Attentional control in middle childhood is highly dynamic - Strong initial distraction is followed by advanced attention control

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Data Availability

Data is available on request from the authors. Data was pooled from previous studies: Wetzel, Scharf, & Widmann, 2019; Wetzel, Schröger, & Widmann, 2016; Wetzel, Widmann, & Scharf, 2021.

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Conflict of interest disclosure

All authors contributing to this study have no conflicts of interests to disclose.

Ethics approval statement

Data of the present study was collected in previous studies which were approved by the local ethics committees.

Research Highlights

1. Children aged 4–10 are initially more distracted by novel sounds than adults in an oddball paradigm.
2. Attentional control is qualitatively different between early and middle childhood: distraction in 6–10-year-olds declines throughout the session to the level of adults. This effect has not been observed in early childhood.
3. Attention control matures continuously during middle childhood: Initial distraction effects decline considerably with increasing age in 6–10-year-olds.
4. Temporal dynamics of distraction effects are rarely investigated but highly relevant in identifying developing attention control potentially explaining inconsistent results from previous developmental studies.

Abstract

The ability to shield against distraction while focusing on a task requires the operation of executive functions and is essential for successful learning. We investigated the short-term dynamics of distraction control in a data set of 269 children aged 4–10 years and 51 adults pooled from three studies using multilevel models. Participants performed a visual categorization task while a task-irrelevant sequence of sounds was presented which consisted of frequently repeated standard sounds and rarely interspersed novel sounds. On average, participants responded slower in the categorization task after novel sounds. This distraction effect was more pronounced in children. Throughout the experiment, the initially strong distraction effects declined to the level of adults in the groups of 6- to 10-year-olds. Such a decline was neither observed in the groups of the 4- and 5-year-olds, who consistently showed a high level of distraction, nor in adults, who showed a constantly low level of distraction throughout the experimental session. Results indicate that distraction control is a highly dynamic process that qualitatively and quantitatively differs between age groups.

We conclude that the analysis of short-term dynamics provides valuable insights into the development of attention control and might explain inconsistent findings regarding distraction control in middle childhood. In addition, models of attention control need to be refined to account for age-dependent rapid learning mechanisms. Our findings have implications for the design of learning situations and provide an additional source of information for the diagnosis and treatment of children with attention deficit disorders.

Keywords: attention, distraction, control, children, auditory, oddball

Introduction

During an exam in a classroom, the sound of a pencil hitting the floor distracts test takers from their task. The ability to focus attention on a task in the context of surrounding task-irrelevant and unexpected stimuli (distractors) is essential to successfully perform a task at hand – especially in a noisy classroom. To optimize learning environments for learners, it is important to identify factors that influence the successful control of attention in children of different ages. We investigated whether irrelevant stimuli cause more distraction in a school beginner than in older pupils and how children can learn to cope with distractors. Previous research suggests that children in early and middle childhood typically have trouble controlling their attention in noisy and distracting environments in general (Klatte, Bergström, & Lachmann, 2013). There are hints that children aged 6–10-years are initially highly distracted, but are able to increasingly control distraction after sufficient exposure to a distracting context (Wetzel, Widmann, & Scharf, 2021). In our classroom example, test takers would be able to better focus on the task after being exposed to several distractor sounds (e.g., dropping down pencils, sneezing, yawning, ...), because they increasingly ignore sounds that are irrelevant for the task (i.e., solving the exam questions). Previous data from a single study suggest that older children can adapt to such situations considerably faster than younger children (Wetzel et al., 2021).

The analysis of such short-term dynamics of exposure-dependent attention control could provide new insights into the development of attention control and would have profound implications for developmental models of attention control and for the design of studies investigating these models. Here, we present a reanalysis of a large sample of children and adults from several previous studies in which we investigated children's ability to control attention in the presence of distractors. In particular, we aimed to answer three questions: (1) Do children and adults differ in the extent to which they are distracted on average or rather in their ability to dynamically adapt to distracting environments? (2) When do qualitative

developmental changes (e.g., emergence of a new result patterns) and quantitative developmental changes (e.g., changing effect sizes) occur regarding the ability to cope with distracting environments? (3) What are the methodological implications of short-term dynamics in children's ability to control distraction?

