Towards improving treatment for childhood OCD: Analyzing mediating mechanisms & non-response
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Chapter 3

The time-course of threat processing in children: A temporal dissociation between selective attention and behavioral interference

Lidewij H. Wolters, Else de Haan, Leentje Vervoort, Sanne M. Hogendoorn, Frits Boer, & Pier J.M. Prins

Abstract

Although selective attention to threatening information is an adaptive mechanism, exaggerated attention to threat may be related to anxiety disorders. However, studies examining threat processing in children have obtained mixed findings. In the present study, the time-course of attentional bias for threat and behavioral interference was analyzed in a community sample of 8-to-18-years-old children (N = 33) using a pictorial dot probe task. Threatening and neutral stimuli were shown during 17 ms (masked), 500 ms, and 1250 ms. Results provide preliminary evidence of an automatic attentional bias for threat at 17 ms that persists during later, more controlled stages of information processing (500 and 1250 ms). Furthermore, participants showed a delayed response to threat-containing trials relative to neutral trials in the 500 and 1250 ms condition, which may indicate interference by threat.

Together, these results suggest that an attentional bias for threat precedes behavioral interference in children. Furthermore, results indicate that performance in daily life can be temporarily interrupted by the processing of threatening information. In addition, results of earlier studies into selective attention in children using tasks based on behavioral responses may have been confounded by interference effects of threat. For future studies, we recommend to take behavioral interference into account.
Introduction

Selective attention to threatening information is an adaptive process that allows prompt responding to potential dangers in the environment (Lang, Bradley, & Cuthbert, 1997). There is a large amount of behavioral as well as neuroimaging data showing that individuals can rapidly attend to motivationally relevant information in complex visual scenes (e.g., Koster, Crombez, Verschuere, Vanvolsem, & De Houwer, 2007; Schupp, Junghöfer, Weike, & Hamm, 2004). Selective attention to threatening information is already evident at early, preconscious stages of information processing. Subsequently, processing of threatening information commands attentional processes as well as behavior as the processing of threat can interrupt ongoing activity (see Mogg & Bradley, 1998).

Exaggerated attention to threat is considered to be related to anxiety disorders (e.g., Derryberry & Reed, 2002; Lonigan, Vasey, Phillips, & Hazen, 2004; Mogg & Bradley, 1998). In order to examine whether an attentional bias for threat is involved in the etiology of anxiety disorders, researchers have started to investigate attentional bias in anxious and non-anxious individuals. In general, results indicate that anxious individuals show an attentional bias to threatening information (see for a meta-analysis Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007). However, whereas these results only indicate a relation between anxiety and an attentional bias to threat, the potential role of attentional processes in the development and maintenance of anxiety disorders is still unclear.

Most research into selective attention has been conducted with adults and considerably fewer studies have focused on children and adolescents. In the latter domain, several studies reported an attentional bias favoring threat relative to neutral information in anxious children, and no attentional bias or a bias away from threat in non-anxious children (e.g., Dalgleish et al., 2003; Hunt, Keogh & French, 2007; Roy et al., 2008; Taghavi, Neshat-Doost, Moradi, Yule, & Dalgleish, 1999; Vasey, Daleiden, Williams, & Brown, 1995; Vasey, Elhag, & Daleiden, 1996; Waters, Henry, Mogg, Bradley, & Pine, 2010; Waters, Mogg, Bradley, & Pine, 2008, Waters, Wharton, Zimmer-Gembeck, & Craske, 2008 (posttreatment)). In other studies no difference was observed between both groups with all children attending more to threatening than to neutral information (e.g., Kindt, Bierman, & Brosschot, 1997; Kindt, Brosschot
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& Everaerd, 1997; Kindt, Van den Hout, De Jong, & Hoekzema, 2000; Waters, Lipp and Spence, 2004; Waters, Wharton, et al., 2008 (pretreatment). The latter finding has led several theorists to assume that children tend to allocate attention preferentially to threat more than adults. During lifetime, selective attention to threat may decrease with age through increased encounters with threatening information and development of attentional control. Kindt and Van den Hout (2001) hypothesized that during childhood children learn to strategically inhibit an attentional bias towards threat. Anxious children may not acquire this skill adequately, and therefore show persistence of attentional bias to threat (Kindt & Van den Hout, 2001). However, this theory is not unambiguously supported by the extant data (see for a review Puliafico & Kendall, 2006). Interpretation of results is further complicated because several factors may contribute to the inconsistencies across studies, including research with different paradigms, differences between samples (clinical versus non-clinical anxious, non-clinical high versus low anxious) and age, the use of varying stimulus exposure durations, and the selection of stimuli (e.g., threat value of the stimuli; words, pictures or faces; specificity of the match between the stimuli and children's anxiety-related concerns).

