What's new? The interaction between novelty and cognition

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CHAPTER 4

Happier, faster: Developmental changes in the effects of mood and novelty on responses

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Abstract

Positive mood ameliorates several cognitive processes: It can enhance cognitive control, increase flexibility, and promote variety seeking in decision making. These effects of positive mood have been suggested to depend on frontostriatal dopamine, which is also associated with the detection of novelty. This suggests that positive mood could also affect novelty detection. In the present study, children and adults saw either a happy or a neutral movie to induce a positive or neutral mood. After that, they were shown novel and familiar images. On some trials a beep was presented over headphones either at the same time as the image or with a 200 ms stimulus onset asynchrony (SOA), and the task of the participant was to detect these auditory targets. Children were slower in responding than adults. Positive mood, however, speeded responses especially in children, and induced facilitatory effects of novelty. These effects were consistent with increased arousal. Although effects of novelty were more consistent with an attentional response, in children who had watched a happy movie the novel images increased arousal. This suggests that mood and novelty may affect behavior through partially overlapping mechanisms.

Introduction

The brain is tuned towards new things in the environment: Novel information often automatically attracts attention (Knight, 1996; Lisman & Grace, 2005), and sometimes elicits an overt behavioral response known as the orienting response (Sokolov, 1963a, 1963b). This response is believed to be crucial for many species in order to explore the environment and adapt to present demands (Panksepp, 1998).

Such orienting behavior can have detrimental as well as beneficial effects on task performance (SanMiguel, Morgan, et al., 2010; Wetzel et al., 2012). On the one hand, the task-irrelevant novel stimulus may distract observers from tasks they perform because they orient towards the stimulus and thus away from the task. On the other, a novel stimulus may facilitate task performance. Novel stimuli can do this either by acting as a warning signal eliciting a general alerting response (Aston-Jones & Cohen, 2005b; Bernstein et al., 1973; Hackley & Valle-Inclan, 1998; Nieuwenhuis et al., 2005; Schomaker & Meeter, 2014a; Wetzel et al., 2012), *or* by recruiting attention (Schomaker & Meeter, 2012). The first, general alerting, leads to an increase in arousal and will typically result in speeded responses, a shift towards a more liberal response criterion, and the same or a reduced accuracy. The second, an increase in attention, may result in faster responses, and will typically result in increased accuracy (Posner, 1978). Some have suggested that both distracting and facilitating effects are the result of the same process (Näätänen, 1992; SanMiguel, Linden, et al., 2010; Wetzel et al., 2012). Whether facilitation or distraction will occur then depends on several factors, such as task demands (SanMiguel, Linden, et al., 2010), informational value (Parmentier et al., 2010; Wetzel et al., 2013; Wetzel et al., 2012), and stimulus characteristics (Schomaker & Meeter, 2014a). Facilitation typically only occurs when attentional demands are low, standard stimuli setting the stimulus context are simple, and novel stimuli are deviant as a category, while distraction typically occurs when the attentional demands are high and the novel stimuli provide of task-relevant information (Wetzel et al., 2012).

Observer variables may also affect novelty processing and its subsequent effects on behavior. In particular, several studies have reported age-related differences in responses to novelty. Novel stimuli elicit a novelty P3, an event-related potential (ERP) component believed to be the physiological manifestation of the orienting response or the evaluation of novelty (Friedman et al., 2001; Friedman, Goldman, Stern, & Brown, 2009). The novelty P3 has a more frontal and more generalized distribution in children, and a more central scalp orientation in adults (Maatta et al., 2005) and adolescents (Brinkman & Stauder, 2008; Wetzel & Schröger, 2007). The more anterior novelty P3 in children might be due to stronger frontal lobe involvement. The frontal lobe is a region where myelination continues well into the second decade of life (Klingberg, Vaidya, Gabrieli, Moseley, & Hedehus, 1999). In general, myelination is associated with processing speed (Brouwer et al., 2012), and therefore children can be expected to respond more slowly than young adults. Higher involvement of frontal brain regions in novelty processing has been suggested to reflect increased distraction in children (Wetzel & Schröger, 2007). Thus, the way the brain processes novelty changes with age. However, no previous studies have investigated the effects of novelty on behavior in children compared to adults.