In early and middle childhood, the control of selective attention is frequently described as immature (Amso & Scerif, 2015; Casey, Giedd, & Thomas, 2000; Gomes, Molholm, Christodoulou, Ritter, & Cowan, 2000; Hoyer, Elshafei, Hemmerlin, Bouet, & Bidet-Caulet, 2021; Ridderinkhof & van der Stelt, 2000). This is especially important in the context of highly dynamic auditory information which has privileged access to perception and consciousness and needs to be controlled by attention (Demany, Semal, Cazalets, & Pressnitzer, 2010). Attentional focus on task-relevant and inhibition of task-irrelevant stimuli (e.g., falling pencil) involves the core executive functions, i.e. inhibition, shifting, and updating that enable individuals to cope with complex and dynamic environments (for review see Diamond, 2013; Friedman & Miyake, 2017). These executive core functions develop throughout childhood (Davidson, Amso, Anderson, & Diamond, 2006) but are assumed to mature with different time courses (Anderson, 2002; Brocki & Bohlin, 2004; Richardson, Anderson, Reid, & Fox, 2018). In late childhood at least two domains of executive core functions are clearly distinguishable: inhibition and working memory (Brydges, Fox, Reid, & Anderson, 2014). Inhibition mechanisms that include the ability to shield one's self against distraction are especially important for attention control and develop at least until the age of 10 (Halperin, McKay, Matier, & Sharma, 1994; Klenberg, Korkman, & Lahti-Nuuttila, 2001; Simonds, Kieras, Rueda, & Rothbart, 2007).

Task-irrelevant but potentially motivationally significant sounds can involuntarily capture attention and can result in reduced task performance (Näätänen, Kujala, & Winkler, 2011). The consequences of distraction (*distraction effects*) are often investigated in active oddball paradigms in which participants perform a task such as a visual categorization task

while either frequent or rare unexpected sounds are presented. Distraction effects are frequently observed as prolonged reaction times (RT) or occasionally as reduced accuracy in trials including a novel or deviant sound compared to trials including a frequent standard sound (e.g. Horváth, Winkler, & Bendixen, 2008; Parmentier, Elsley, Andrés, & Barceló, 2011; Wetzel & Schröger, 2014).

A systematic review of pure oddball studies that included children in their sample showed inconsistent results regarding behavioral distraction effects (see Table 1). Some studies reported increased distraction effects reflected by RT or hit rate in younger compared to older children (based on RT, Gumenyuk, Korzyukov, Alho, Escera, & Näätänen, 2004; Wetzel, Scharf, & Widmann, 2019; Wetzel, Schröger, & Widmann, 2016) or in children compared to adults (Hoyer, Elshafei et al., 2021; Wetzel et al., 2019; Wetzel et al., 2021; Wetzel, Widmann, Berti, & Schröger, 2006). Other studies did not find increased distraction effects in children compared to adults (Horváth, Czigler, Birkás, Winkler, & Gervai, 2009; Leiva, Andrés, Servera, Verbruggen, & Parmentier, 2016; Ruhnau et al., 2013; Ruhnau, Wetzel, Widmann, & Schröger, 2010; Wetzel, 2015; Wetzel, Widmann, & Schröger, 2009) or observed similar distraction between younger and older children (Gumenyuk et al., 2001; based on hitrate, Gumenyuk et al., 2004; Hoyer, Elshafei et al., 2021; Wetzel et al., 2006; Wetzel & Schröger, 2007). These partially diverging results might be caused by several factors of the experimental design, for example characteristics of sounds (e.g., novelty, complexity) or modality and type or demands of the task. In addition, the diverging findings may be partially attributed to the small sample sizes in many studies in this field. Importantly, recent findings show that distraction effects in children aged 6–10 (but not in adults) may also be modulated by the novelty of the experimental situation itself (Wetzel et al., 2016; Wetzel et al., 2021), as indicated by a decline of distraction effects from the beginning to the end of an experimental session.