Attentional tasks used in child studies like the emotional Stroop task and the dot probe task rely on manual or verbal responding. In such tasks reaction times tend to be slower and show more variability in children than in adults (e.g., Van Damme & Crombez, 2009). This may be due to a limited information-processing capacity and difficulties with voluntary response suppression, which may not be fully developed until early adulthood (Kindt & Van den Hout, 2001; Puliafico & Kendall, 2006). In tasks like the emotional Stroop and the dot probe, the threatening information is irrelevant for a correct response. When cognitive resources are nevertheless allocated to threatening stimuli, insufficient resources are available for other processes (e.g., responding to the task). The processing of threat then interferes with other activity, resulting in a delayed response to the task (Flykt, 2006; Kindt & Van den Hout, 2001). This interference can act as a confounder in studies measuring attentional bias relying on behavioral responses. However, when behavioral interference is measured separately, it can reveal important information about the processing of threat in children.

The dot probe task could be used to differentiate between attentional bias and behavioral interference. In the dot probe task, originally developed
by MacLeod, Mathews, and Tata (1986), two stimuli are simultaneously presented on a computer screen: one stimulus left and one stimulus right of the centre of the screen (stimuli can also be presented vertically). In general, one of the stimuli is threatening, and the other is neutral. After a short delay, these stimuli disappear and a small dot is presented at one of the locations of the preceding stimuli. Participants indicate the location of the dot as fast as possible by pressing a response button. When the dot appears at the location of the threatening stimulus (congruent trial), and individuals direct attention to threat, the dot is easily detected resulting in a fast response. When the dot appears at the neutral location (incongruent trial), the participant focuses at the wrong location, resulting in a delayed response. The difference in reaction time between congruent and incongruent trials indicates whether participants show an attentional bias to or away from threat. However, when the processing of threatening information interferes with task demands, response time will be delayed in trials containing threatening stimuli. This interference effect can be measured by comparing response time for threat trials with neutral trials. A slower response to trials containing threatening information than to trials containing neutral information indicates behavioral interference by threat.

Most dot probe studies in children have used a single, quite long presentation duration of threatening stimuli (≥ 1250 ms; e.g., Taghavi et al., 1999; Vasey et al., 1995). This allows only a snapshot of attention and provides little information on early, automatic processes versus later, more controlled processes. Studying the time-course of attentional processes may provide important information about the relation between attentional bias and anxiety as attentional biases can result from automatic as well as controlled processes. Automatic processes are fast, effortless, and occur outside awareness. Controlled processes are strategic, effortful, conscious and take more time (Vasey & MacLeod, 2001). Lonigan and colleagues (2004) hypothesized that highly anxious individuals display an automatic bias toward threatening information. This automatic bias can be overridden by controlled processes. Only when controlled processes do not succeed in redirecting the automatic bias, the bias persists and increases risk for pathological anxiety. Non-clinical, high trait-anxious individuals may differ from clinically anxious individuals in their ability to overcome their automatic bias and redirect attention away from threat (Lonigan et al., 2004). Automatic processes can be examined by using very short stimulus exposure duration (e.g., 30 ms) followed by backward
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masking (Ohman & Soares, 1994). A presentation duration of 500 ms is long enough for conscious awareness of the stimulus and allows strategic processes to occur. However, it may still provide information on initial orienting of attention (Bradley, Mogg, & Millar, 2000; Schrooten & Smulders, 2010). Longer stimulus presentation durations (e.g., 1250 ms and longer) may provide information of later controlled processes, such as allocating attention away from threat or recovering from interference (e.g., Lonigan & Vasey, 2009). To the best of our knowledge, only one dot probe study has examined the time-course of attentional processes in children in relation to anxiety including automatic as well as controlled processes. In this study it was concluded that children (8–10 years) high in anxiety sensitivity (AS) displayed an attentional bias to emotional words (threat and positive) compared to children low in AS irrespective of whether the stimulus presentation duration allowed automatic processes or controlled processes to occur (Hunt et al., 2007).