One other factor possibly affecting performance on a reaction time task is mood or affect. Positive mood has been shown to affect performance on cognitive tasks: It enhances cognitive control in an antisaccade test (Van der Stigchel, Imants, & Ridderinkhof, 2011), increases flexibility and evaluative control (van Wouwe, Wylie, Band, van den Wildenberg, & Ridderinkhof, 2010), and leads to variety seeking in decision making (Kahn & Isen, 1993); however, such benefits may occur at the cost of distraction (Aarts, van Holstein, & Cools, 2011; Dreisbach & Goschke, 2004). Transient boosts in frontostriatal dopamine have been suggested to underlie the beneficial effects (Ridderinkhof et al., 2012). Interestingly, also detection of novelty has been suggested to depend on dopamine (Heitland, Kenemans, Oosting, Baas, & Bocker, 2013; Rangel-Gomez et al., 2013).

Under certain conditions, novelty and positive mood can thus both lead to enhanced performance, and both are thought to rely on the same dopaminergic responses for part or all of their effects. Via their effects on dopamine, mood and novelty may interact in facilitating responses: Positive mood may promote novelty processing, thereby strengthening novelty's facilitatory effects. Such an effect of mood on novelty is suggested by the broaden-and-build theory proposes which proposes that positive emotions can stimulate exploratory behavior (Fredrickson, 2004). In line with this theory, people are more inclined to switch from buying one product to another when they are in a happy mood (Kahn & Isen, 1993). In addition, positive mood as induced by humorous movies increases sympathetic arousal (Lackner, Weiss, Hinghofer-Szalkay, & Papousek, 2013). Positive mood may thus affect task performance by increasing arousal.

In the present study a large sample of children and adults was tested on an auditory target detection task while complex novel and familiar (standard) fractal images were presented in order to obtain a developmental perspective on the effects of novelty on responses. This task is an adaptation of a task used by Schomaker & Meeter (Schomaker & Meeter, 2012), in which novel fractals, seen just once in an experiment, were shown to lead to better perception of a faint visual target presented afterwards, than familiar fractals seen many times. Here, we looked at whether novel stimuli would also yield faster detection of auditory targets, and whether these effects would interact with mood and with age. For this purpose, half of the participants watched a neutral and the other half a happy movie before performing the task, to manipulate mood.

After the start of the current project, we found that novel fractals do not yield faster target detection than familiar fractals (Schomaker & Meeter, 2014a). Although in the present study, no novelty-induced response facilitation could thus be expected in adults, it was still possible that positive affect and novelty would interact in affecting task performance, and that either or both factors would interact with age. To preview results, this was exactly what we found in children. Our expectations were that children would perform worse than adults and that positive mood would enhance performance and induce facilitatory effects of novelty.

Material and methods

Participants

173 volunteers (age 6-70 years, mean =27.8, sd = 16.5) with normal or corrected-to-normal vision completed the task in the present study. Six participants decided to quit the experiment and were excluded from the analyses. Of the included participants (*n* = 167), 62 were children (age ≤ 17 years), and 105 were adults (age ≥ 18). All participants were visitors of the Nemo Science Center in Amsterdam, the Netherlands. The lack of balance in the size of the age groups was the result of the age distribution of the visitors of the Nemo Science Center, which could not be forecasted in advance. Prior to the experiment 86 participants saw a neutral and 81 a happy movie clip. Seven participants did not fill one of two mood ratings. The project was part of the Science Live Program (see http://www.sciencelive.nl/), and received ethical approval from the ethics committee of the Faculty of Psychology and Education of the VU University Amsterdam.

