this is the lag at which participants are more often unsure about their answer and therefore make a guess.

Anderson (2005) addressed this issue in a study examining the efficiency with which taboo stimuli are encoded. He coded all incorrect responses as being neutral or taboo on the basis of their meaning and found that neutral guesses were more frequent than taboo guesses. Based on this observation, he concluded that there was no bias to report taboo words. For each of the experiments described above, we have performed similar analyses. Results show that participants always made more guesses referring to random words than guesses referring to words belonging to the salient coherent category.[3] However, because there are many more neutral words than there are words belonging to the specific categories presented in our experiments, the baseline for guessing words belonging to a specific category is much lower than the baseline for guessing the random words that were presented in our experiment. The analyses as proposed by Anderson may thus not be strict enough to detect a response bias. We therefore calculated the number of incorrect guesses referring only to words that were presented in the experiment (i.e., "old" words) without taking into account words that were generated by the participants but never presented as a T2 stimulus (i.e., "new" words). These analyses showed that there was no difference in the number of incorrect responses referring to "old" words belonging to the coherent category compared to random words in Experiment 1 and Experiment 3. In Experiment 2, participants did incorrectly report more "old" words referring to numbers than random words.[4] It is important to note, however, that the number of incorrect responses that referred to numbers was extremely low, an average of 4.21 responses in an experiment that consisted of 160 trials. It is thus very unlikely that the modulation of the AB by stimuli that form a coherent category is due to a response bias, even in Experiment 2.

Nevertheless, different experimental designs are needed to fully exclude this possibility. In a recent study, Tibboel, Van Bockstaele, and De Houwer (in press) have used signal detection theory (SDT) to explore whether attenuation of the AB for taboo T2 stimuli was caused by a bias to report taboo words. Their data showed that this was not the case. More recent studies at our lab (Tibboel, Van Bockstaele, Verschuere, & De Houwer, in preparation) confirmed that the modulation of the AB by other types of salient stimuli, including the participants own name (see Shapiro et al., 1997) and, most important for the present paper, words that belong to a coherent category of T2 stimuli, also cannot be explained by a response bias. This further strengthens the conclusion that salient stimuli, including stimuli that are salient because they form a coherent category of T2 stimuli, result in a smaller AB because they have privileged access to awareness. Note, however, that regardless of the reasons for why the AB is reduced for coherent stimuli, our studies support the important practical conclusion that researchers should control for the effects of coherence when studying whether other stimulus properties (e.g., emotional valence, personal relevance) modulate the AB effect.

Finally, the present data are in line with the idea that humans have a tendency to spontaneously categorize stimuli and to use this category knowledge to structure incoming stimulus information. A plausible hypothesis is that our cognitive system is indeed sensitive to semantic coherence, because it is a useful cue in inducing inferences about the world. It can aid us in predicting the order of events and subsequently helps us to decide which actions are appropriate in specific contexts. Our data suggest that the tendency to detect semantic coherence can facilitate performance by facilitating the access of coherent stimuli to awareness.

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Author note

Helen Tibboel, Jan De Houwer, Adriaan Spruyt, and Geert Crombez, Department of Experimental-Clinical and Health Psychology, Ghent University, Ghent, Belgium.

Helen Tibboel is a Research Assistant of the Flemish Research Foundation (FWO - Vlaanderen). Adriaan Spruyt is Postdoctoral Fellow of the Flemish Research Foundation (FWO - Vlaanderen). The preparation of this manuscript was supported by Grant BOF/GOA2006/001 of Ghent University. Correspondence regarding this article should be addressed to Helen Tibboel, Department of Experimental-Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium. Email: helen.tibboel@ugent.be

Footnotes

[1] We acknowledge that word frequency modulates the AB. The fact that the music-related words were less frequent than the random neutral therefore reduces rather than increases the probability of a Type-I error.

[2] For all three experiments, we performed additional analyses in which all trials were included (i.e., including trials in which T1 was not identified correctly). The results of these analyses were virtually identical.

[3] Because participants tended to not respond at all when they were unsure about their answer, the number of incorrect guesses was relatively low (15 % of all trials in Experiment 1, 9% in Experiment 2, 10% in Experiment 3). Wilcoxon tests showed that of all incorrect trials on which a response was given, 73 % of the responses were random, 17 % belonged to the salient coherent category, and 10 % were non-words in Experiment 1. In Experiment 2, 68% of incorrect answers were random, 21 % belonged to the salient coherent category, and 11 % were non-words. Finally, in Experiment 3, 85 % of the incorrect responses were random and 15% belonged to the salient coherent category. The difference between the number of random guesses and guesses that referred to words belonging to the salient category was always significant, all *z*s > 3.32, all *p*s < .005, suggesting there was a bias to report random words rather than words that belonged to a coherent category.