The dynamics of attention processes in children as a function of exposure to distractors were rarely considered. It has been shown that pre-experimental experience with distractor sounds, can modulate selective attention differentially between age groups, in particular in multisensory paradigms (Matusz, Dikker, Huth, & Perrodin, 2019). Likewise, differences in exposure within an experimental session could result in varying distraction effects depending on the number of trials presented. Such effects are only visible when exposure to the experiment is considered as a predictor of experimental effects, for instance, by analyzing experimental blocks independently (e.g., Cykowicz & Friedman, 1997; Hoyer, Pakulak, Bidet-Caulet, & Karns, 2021; Oja et al., 2016; Wetzel et al., 2021). However, distraction effects are typically computed using the average RTs for standard and distractor sounds across the whole experiment while neglecting temporal or exposure-related dynamics. Therefore, increased distraction effects in the beginning, that decrease throughout the experiment, will average out with increasing length or number of presented stimuli in the experiment. That is, a study with a large number of trials would be less likely to detect differences in initial distraction effects between age groups. Considering that many studies have trial much higher numbers than the ones analyzing this effect of exposure (see Table 1), length of the experiment could be a hidden moderator contributing to inconsistent results in middle childhood.

The aims of the present study were three-fold: Our first aim was to estimate distraction effects over the course of the experiment in a large sample of participants. This analysis will show whether children of different ages and adults differ in their distraction effects in general or rather in the extent to which they decline with increasing experimental exposure. We expected strong distraction effects at the beginning of an experimental session in children but not in adults (Wetzel et al., 2021). Our second aim was to gain deeper insights into the maturation of distraction control by comparing distraction effects and their dynamics over the experiment between age groups. Specifically, we investigated whether the development of

distraction control resembles a continuous maturation process characterized only by quantitative changes in distraction effects or if distinct qualitatively different developmental stages can be identified based on performance. Our large pooled sample allowed for more informative comparisons between adjacent age groups and for an increased age range from early childhood (4-year-olds) throughout middle childhood (until 10-year-olds) compared to previous studies. With increasing age, we expected decreasing initial distraction effects and a steeper decline toward the levels of adults throughout the experiment. Our third aim was to investigate the implications of including experimental exposure as a predictor in the behavioral distraction analyses. Distraction effects are typically analyzed by averaging the data across the whole experiment without regard for varying attentional dynamics. This procedure could conceal initial distraction differences between children and adults. We discuss this possibility and its implication for developmental distraction studies based on our findings.

Method

Participants

We pooled data from three previous studies with a similar experimental design (Wetzel et al., 2016; Wetzel et al., 2019; Wetzel et al., 2021; see Table 2). Across all studies a total of 352 children and adults participated. The studies were performed either in quiet rooms in kindergartens, after-school care or laboratory rooms of the institute. Participation was rewarded by age-appropriate gifts (e.g., vouchers for a local toy shop for children, money for adults). Adult participants gave written informed consent and confirmed that they did not suffer from hearing disorders, neurological diseases, or attention deficit hyperactivity disorder and that they had not taken any medication affecting the central nervous system. Parents confirmed the absence of these disorders for their children. Additionally, children gave oral consent. The studies were approved by the local ethics committees.

Since these criteria for participant inclusion were identical between contributing studies, we applied the same exclusion criteria that were used in the respective studies. Across the three studies a total of 299 children and 53 adults participated. Two adults and nine children were excluded because they showed poor performance (more than two SDs away from the mean of the respective age group). Fourteen children did not perform the complete number of blocks and were excluded. Disturbances, technical problems or misunderstanding the task led to the exclusion of an additional seven children. The total number of participants in the pooled sample was 320. More details on the participants from the subsets can be found in Table 3.

Task

Participants were asked to categorize two different visual targets by button press as fast and as correctly as possible and to ignore the sound sequence.

Stimuli

Sounds

The analyzed conditions of the three studies included environmental novel sounds that were rated as identifiable in a previous study (sounds were rated in Wetzel, Widmann, & Schröger, 2011). Duration was 500 ms including raised cosine 10 ms fade-in and fade-out windows. In all three studies sounds were presented at an average loudness of 55 dB SPL. In Wetzel et al. (2016) and Wetzel et al. (2021) sound intensity was equalized to 6.5 sone (Zwicker et al., 1991). In Wetzel et al. (2019) sound intensity was RMS equalized. We referred to frequently presented sounds as standard sounds and to infrequently presented ones as distractor sounds. Furthermore, standard sounds used by Wetzel et al. (2021) differed across participants whereas the other studies established one sound for all standard trials (fragment of a bell).