Stimuli and apparatus

In the present study we used 270 fractal images, pictures produced by iterative mathematical computations using the open-source program ChaosPro 4.0 (http://chaospro.de). The fractals are not semantically meaningful and were never experienced before by the participants (the same stimuli were used by Schomaker & Meeter, 2012). The fractals covered a visual angle of about 24x18° on the laptop screen. One fractal image, randomly drawn from the pool, acted as a standard stimulus. All other stimuli were novel fractals, presented only once throughout the experiment. The auditory target was a 50 ms beep consisting of a 1000 Hz pure tone, presented through sound-attenuating headphones. A response was given by a button-press on a serial response box.

Design and procedure

Figure 1 shows the experimental design. Participants were seated in a sound-attenuated room with the atmosphere of a living room. Before the start of the experiment participants, or in the case of minors, parents/guardians signed informed consent. Participants indicated their mood state on a Visual Analogue Scale (VAS) on a scale of 0-100. The experimental stimuli were presented on a laptop (1024x768 pixels, 60 Hz refresh rate) at a viewing distance of about 30-40 cm. Before the start of the task participants viewed either a neutral (a person mowing the lawn) or a happy (a laughing baby) mood induction movie of one-minute duration. The subsequent task was an auditory detection task, in which participants also passively viewed a sequence of stimuli. Figure 1B shows an example stimulus sequence from the experimental task. On 20% of the trials an auditory target was presented that required a speeded response (a button press), which could be made by the index finger of the preferred hand. In a short practice block of nine trials the auditory target was presented three times in order to ascertain that the participant understood the task. In total, participants performed 240 trials of the main task with a break after every 40 trials. In this self-paced break participants received feedback on their accuracy and response times, with respect to previous blocks. A block had a duration of about 2 minutes.