To better understand the relation between selective attention for threat in children and the development and maintenance of anxiety disorders, as a first step we could examine threat-processing in normal, non-anxious children and compare these processes with threat-processing in anxious children. Differences in attentional processes between these groups could provide clues for prevention and treatment of anxiety disorders in children. Bearing the above issues in mind, we conducted a study to examine the time-course of processing of threat in a community sample of children using a pictorial dot probe task. The main objective of the study was to examine whether non-selected children show an automatic attentional bias to threatening scenes and whether this attentional bias can be controlled with longer presentation durations. Furthermore, we examined behavioral interference by threat over time. We used a dot probe task that included several stimulus exposure durations (17 ms masked, 500 ms, and 1250 ms). Following the normal procedure we included congruent as well as incongruent threat trials (threat-neutral picture pairs). To study interference we compared neutral trials (neutral-neutral picture pairs) with threat trials (threat-threat and threat-neutral picture pairs) to see if there was a slowing effect of threatening information in general.

We hypothesized that all children would orient attention towards threat automatically (17 ms). We expected no interference in this condition, as interfering processes may be activated in later stages in the information processing system, after the stimulus has been evaluated as threatening.
by automatic processes (Fox, 1993; Mogg & Bradley, 1998). In the 500 ms condition, we expected a prolonged attentional bias towards threat, as well as interference by threat. Differences in attentional bias between highly and low anxious children were more often found in studies with older children (9–17 years) than in studies with younger children (7–12 years) (Lonigan et al., 2004; Vasey & MacLeod, 2001). Based on these findings it could be expected that at approximately 10–12 years of age, children may develop the ability to inhibit the tendency to selectively attend to threat and redirect attention away from threat. Therefore we expected a decrease of attentional bias and interference in the 1250 ms condition, at least for older children (from 12 years and over).

Method

Participants
Thirty-three children (26 girls), 8 to 18 years old (M = 12.4, SD = 3.3), participated in this study which was part of a broader study into information processing and emotional regulation in children. Participants were recruited from a Dutch elementary school and two secondary schools of different educational levels. Children were excluded if they (had) received treatment for anxiety. Written informed consent of all parents and children was obtained. Age was equally distributed throughout the sample. Sixteen children were 8 to 11 years old (M = 9.4, SD = 1.0), 17 children were 12 to 18 years old (M = 15.2, SD = 1.8). State and trait anxiety levels were within the normal range, as indicated by a mean z-score of -0.20 (SD = 0.79, range -1.45 to 2.41) on the state anxiety subscale, and a mean z-score of -0.15 (SD = 0.88, range -1.58 to 2.18) on the trait anxiety subscale of the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) (n = 12) or the State-Trait Anxiety Inventory for Children (STAI-C; Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973) (n = 21).

Measures

Anxiety

The State-Trait Anxiety Inventory for Children (STAI-C; Bakker, Van Wieringen, Van der Ploeg & Spielberger, 1989; Spielberger et al., 1973) consists of a state anxiety and a trait anxiety subscale, containing 20 items each (item score 1 to 3). A higher score indicates a higher level of anxiety. For children 15 years and
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older, the adult version was used (STAI; Spielberger, 1983; Van der Ploeg, 2000). In the STAI, answer categories range from 1 to 4. To compare scores across these questionnaires, answers for the STAI-C and STAI are converted to z-scores based on the norm tables in the corresponding manual. Reference groups are primary school or secondary school (boys/girls) for the STAI-C (Bakker et al., 1989), and community sample (inhabitants of Leiden; young; men/women) for the STAI (Van der Ploeg, 2000).