Visual Stimuli

Each study contributed data from three experimental blocks to the pooled sample. In each block one of three background scenes containing the targets' preferred places and a pair of associated targets were presented: princesses and knights in front of a palace and fortress, cats and hens in front of a basket and a hen-roost in a village, and butterflies and fish in front of flowering shrub and a pond in a coastal landscape. The order of the background scenes was counterbalanced across participants. Furthermore, within each block two variations of the two targets were presented with equal probability (25% each) in a pseudo-randomized order. The variations of targets differed in their orientation (facing left or right), shape and color.

Distractor Conditions

All three studies contained a nearly identical condition in which uniquely presented environmental sounds were used as distractor sounds. This was the main reason why these three studies were chosen for pooling. However, Wetzel et al. (2016) and Wetzel et al. (2021) used an experimental design with two conditions with three blocks each. We only included data from the novel distractor condition from these studies because the previous studies showed that distraction effects differed between the novel distractor condition and the respective other condition (Wetzel et al., 2016; Wetzel et al., 2021). The order in which the two experimental conditions were presented was randomized across participants. Therefore, one half of the participants were presented with three blocks of the other experimental condition before the novel distractor condition. Possible implications on performance were considered (see *Poolability Analysis*).

Procedure

Within the novel distractor condition, the experimental structure was identical across studies. Trial and block structures are displayed in Figure 1. A preceding training block

familiarized the participants with the background and targets of the respective following experimental block. The training block was repeated if the participant did not respond correctly in at least 50% of the trials. One child had to repeat the training block (Wetzel et al., 2016). The response time window was not limited in training trials. The duration per block was approximately 2 min. The block order and therefore the visual stimuli were counter-balanced across participants. The sequence of standard and distractor sounds within blocks was pseudo-randomized and unique for every participant. Allocation of sound types to the four target versions was balanced and every distractor sound was preceded by at least two standard sounds.

The experimenter explained the procedure to the participant, asked whether they wanted to perform the task and answered any questions. The task was presented as a “story” in which participants were asked to help the target objects reach their home or their most favored place as fast and correctly as possible. Participants were asked to press one of two buttons assigned to the target category. For example, if the target belongs to the place on the right (e.g., pond on the right side if a fish is the target) participants were asked to press the right button with their right index finger. One child in Wetzel et al. (2019) preferred to perform the task with their thumbs and was allowed to do so. Correct responses were rewarded by a short stop-motion animation of the target moving toward the preferred place (e.g., butterfly flying to the bush) with a duration of 600 ms and an immediate onset upon correct response, but not earlier than 200 ms after the target offset. A response was considered correct if the button press occurred within the response window of 2 s after target onset and if the correct button was pressed.

The experiments were presented using a Macbook (13.3”), Matlab (The MathWorks, Natick, U.S.) and the Psychtoolbox (Kleiner, Brainard, & Pelli, 2007). Sounds were presented via external loudspeakers placed on the left and right side of the laptop. Responses were

measured using a RTBox (Lee et al., 2012) and two response buttons suitable for children to the laptops' left and right side.

Data Analysis

Exclusion Criteria for Trials

All analyses and data management procedures were performed using *R* version 4.0.2 (R Core Team, 2020). A minimum of two standard sounds is needed to establish a rule distinguishing standard and distractor sounds, thus, the first two trials per block were excluded from further analyses (Bendixen, Roeber, & Schröger, 2007). Trials without any response, with an incorrect response, with a response later than 2000 ms or faster than 100 ms after target onset were defined as invalid and thus excluded from analysis. The performance in the first trial after a distractor trial can suffer from carry-over effects such as reallocation of attention (Roeber, Widmann, & Schröger, 2003; Wetzel, 2015) and prolonged responses in younger children were observed in these trials (Wetzel et al., 2019). For this reason, the first standard trial after distractor trials was excluded.

Poolability Analysis

We pooled data provided by three previous auditory oddball studies using the same visual categorization task. Because small differences in methodology could threaten the validity of pooled data analyses, methodology of the studies providing sub-samples was reviewed and emerging deviations were highlighted (see Table 2). The review ensured that studies' design, methodology, and selection of participants were comparable. In addition, we compared the performance of age groups between experiments where possible to assure the actual behavior of participants was also comparable between studies.