[4] In Experiment 1, the average number of incorrectly reported music-related and random "old" words did not differ, $M = 2.07$, $SD = 1.44$, and $M = 1.33$, $SD = .89$, respectively, $z < .97$. In Experiment 2, participants incorrectly reported more "old" words referring to numbers, $M = 4.21$, $SD = 2.83$, than random words, $M = 1.58$, $SD = 1.00$, $z = 2.44$, $p < .05$. Finally, in Experiment 3, the average number of incorrectly reported old words that belong to the coherent category and random words did not differ, $M = 1.84$, $SD = 1.00$, and $M = 1.78$, $SD = .99$, respectively, $z < .36$.

Table 1

Mean T2 accuracy given correct identification of T1 for Experiment 1

	Lag 2		Lag 4		Lag 6	
T2 type	*M*	*SD*	*M*	*SD*	*M*	*SD*
Coherent (music)	.41	.21	.73	.22	.84	.13
Random (neutral)	.35	.24	.72	.16	.86	.13

Table 2

Mean T2 accuracy given correct identification of T1 for Experiment 2

	Lag 2		Lag 8	
T2 type	*M*	*SD*	*M*	*SD*
Coherent (numbers)	.75	.21	.98	.02
Random (neutral)	.58	.23	.97	.04

Table 3

Mean T2 accuracy given correct identification of T1 for Experiment 3

	Lag 2		Lag 8	
T2 type	*M*	*SD*	*M*	*SD*
	Body parts condition			
Salient coherent	.70	.25	.96	.05
Control coherent	.70	.22	.93	.08
Random	.61	.24	.92	.08
	Weather phenomena condition			
Salient coherent	.71	.19	.95	.07
Control coherent	.64	.25	.94	.08
Random (neutral)	.62	.19	.93	.08

Appendix A

T2 stimuli Experiment 1

Music-related words:

ACCORDEON (accordion), CELLO (cello), CONCERT (concert), CONTRABAS (contrabass), DRUMSTEL (drum set), DWARSFLUIT (transverse flute), GITAAR (guitar), HARP (harp), HOBO (oboe), HOORN (horn), JAZZ (jazz), KLARINET (clarinet), KOOR (choir), LIED (song), MELODIE (melody), MICROFOON (microphone), ORGEL (organ), ORKEST (orchestra), PIANO (piano), PODIUM (stage), RITME (rhythm), SAXOFOON (saxophone), STEREO (stereo), SYMFONIE (symphony), TRIANGEL (triangle), TROMBONE (trombone), TROMMEL (drum), TROMPET (trumpet), VIOOL (violin), ZANG (singing)

Random Neutral words:

APPEL (apple), BESTEK (cutlery), BLADEREN (leaf through), BUREAU (desk) DATUM (date), DRUPPEL (drop), HANGMAT (hammock), HERFST (autumn), HOUT (wood), IJZER (iron), KATOEN (cotton), KIMONO (kimono), LAARS (boot), MIDDAG (afternoon), PLANK (plank), PORSELEIN (porcelain), SCHERM (screen), SLEUTEL (key), STEEN (rock), STOEP (pavement), STOF (dust), STREEP (line), TANTE (aunt), TAPIJT (carpet), VAREN (sail), VIERKANT (square), VRACHT (freight), WAGON (carriage), WORTEL (carrot), ZEGEL (seal).

Appendix B

T2 stimuli Experiment 2

Words referring to numbers:

TWEE (two), DRIE (three), VIJF (five), ZES (six), ACHT (eight), NEGEN (nine), TIEN (ten), TWAALF (twelve), VIER (four), ZEVEN (seven)

Random Neutral words:

TANTE (aunt), BLAD (leaf), GELUID (sound), LUCHT (sky), STRAAT (street), ETEN (food), BED (bed), WATER (water), DEUR (door), WOORD (word)

Appendix C

T2 stimuli Experiment 3

T2 stimuli referring to body parts (presented in both conditions):

BUIK (stomach), HEUP (hip), KNIE (knee), POLS (wrist)

Filler T2 stimuli referring to body parts (presented only in body parts condition):

ELLEBOOG (elbow), HALS (neck), HIEL (heel), KUIT (calf), NEUS (nose), ROMP (torso), TEEN (toe), VINGER (finger)

T2 stimuli referring to weather phenomena (presented in both conditions):

REGEN (rain), SNEEUW (snow), WOLK (cloud), ZON (sun)

Filler T2 stimuli referring to weather phenomena (presented only in weather phenomena condition):

BLIKSEM (lightning), DONDER (thunder), MIST (fog), NEVEL (mist), ONWEER (thunderstorm), STORM (gale), VORST (frost), WIND (wind)

Random neutral words (presented in both conditions):

APPEL (apple), BANK (bank), FIETS (bicycle), GOUD (gold), HEMD (shirt), KWARTIER (quarter of an hour), NEEF (cousin), SCHAAP (sheep)