Dot probe
Stimuli were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) based on the ratings provided in the manual of all subjects and when available children’s ratings (Lang, Bradley, & Cuthbert, 2005). The selection of IAPS pictures in other childhood studies (Waters et al., 2004; Waters, Lipp, & Spence, 2005) was taken into account. Furthermore, a selection of IAPS stimuli was validated in Dutch children (Kolman, 2009). The selected stimuli were considered suitable for children according to experienced child therapists (second and sixth author). Threatening pictures (T; n = 20) had a low valence score (< 4.0) and/or were representative for different subtypes of anxiety, and included animals, medical scenes, disasters (e.g., nature, fire), accidents, violence, and test anxiety. Neutral stimuli (N; n = 40), e.g., household items and mushrooms, were defined as having a medium valence (4.0–6.0) and a low arousal (< 4.0) score. As part of a larger study, OCD-relevant (O) and positive (P) pictures were included. Masks were created by scrambling the pictures and inversing the colors.

Pictures were combined making up nine different trial types: TN-congruent, TN-incongruent, ON-congruent, ON-incongruent, PN-congruent, PN-incongruent, NN, TT, and OO. All trial types were presented ten times for each stimulus exposure duration (17 ms, 500 ms, and 1250 ms), leading to 270 trials in total. The location of the emotional stimulus (left or right) and the location of the dot were equally distributed within each trial type per stimulus exposure duration. Pictures were matched on brightness, complexity, and color. Each picture was displayed six times, in two different matches.

2 The following IAPS pictures were used: Threat: 1120, 1205, 1525, 1932, 2410, 3210, 3230, 3280, 3550, 5950, 6250, 6312, 6350, 6370, 8485, 9050, 9592, 9910, 9911, 9921; OCD: 1280, 2446, 2720, 2750, 3230, 3550, 4613, 7057, 7360, 7710, 8485, 9008, 9050, 9290, 9301, 9373, 9390, 9910, 9911, 9921; Neutral: 2038, 2102, 2191, 2396, 2579, 2593, 2620, 2870, 2880, 2980, 5390, 5471, 5500, 5520, 5533, 5538, 5543, 5731, 5574, 7010, 7030, 7035, 7036, 7037, 7038, 7039, 7041, 7050, 7056, 7058, 7100, 7130, 7170, 7217, 7242, 7490, 7546, 7590, 7595, 9210, 9360; Practice: 2513, 5532, 7034, 7055, 7080, 7090, 7233, 7235, 7550, 7950.
The dot probe task consisted of ten practice trials and three blocks of 90 trials each, separated by short breaks. The sequence of trials was randomized within three blocks of 90 trials for each participant. Within each block, all trial types were equally represented. Each trial started with a white fixation cross at the center of the screen for 1000 ms, followed by a pair of colored pictures on a black background. Pictures (94 x 70 mm) were surrounded by a white boarder. The pictures appeared left and right of the centre of the screen; the centre of the pictures was located at respectively 1/4th and 3/4th of the width of the screen (95 mm distance from the fixation cross). Ninety picture pairs were displayed for 17 ms immediately followed by a mask for 100 ms, 90 pairs were displayed for 500 ms, and 90 pairs for 1250 ms. Immediately following the pictures, a white dot (5 mm diameter) appeared at one of the picture locations. The participant had to indicate the position of the dot as fast as possible by pressing one of the two response buttons (“Q” or “P”) using a QWERTY keyboard. Response time was recorded as soon as the participant pressed a response button. The dot remained visible until response. The intertrial interval was 1000 ms.

The dot probe task was presented on a Dell Inspiron 9300 laptop with a 17-inch color monitor. The task was run in E-prime (version 1).

**Procedure**

Children were individually tested in a quiet room at their school by a psychologist (LW, LV, SH). After the purpose and procedure of the study were explained, participants filled out the STAI or STAI-C. Children sat behind the computer approximately 60 cm from the computer screen and completed the dot probe task.