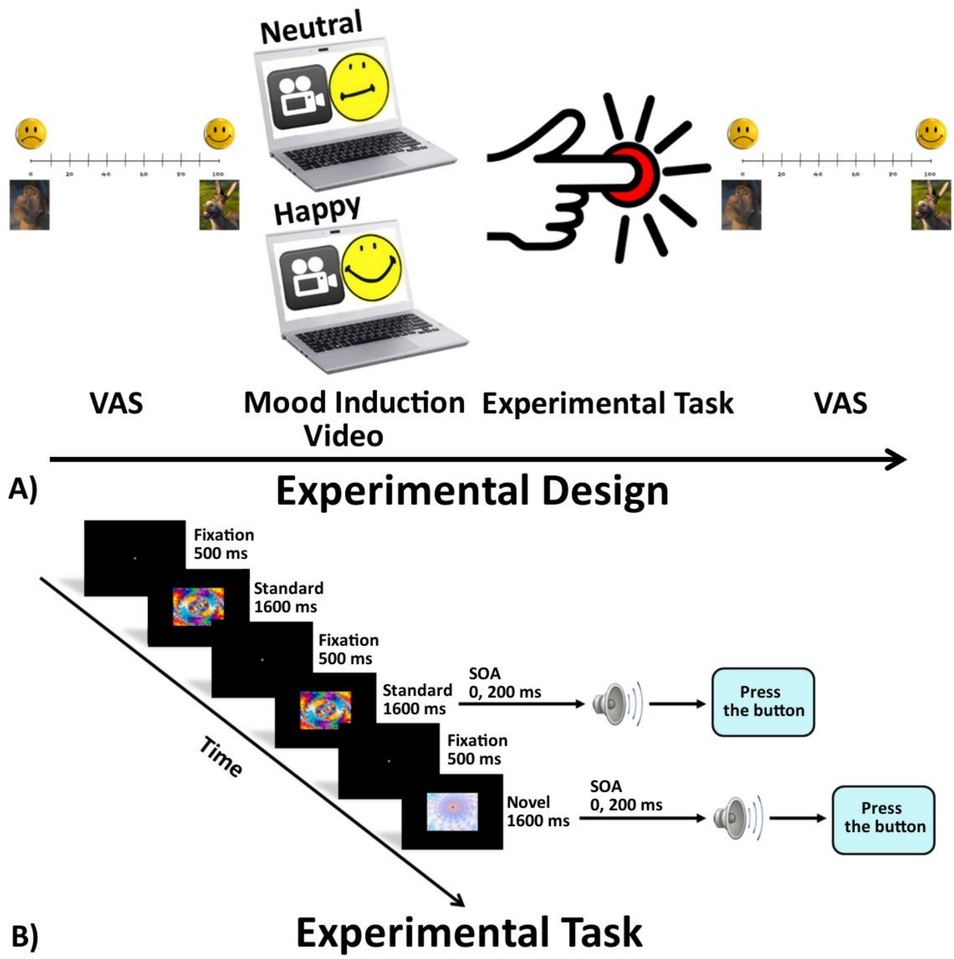

Figure 1. *Experimental Design and Experimental Task. A) Participants first filled in a Visual Analogue Scale (VAS) to indicate their happiness. Next they watched a happy or neutral movie. Then they performed the experimental task, after which they again filled in the VAS. B) Example stimulus sequence.*

A trial started with a fixation point in the form of the iris of an eye presented for 500 ms in the middle of the screen, followed by a visual stimulus. The visual stimulus could be of two kinds: On 50% of all trials a repeated standard stimulus (a fractal) and on the other 50% of all trials an unrepeated unique fractal (the novels), randomly drawn from a set of 270 fractals. An auditory target, a beep, was presented on 20% of all trials with equiprobability to occur together with a novel or standard image. The beep was presented at one of two stimulus onset asynchronies (SOA; 0 or 200 ms) after the onset of the visual stimulus. The visual stimulus stayed on the screen until the auditory target was presented and for an additional 1600 ms. After presentation of the auditory target, feedback was presented on the screen. In case of a correct, a too late, or no response within 1600 ms, the text 'Correct', or 'Here, a response was required' was shown for 500 ms.

After finishing the task, participants rated ten figures on their novelty as a pilot for other studies, and adults then completed the Novelty Seeking scale of the Tridimensional Personality Questionnaire (Cloninger, 1987; Cloninger, Przybeck, & Svrakic, 1991). No correlations between personality and behavior were found, and we will not report on the ratings or these personality measures. Finally, participants again rated their mood on the VAS. The entire session lasted about 15-18 minutes.

Statistical Analyses

Participants were divided in two age groups: Children younger than eighteen years, and adults age eighteen and up[1]. Response times were investigated with a repeated measures 2*2*(2*2) ANOVA with Stimulus (Novel, Standard), and SOA (0 ms, 200 ms) as within-subjects factors and Age (Children, Adults), and Mood (Happy, Neutral) as between-subjects factors. Three-way interactions with Mood were further investigated with 2*2*2 ANOVAs. All main effects, and significant interactions are reported. Accuracy was defined by $d' = Z(\text{hit rate}) - Z(\text{false alarm rate})$. Also response bias, $\beta = -(Z(\text{hit rate}) + Z(\text{false alarm rate}))/2$, was calculated. Accuracy and response bias were subjected to the same ANOVA as used for response times. Mood was investigated by comparing the pre- and posttest scores on the VAS with a paired-samples *t*-test. In addition, mood change as measured by the difference of the posttest minus the pretest was compared between mood groups with an independent samples *t*-test.

Results

[1] In additional analyses children age 7-12 years and children 13-17 years were compared. Younger children were generally slower and less accurate than the older children; however, no other differences were found between these age groups, and therefore they were taken together.

The pre- and posttest mood ratings did not differ (pretest mean: 74.1, standard deviation (SD): 13.4; posttest mean: 73.1, SD: 13.4), $t(159) = 1.27$, $p = .204$, and this difference did not differ for the two mood groups ('happy' group mean: 0.1, SD: 13.2; neutral group: 2.25, SD: 11.0), $t(158) = 1.12$, $p = .263$.