After the allocation of participants to eight age groups (4- to 10-year-olds, adults), we compared the response times between subsamples in the respective age groups (Table 3). As mentioned above, children aged 4 and 5 were only tested in one of the studies and hence no

such comparison was possible. Distractor and standard trials elicited fundamentally different response patterns (e.g. Schröger & Wolff, 1998) and were therefore analyzed separately. Participants within age groups showed overall similar performance across the studies in standard trials (Table 3, all $p_{\text{Standard Trial}} > .05$). Therefore, the block-wise variation of the specific standard sound in Wetzel et al. (2021) did not affect performance. However, 6-year-olds and adults showed smaller distraction effects from distractor sounds in Wetzel et al. (2021) compared to Wetzel et al. (2019) which may be attributed to different recruiting strategies (after-school care center vs. kindergarten, cf. Table 2).

Two of the three studies included two conditions. Participants who started the experiments with the novel distractor condition could be at a disadvantage compared to the other randomization order as they had less training opportunities. In Wetzel et al. (2016) no significant difference in RT between the randomization orders emerged for either standard trials or distractor trials (Table 4). However, significant RT reduction in distractor trials can be observed in participants who performed the novel condition as their second condition in Wetzel et al. (2021). We decided to include all participants despite this discrepancy because a loss of over 28% of the participants seemed hardly justified given the small effect of randomization ($\eta^2_G = .039$)¹. In addition, size and direction of all age-, stimulus-, and exposure-related effects was virtually identical (cf. Figure 2 vs. Supplemental Figure S4). Thus, we decided that the sub-samples can be pooled.

¹ We investigated the effects of a more homogenous sample by computing the main model with the exclusion of participants who had experimental exposure before the novel condition. The results are provided in the supplement.

Main Analyses

We estimated several linear mixed effect models (LMM) using the *nlme* package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2020). The best-fitting model was chosen from a set of candidate models using information criteria (Burnham & Anderson, 2004). We also investigated the hypothesis that differences in distraction effects merely reflect general speed differences between age groups by comparing a proportionally restricted interaction model with a free interaction model (cf. Supplement: Ratio Model). Finally, we investigated individual distraction effect and block effect estimates based on the LMM results.

The dependent variable of the LMM was RT on the level of single trials (“level 1”). Participants were the clustering variable (“level 2”). Contrary to methods such as analyses of variance, no aggregation of RT over participants was needed. Model predictors were *Sound Type* (standard vs. distractor), *Age Group* (4–10, adults), and *Block* (1–3). All predictors were treated as categorical. With respect to *Block* and *Age Group* this specification was chosen because we did not want to restrict the model to a specific form of relationship (e.g., a linear trend). Specifically, we expected that the largest decrease of distraction effects would occur from the first to the second block as this was reported for the novel condition in earlier research (Wetzel et al., 2016). Hence, the observed RTs might not be described appropriately by a linear trajectory. *Age Group* was treated as categorical for similar reasons: A strong decline in RT in younger children was expected as well as almost adultlike performance in older children. In previous studies, children showed larger distraction than adults and short-term learning was expected to differ across age groups. Consequently, the model included interactions of *Sound Type*, *Age Group*, and *Block*. Since children showed different magnitudes in their distraction effects and in some studies children did not show prolonged RTs due to distractors (e.g. Ruhnau et al., 2010), random intercepts and random slopes for the predictor *Sound Type* were included in the model.

Except for model comparisons, for which we used the maximum likelihood estimation method, the restricted maximum likelihood estimation method was used in the models. Age group differences in RT variability were found in Wetzel et al. (2019) and in the current data set (Table 3), therefore, the model allowed for heteroscedastic trial-level residual variance between age groups. The final model was chosen from a set of plausible candidate models using AIC and BIC. Specifically, we investigated whether the inclusion of experimental block as a predictor reflecting experimental exposure would improve model fit by comparing a *Sound Type* $\times$ *Age* $\times$ *Block* model with a model only including the interaction *Sound Type* $\times$ *Age*. We also investigated if the inclusion of the predictor Study was necessary to account for potential differences between studies. Finally, we tested whether the inclusion of (1st order) auto-correlated residuals on the levels of trials would improve the model fit.