**Results**

**Error and response time preparation**

Response time (RT), the time from the appearance of the dot until response by pressing a button, was measured in milliseconds. Erroneous responses and outliers (RT < 200 ms, > 3000 ms, and > 3 SD from the individual mean) were excluded from analyses (3.5% of the data). Table 1 presents mean RT and standard deviations. Results for OCD-relevant and positive trials were not described as this is beyond the scope of this article.
Table 1. Mean RT and SD for neutral and threat-containing trials

<table>
<thead>
<tr>
<th>Stimulus Valence</th>
<th>17 ms + mask</th>
<th>500 ms</th>
<th>1250 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT M (SD)</td>
<td>RT M (SD)</td>
<td>RT M (SD)</td>
</tr>
<tr>
<td>TN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congruent</td>
<td>517 (153)</td>
<td>571 (210)</td>
<td>546 (209)</td>
</tr>
<tr>
<td>Incongruent</td>
<td>540 (193)</td>
<td>583 (208)</td>
<td>552 (201)</td>
</tr>
<tr>
<td>TT</td>
<td>533 (188)</td>
<td>581 (200)</td>
<td>561 (221)</td>
</tr>
<tr>
<td>NN</td>
<td>547 (201)</td>
<td>533 (175)</td>
<td>530 (191)</td>
</tr>
</tbody>
</table>

Note. T = threat, N = neutral.

Attentional bias
To examine the effect of congruency, a 3 (stimulus exposure duration: 17 ms, 500 ms, 1250 ms) X 2 (congruency: congruent, incongruent) Repeated Measures ANOVA was performed for threat-neutral trials with age group (< 12 years versus ≥ 12 years) as between subjects factor. Because RT was not normally distributed, data were log-transformed. In the tables we report non-transformed values, reported values for mean RT and standard deviations in the text are also non-transformed.3

Results revealed a significant effect of age group, \( F(1, 31) = 20.07, p = .001 \). Younger children responded slower to TN trials (\( M = 666 \) ms, \( SD = 198 \)) than older children (\( M = 445 \) ms, \( SD = 98 \)). The effect size was large, generalized eta squared (\( \eta^2_G \)) = .28 (Bakeman, 2005).

There was a significant main effect of stimulus exposure duration on RT, \( F(2, 62) = 11.91, p < .001 \). Contrasts revealed that RT in the 500 ms condition was significant longer than RT in the 17 ms condition, \( F(1, 31) = 27.55, p < .001 \), and than RT in the 1250 ms condition, \( F(1, 31) = 12.86, p = .001 \). The effect size was small, \( \eta^2_G = .05 \).

There was a significant interaction effect between stimulus exposure duration and age group, \( F(2, 62) = 4.57, p < .05, \eta^2_G = .02 \). This indicates that stimulus exposure duration had an overall effect on RT for TN trials, and this effect differed between younger and older children.

3 To examine whether the large reaction time variability influenced attentional bias scores, we performed quintile analyses of the reaction times (see Ratcliff, 1979; Van Damme & Crombez, 2009). A repeated measures ANOVA with quintile and stimulus exposure duration as independent variables and attentional bias score as dependent variable revealed no significant main effect of quintile, \( F(1.6, 52.7) = .53, p > .05 \), or stimulus exposure duration, \( F(2, 64) = .30, p > .05 \), and no significant interaction effect, \( F(2.1, 67.3) = .61, p > .05 \). (Mauchly’s test indicated that the assumption of sphericity had been violated for the main effect of quintile, \( \chi^2(9) = 131, p < .001 \), and the interaction effect of quintile by exposure duration, \( \chi^2(35) = 297, p < .001 \). Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, \( \epsilon = .41 \) for quintile, and \( \epsilon = .26 \) for the interaction effect of quintile by exposure duration.) These results indicate that attentional bias scores did not significantly differ for faster and slower reaction times.
Time-course of threat processing in children

There was also a significant main effect of congruency, $F(1, 31) = 6.24, p < .05$. Children reacted significantly faster to congruent ($M = 546$ ms; $SD = 187$) than to incongruent threat trials ($M = 558$ ms; $SD = 193$), indicating an attentional bias towards threat across all stimulus durations. Generalized eta squared = .005, reflecting a small effect.