Response times

Figure 2 shows average response times, accuracy, and response bias for novel and standard stimuli at both SOAs for children and adults for both mood groups for both conditions. Response times were not affected by Stimulus type or SOA ($F < 1$). Age group had a main effect, with adults responding faster than children, $F(1,163) = 31.23$, $p < .001$, $\eta^2 = .16$. Also Mood affected response times, with faster responses in the 'happy' than in the neutral group, $F(1,163) = 5.29$, $p = .023$, $\eta^2 = .03$. Mood and Age interacted, $F(1,163) = 4.64$, $p = .033$, $\eta^2 = .03$: children in the 'happy' compared to the neutral group were faster, $F(1,60) = 5.74$, $p = .020$, $\eta^2 = .09$, while adults were not affected by mood ($F < 1$). Thus, the main effect of mood was driven by the effects in children. In addition, Stimulus, Mood, and Age interacted, $F(1,163) = 4.26$, $p = .041$, $\eta^2 = .03$. This interaction was further investigated with a 2*2*2 ANOVA per stimulus type. Mood and Age interacted for novel stimuli, $F(1,163) = 5.92$, $p = .016$, $\eta^2 = .04$: Children in the 'happy' group were faster after presentation of a novel image than children in the neutral group, whereas adults did not show an effect of mood. This effect was much weaker for standard images, $F(1,163) = 3.31$, $p = .071$, $\eta^2 = .02$. No other interactions were significant ($p > .117$).