We estimated the final model in two parametrizations, the aim of the first parametrization (hereinafter referred as *main model*) was to compute RT estimates and confidence intervals for all combinations of age group, sound type, and block order – this approach is roughly equivalent to the estimation of average RTs for each predictor combination but it has the advantage that the CIs account for heteroscedasticity and autocorrelation between trials. The second parametrization (*block contrast model*) was used to compare initial distraction effects and RTs to those of the rest of the experiment in an efficient and comprehensible manner. We assumed that distraction reduction would decline after the first block as reported by Wetzel et al. (2016) and Wetzel et al. (2021), therefore, the first block was compared to subsequent blocks. This model was identical to the main model except for the specification of a Helmert contrast for the predictor *Block*: contrast =

$$\frac{\text{RT Block 2} + \text{RT Block 3}}{2} - \text{RT Block 1} .$$

This contrast provided an efficient way to compare

performance in the first block against the average of the second and third block without inflationary pairwise comparisons of all block combinations. A second comparison provided the estimated difference between the second and third block. Hypotheses tests regarding the

parameters of the main model and the block contrast model were conducted with *t*-tests for the single parameters. To test all pairwise comparisons of the DE and block number between all age groups, the reference category was recoded across levels of the predictors. Addressing the problem of multiple testing, the false discovery rate was controlled at the level of 5% (Benjamini & Hochberg, 1995).

The random effect structure (random slope and intercept for *Sound Type* for each participant) did not appropriately address the fact that learning across blocks might differ between participants, which is what we hypothesized. Unfortunately, the model including the random effect interaction *Sound Type* $\times$ *Block* to explore this hypothesis did not converge using the maximum likelihood estimator implemented in *nlme*. Therefore, we refitted the model using a Bayesian LMM as implemented in *brms* (Bürkner, 2018). We specified the same model except for the inclusion of random slopes for the effects of *Block* and *Sound Type* $\times$ *Block*. Default, mildly informative priors were used. The fixed effect estimates (and their uncertainty estimates) were highly similar to the model estimated in *nlme* – indicating that the estimation method did not bias the results in any substantial way. Individual random effect estimates were extracted from this Bayesian LMM (cf. Figure 4).

Results

Model Comparison

The *Sound Type* $\times$ *Age* $\times$ *Block* model *with* auto-correlated residuals outperformed the other models according to both AIC and BIC (see Table 5). Neither removing *Block* including its interactions nor adding *Study* as a predictor without interactions improved model fit. That is, a model considering experimental exposure as predictor seemed to be appropriate for the data. All main effects and interactions of this model were significant (see Table 6).

Response Times in Standard and Distractor Trials

Estimated RTs of the *Sound Type* $\times$ *Age* $\times$ *Block* main model are displayed in Figure 2 (for complete model description see Supplement Model Output). In general, with increasing age participants responded faster. All age groups showed significantly prolonged RTs in distractor trials compared to standard trials in all blocks (cf. CIs for differences in Figure 2). Especially for distractor trials, RTs decreased with increasing number of blocks. Estimates did not deviate from this general response pattern when participants with previous experimental exposure were excluded (Supplement Exclusion Model).

In the first block, children aged 7- to 9-years-old responded similarly fast in standard trials ($RT_{\text{Age } 7} = 564.07$ ms; $RT_{\text{Age } 8} = 551.37$ ms; $RT_{\text{Age } 9} = 528.37$ ms, pairwise $p_{\text{FDR corrected}} > .05$) and 10-year-olds performed on par with 8–9-year-olds ($RT_{\text{Age } 10} = 495.99$ ms, pairwise $p_{\text{FDR corrected}} > .05$). All remaining pairwise comparisons between age groups in their standard RTs in the first block were significant. No significant differences in standard trial RT emerged between blocks ($p_{\text{FDR corrected}} > .096$). The only exception were 5-year-old children whose RTs in standard trials significantly decreased from the first to the second block ($\Delta RT = -49.09$ ms, $t(22181) = -3.63$, $p_{\text{FDR corrected}} = .007$).

In contrast, all age groups showed a significant decrease in RTs in distractor trials between the first block and second block (all $p_{\text{FDR corrected}} < .05$). When comparing the second to the third block no significant differences emerged in any age group (all $p_{\text{FDR corrected}} > .156$).