The interaction effect between stimulus exposure duration and congruency was not significant, $F(2, 62) = 0.17, p > .05$, which suggests that attentional bias was not significantly influenced by stimulus exposure duration. In addition, no other effects were significant.

**Interference**

To examine behavioral interference by threat, we performed a 3 (stimulus exposure duration: 17 ms, 500 ms, 1250 ms) X 2 (valence: NN versus threat (TT, TN-congruent, TN-incongruent)) repeated measures ANOVA with age group (< 12 years versus ≥ 12 years) as between subjects factor. Data were log-transformed, reported values for mean RT and standard deviations are non-transformed.

Results revealed a significant effect of age group, $F(1, 31) = 18.41, p < .001$. Younger children responded slower ($M = 663$ ms, $SD = 202$) than older children ($M = 443$ ms, $SD = 95$). A $\eta^2_G$ value of .30 indicated a large effect size.

The main effect of stimulus exposure duration was significant, $F(2, 62) = 3.46, p < .05, \eta^2_G = .01$. Contrasts revealed that RT in the 500 ms condition was significant longer than RT in the 1250 ms condition, $F(1, 31) = 8.60, p < .01$.

There was also a significant main effect of valence, $F(1, 31) = 15.26, p < .001, \eta^2_G = .01$. Children reacted slower to threat trials ($M = 554$ ms, $SD = 193$) than to NN trials ($M = 537$ ms, $SD = 184$).

Results showed a significant interaction effect between stimulus exposure duration and valence, $F(1.4, 42.5) = 13.57, p < .001$. Mauchly’s test indicated that the assumption of sphericity had been violated for this interaction effect, $\chi^2(2) = 18.52, p < .001$. Therefore degrees of freedom were corrected using Geenhouse-Geisser estimate of sphericity ($\epsilon = .69$). This indicates that stimulus exposure duration had a different effect on RT for threat trials than for NN trials. The effect size was small, $\eta^2_G = .02$.

No other effects were significant.

To further explore the interaction between stimulus exposure duration and interference, $t$-tests were performed to test whether RT for threat trials
differed significantly from RT for NN trials (interference score) for each stimulus exposure duration (data were log-transformed). Children reacted significantly slower to threat trials than NN trials in the 500 ms condition, \( t(32) = -5.00, p < .001 \); and in the 1250 ms condition \( t(32) = -3.39, p < .01 \); but not in the 17 ms condition \( p > .05 \).

**Correlational Analyses**

To examine whether there was an effect of anxiety on attentional processes, correlations between self-reported state and trait anxiety (STAI/STAI-C z-score) and attentional bias and interference scores were calculated. Attentional bias scores were calculated by subtracting the average RT on congruent trials from the average RT on incongruent trials for each participant (e.g., Mogg & Bradley, 2002; Bradley et al., 1998). Interference scores were calculated by subtracting the average RT for threat trials from the average RT for NN trials for each participant. Because parametric assumptions were violated, Spearman’s correlation coefficient was used. Table 2 shows that both trait and state anxiety were not significantly related to attentional bias scores or interference, although there was a trend for a relation between trait anxiety and attentional bias score in the 17 ms condition \( r_s = .30; p < .10 \).

**Table 2. Correlations (Spearman’s rho) between attentional bias and interference scores, and anxiety**

<table>
<thead>
<tr>
<th></th>
<th>Attentional bias score</th>
<th>Interference score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 ms</td>
<td>500 ms</td>
</tr>
<tr>
<td>Trait anxiety</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( r_s )</td>
<td>( r_s )</td>
</tr>
<tr>
<td>State anxiety</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( r_s )</td>
<td>( r_s )</td>
</tr>
</tbody>
</table>

Note. \( ^* p = .05–.10 \).