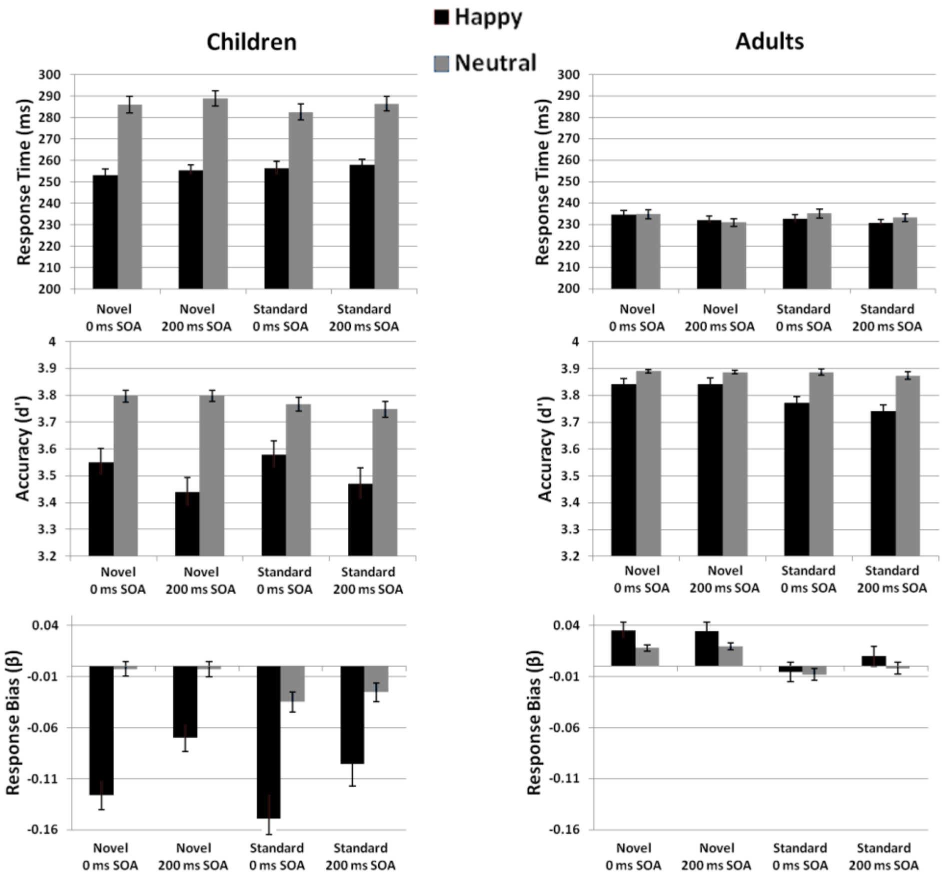

Figure 2. *Performance on the experimental task for children and adults in the happy and the neutral groups. Average response times (in milliseconds), accuracy (in d'), response bias (in β – a negative β reflects a more liberal and a positive β a more conservative criterion) for novel and standard stimuli at the 0 and 200 ms SOA. Error bars reflect one standard error of the mean.*

Accuracy

There was no main effect of Stimulus on accuracy, $F(1,163) = 1.48$, $p = .226$, $\eta^2 = .01$. SOA did affect accuracy, $F(1,163) = 18.25$, $p < .001$, $\eta^2 = .10$, with higher accuracy at the 200 than the 0 ms SOA. Accuracy was higher in the neutral group than in the 'happy' group, $F(1,163) = 5.73$, $p = .018$, $\eta^2 = .03$, and higher for adults than for children, $F(1,163) = 7.42$, $p = .008$, $\eta^2 = .04$. SOA and Mood interacted, $F(1,163) = 10.49$, $p = .001$, $\eta^2 = .06$, as did SOA and Age, $F(1,163) = 8.41$, $p = .004$, $\eta^2 = .05$, and all three factors SOA, Age, and Mood, $F(1,163) = 7.89$, $p = .006$, $\eta^2 = .05$. This three-way interaction was further investigated per Mood group. In the 'happy' group, children had lower accuracy than adults especially at the 200 ms SOA, $F(1,79) = 11.12$, $p = .001$, $\eta^2 = .12$. No interaction of SOA and Age was found in the neutral group ($F < 1$), suggesting that the three-way interaction was driven by the effects in the 'happy' group. There was a trend for an interaction between Stimulus, Mood, and Age, $F(1,163) = 2.88$, $p = .092$, $\eta^2 = .02$, consistent with lower accuracy for novel stimuli specifically for children in the 'happy' group. No other interactions were found for accuracy ($p > .321$).

Response bias

During the presentation of novel stimuli participants adopted a more conservative response criterion (less hits and/or less false alarms) than during the presentation of standards, $F(1,163) = 4.38$, $p = .038$, $\eta^2 = .03$. At the 200 ms SOA the response bias was more conservative than at the 0 ms SOA, $F(1,163) = 18.25$, $p < .001$, $\eta^2 = .10$. Response bias did not differ between the two Mood groups, $F(163) = 2.59$, $p = .110$, $\eta^2 = .02$. Adults adopted a more conservative criterion than children, $F(1,163) = 8.84$, $p = .003$, $\eta^2 = .05$.

Age and Mood interacted, $F(1,163) = 4.25$, $p = .041$, $\eta^2 = .03$, with children in the 'happy' condition adopting a more liberal response criterion than children in the neutral condition, while no such effect was found for adults. In addition, Age and SOA interacted, $F(1,163) = 8.41$, $p = .004$, $\eta^2 = .05$, as did SOA and Mood did, $F(1,163) = 10.49$, $p = .001$, $\eta^2 = .06$, and SOA, Mood, and Age, $F(1,163) = 7.89$, $p = .006$, $\eta^2 = .05$. The latter three-way interaction was further investigated per Mood group. In the 'happy' group, for children the response bias was more liberal at the 0 ms SOA compared to the 200 ms SOA, whereas it was similar at both SOAs for adults, $F(1,79) = 11.12$, $p = .001$, $\eta^2 = .12$. SOA and Age did not interact for the neutral group ($F < 1$), which suggests that the interaction SOA and Age was mainly driven by the effects in the 'happy' group. The other factors did not affect the response criterion ($p > .321$).