**Discussion**

In the present study, the time-course of attentional bias and behavioral interference was analyzed in a community sample of 8-to-18-years-old children using a pictorial dot probe task. Results indicate that typically developing children show selective attention for threat, irrespective of the exposure duration to the threatening stimulus and irrespective of age. Attentional bias
for threat was observed at the level of early, automatic processes, as well as during later, more controlled processes. Furthermore, results revealed that children reacted significantly slower to threat trials than neutral trials, indicating behavioral interference by threatening information. Behavioral interference was observed when stimuli were exposed for 500 ms and for 1250 ms, but not for 17 ms stimulus exposure. This suggests that an attentional bias precedes behavioral interference by threat in children.

Our findings are in line with the cognitive-motivational model of Mogg and Bradley (1998). According to this model, the Valence Evaluation System (VES) evaluates the emotional valence of stimuli. It operates at the automatic phases of information processing. When a stimulus is appraised as threatening a second system, the Goal Engagement System (GES), will react by interrupting current activity and allocating cognitive resources towards the threat. This sequence of processes may be reflected in our data: first we found an automatic attentional bias towards threat which was not accompanied by behavioral interference (17 ms condition), suggesting activity of the VES which may have appraised the threat-related stimuli as threatening, but not yet of the GES. Subsequently, the GES may have interrupted ongoing activity (pressing the response button), resulting in an interference effect of threat in the 500 ms and 1250 ms condition.

The finding of the present study that children showed an attentional bias towards threat irrespective of conscious awareness of the stimuli is not completely in line with the only other dot probe study in children assessing automatic as well as controlled attentional processes in relation to anxiety (Hunt et al., 2007). In the latter study, highly anxious children showed an attentional bias for emotional words compared to low anxious children irrespective of whether the stimulus presentation duration allowed automatic or controlled processes to occur. However, results of this study also indicated that overall (when the high and low anxious groups were taken together), there was an effect of stimulus presentation duration on attentional bias which changed from slight avoidance in the automatic condition to a small bias towards emotional words in the controlled condition (Hunt et al., 2007).

Although it is no common practice to examine behavioral interference directly in dot probe studies, interference effects may have played a role in other dot probe studies too. Similarly to our findings, Koster and colleagues (2004) reported a delayed response to threat trials compared to neutral trials.
for severely threatening pictures in a dot probe task completed by students. Furthermore, response time was linearly delayed with presentation of increasing threat (Koster, Crombez, Verschuere, & De Houwer, 2004). In another dot probe study, Yiend and Mathews (2001) reported that high and low anxious students responded slower to trials with highly threatening pictures than to trials with mildly threatening pictures, irrespective of congruency. A comparable finding was reported by Legerstee et al. (2009), who examined attentional processes with a dot probe task in anxiety disordered children. When the level of threat increased (from neutral, mild, to severe threatening stimuli), response time linearly slowed down.

Results of the present study suggest no effect of state and trait anxiety on attentional bias or interference by threat, although there was a trend for a relation between trait anxiety and attentional bias score in the 17 ms condition. The absence of significant effects of state and trait anxiety may be due to a lack of power. The present sample consisted of children reporting small variation in trait and state anxiety level, which made it difficult to detect effects of trait and state anxiety on attentional processes.

To take developmental differences into account we split up the sample into younger (8–11 years) and older children (12–18 years). Although there was a general effect of age, younger children (8–11 years) responded slower than older children (12–18 years), no significant relation was observed between age group and attentional bias or interference by threat. Results with regard to the relation between age and attentional bias are not consistent across studies. Morren and colleagues reported no relation between age and attentional bias in a sample of 7-to-11-years-old children with high and low spider fear using an emotional Stroop task (Morren, Kindt, Van den Hout, & van Kasteren, 2003). However, in two other studies using an emotional Stroop task in spider fearful children and a control group (8–12 years), attentional bias decreased with age in the control group and not in the anxious group (Kindt, Bierman et al., 1997; Kindt et al., 2000). Differences across studies in paradigm, samples and age range make it difficult to draw clear conclusions. In addition, due to the small sample size in the present study, differences between younger and older children may have failed to reach statistical significance. Furthermore, it is difficult to set a clear age criterion, as cognitive development continues throughout childhood and adolescence (Puliafico & Kendall, 2006).

In the present study the dot probe detection task was used. In this version
of the dot probe task participants have to indicate the position of the probe (e.g., left or right). In the dot probe classification task, participants do not respond to the position of the probe, but they have to discriminate between two different probes (e.g., a horizontal or vertical pair of dots). A disadvantage of the detection task is that participants can adopt a strategy to focus at just one side of the screen and base their responses on the presence or absence of the probe at that side. This strategy does not satisfy in the classification task. Although it was found that both versions have similar sensitivity to anxiety-related attentional biases and the simpler detection task has been recommended for child studies (Mogg & Bradley, 1999), in the present study children could have used this strategy. We tested this hypothesis by performing a 3 (stimulus exposure: 17 ms, 500 ms, 1250 ms) x 2 (dot left versus right) x 4 (trial type: TT, NN, TN congruent, TN incongruent) Repeated Measures ANOVA (data were log transformed). Results revealed no significant main effect and no interaction effects of position of the dot, which indicate that participants did not focus at one side of the screen.

Several limitations should be considered. An important limitation of the present study was the small sample size. Second, within our community sample there was only small variation in anxiety, making it difficult to detect effects of trait or state anxiety. Third, the sample consisted of children between 8 and 18 years old. Although a broad age range creates the opportunity to examine developmental influences from childhood to adolescence, due to the small sample we may not have been able to detect age effects. Fourth, the aim of the present study was to examine threat-processing in children, and therefore we decided to limit results to threat-related stimuli only. However, we cannot rule out the possibility of emotional valence effects of positive and OCD-related stimuli. In addition, although NN, TT and OO picture pairs were included, no PP combinations were shown. Consequently, the number of positive trials was not exactly equal to the number of threatening and OCD-relevant trials. On the other hand, adding PP trials would have further lengthened the task which could result in loss of concentration at the end of the task. Furthermore, the order of trials was randomized and different combinations of stimuli were alternated throughout the task. For this reason, we do not expect that exclusion of PP trials has influenced responses to threat and neutral trials. Another limitation was the absence of an awareness check for the stimuli shown in the 17 ms condition. We cannot rule out the possibility of conscious awareness of
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the content of the stimuli in this condition. However, earlier studies suggested that presentation of pictorial stimuli for 30 ms followed by a mask precluded conscious awareness of the content of the stimuli in adults (Ohman & Soares, 1994). In child studies, presentation of lexical stimuli for 14 or 20 ms followed by a mask resulted in performance at chance level on an awareness check (Boyer et al., 2006; Hunt et al., 2007). These results suggest that a stimulus presentation of 17 ms followed by a mask may be short enough to preclude conscious awareness of the content of the stimuli.

These limitations notwithstanding, results of the present study provide preliminary evidence of an automatic attentional bias for threat that persists during conscious, more controlled stages of information processing. An automatic attentional bias for threat may precede interference by threat in children and adolescents. Although this should be replicated in larger samples, these results indicate that performance in daily life can be temporarily interrupted by the processing of threatening information in all children. A next step will be to examine in what respect low, medium, high and clinically anxious children differ from each other with regard to the processing of threatening information. Insight in these differences may result in a better understanding of the mechanisms operating at the development and maintenance of anxiety disorders, and may give directions for improvement of treatment of childhood anxiety disorders. For example, when behavioral interference by threat would be more pronounced for anxious than non-anxious children, coping strategies to overcome these interference effects could be supplemented to exposure exercises as part of behavioral therapy. However, thus far, studies into selective attention for threat in children have reported equivocal results. In general, these studies are based on paradigms that rely on manual or verbal responding. Results of the present study suggest that such behavioral responses may be interrupted by the processing of threatening information. Such an interference effect of threat may have confounded results of earlier studies. For future studies using attentional tasks based on verbal or manual responding, we recommend to take behavioral interference effects of threat into account.