Discussion

Adults were generally faster and more accurate in responding to the auditory target than children. The global difference hypothesis proposes that age-related changes are due to differences in processing speed (Kail, 1991, 1992, 1993; Miller & Vernon, 1997). Processing speed depends on myelination of white matter in the frontal lobes (Brouwer et al., 2012), which develops well into puberty (Klingberg et al., 1999). Slower processing speed could thus underlie the slower responses in children than in adults. Reaction time tasks can be sensitive to age-related differences, depending on the specific cognitive processing demands (Kiselev, Espy, & Sheffield, 2009). Specifically when response suppression is required children are slower than adults. In the present auditory target detection task a response was required on only 20% of trials, requiring response suppression on all other trials. This task characteristic may underlie the observed age-differences for response times. Related to response suppression is inhibitory control. The development of inhibitory control is argued to underlie age-related differences in cognition (Ridderinkhof & van der Molen, 1997). In line with inhibitory control still being under development, children in the ‘happy’ group adopted a more liberal response criterion than adults in the present study, producing more false alarms.

Although no differences in mood ratings between the ‘happy’ and neutral group were found at the end of the experiment, mood did affect accuracy and response times. This suggests that mood induction was successful, but that this effect was not reflected by the subjective mood measurement or had worn off by the end of the test when mood was assessed. Children who saw the happy movie were faster than those who saw the neutral movie, whereas in adults no such effects of mood were observed. The finding in children is consistent with earlier reports that positive affect ameliorates performance on several cognitive tasks (Ashby, Isen, & Turken, 1999; Ridderinkhof et al., 2012; Van der Stigchel et al., 2011; van Wouwe et al., 2010). But children who saw the happy movie were less accurate at the 200 ms SOA, and adopted a more liberal response criterion than children who saw the neutral movie and than adults. This combination of effects – faster, but less accurate responding, with a more liberal criterion – is consistent with increased alertness or arousal (Posner, 1978). Positive mood may thus have increased arousal in children, movie, whereas positive mood had no such effect in adults (Fredrickson, 2004; Lackner et al., 2013; Posner, 1978). Alternatively, the mood induction movie may have induced a less strong mood in adults than in children.

In contrast, all participants adopted a more conservative criterion during the presentation of novel than of standard images. Attention has been reported to increase perceptual sensitivity, but can also induce a conservative response bias (Rahnev et al., 2011). Our findings thus suggest that novel stimuli elicit a transient attentional response, inducing a more conservative criterion than standard stimuli, which is in line with previous findings of novel stimuli enhancing perception through an attentional mechanism (Schomaker & Meeter, 2012).

Mood not only differentially affected response speed for children and adults, but also affected the response to novelty in different ways. Children in the ‘happy’ group were speeded by the novel images, while both children in the neutral group and adults did not show this effect. Again, the trend-level decrease in accuracy and the shift to a more liberal criterion were consistent with an increase in arousal for novel images, specifically in children that had seen the happy movie. This effect could be mediated by an increase in frontostriatal dopamine when children viewed the happy movie (Ridderinkhof et al., 2012), promoting novelty processing (Lisman & Grace, 2005; Rangel-Gomez et al., 2013), and increasing novelty's effects on behavior. Novel stimuli have been reported to elicit a broader and more frontally oriented novelty P3 in children and a more parietally oriented component in adults (Brinkman & Stauder, 2008; Maatta et al., 2005; Wetzel & Schröger, 2007). This may reflect increased responsiveness to novelty in children compared to (young) adults (Wetzel & Schröger, 2007), which may explain why effects of novelty on response times were only observed in children.

Conclusion

In summary, children were generally slower and less accurate on the auditory detection task. Positive mood facilitated responses in children but not in adults by increasing arousal. Though novelty in general seemed to result in increased attentional orienting, children who had seen the happy movie showed additionally increased arousal when they were shown novel stimuli. This suggests that mood and novelty may affect behavior more strongly in children than in adults, via partially overlapping mechanisms.