Distraction Effect Analysis

As indicated by CIs in Figure 2, all children showed significant distraction effects which ranged from 202.67 ms (found in the first block in 4-year-olds) to 19.56 ms (found in 9-year-olds in their third block). An overall decrease with age was evident. In all blocks, the youngest children showed significantly larger distraction effects than children aged 6 or older;

all $p_{S \text{ FDR corrected}} < .05$. In the first block, distraction effects in children aged 9 and 10 years were significantly smaller compared to children aged 7 or younger and adults had significantly smaller distraction effects than all children. In the third block, however, distraction effects in children aged 6 and older were not significantly different from each other and from adults ($p_{S \text{ FDR corrected}} > .05$). Only the 4- and 5-years-olds showed increased distraction compared to adults in the third block ($p_{S \text{ FDR corrected}} < .01$). Moreover, the decrease of distraction effects with age exceeded the decrease which would be expected proportionally to the overall decrease of RTs with increasing age (Supplement Ratio Model).

In sum, distraction effects were observed in all groups and distraction effects clearly decreased with age. The block-wise analysis revealed that distraction effects differed between younger and older children and adults in the first block. In the third block, distraction effects of children from age 6 and older and those of adults were similar.

Block Contrast Model: Distraction Effect Reduction

Distraction effects of all age groups declined descriptively (Figure 3). A significant distraction reduction was only observed in children aged 6 to 10 years. We observed constant standard RTs across blocks in 6- to 10-year-olds (all $p_{S \text{ FDR corrected}} > .05$). Distraction reduction was significantly larger for children between the ages 6 and 9, than for adults (pairwise comparisons 6–9-year-olds vs. adults: $p_{S \text{ FDR corrected}} < .05$; 10-year-olds vs. adults, $p_{S \text{ FDR corrected}} = .10$). From ages 6 to 10, the distraction reduction decreased with age: Six- and 7-year-olds showed the largest estimated reduction (75.72 ms, 73.46 ms respectively) and 9- and 10-year-olds showed the smallest reduction (34.88 ms, 37.51 ms respectively) during the experimental session. A significant difference in distraction reduction emerged between children aged 7 and 9 years ($\Delta RT_{\text{Contrast}} = 38.58 \text{ ms}$, $t(22181) = 2.93$, $p_{S \text{ FDR corrected}} = .014$). Distraction reduction of the 4- and 5-year-olds did not differ from any group (all $p_{S \text{ FDR corrected}} > .05$).

Individual Distraction Effect Analysis

The distributions of the model-implied individual distraction effects within the experimental blocks are displayed in Figure 4. Across all age groups, the majority of the participants showed prolonged RTs to distractor sounds (97.2% on average across all blocks). The majority of the children (98.5%) had model-implied distraction effects which were above the adult's average in the first block. Most of our participants had smaller distraction effects in blocks two and three compared to block one (cf. contrast coefficients in Figure 4) but the size of this reduction was much more pronounced for 6- to 10-year-olds compared to adults.

Overall, the analysis of individual distraction effects showed that the effects found on average were representative of underlying intra-individual trends. Importantly, the differences found between age groups *cannot* be attributed to extreme cases because all experimental effects and differences between age groups were clearly representative for the trends in *all* quartiles of the individual effects.

Discussion

We aimed to investigate the development of attention control in children aged 4 to 10 years and adults across three studies. We analyzed the participants' RTs in a visual categorization task during the presentation of task-irrelevant novel and standard sounds. Distraction effects (i.e., prolonged RTs after novel vs. standard sounds) were present in all age groups and in the majority of individuals (see Figure 4) with considerable differences between age groups. The youngest children (4- and 5-year-olds) showed larger distraction effects than older children and adults when distraction effects were averaged across blocks. When considering the distraction effects in the first block only, all groups of children differed from adults, showing the long developmental pathway of attention control. In 6- to 10-year-olds, but not in younger children, these initially strong distraction effects declined throughout the experimental session to the level of adults – indicating considerable qualitative changes of

attention control at the end of early childhood. Adults showed constantly low distraction effects throughout the experiment. The magnitude of the decline decreased gradually across middle childhood, indicating quantitative rather than qualitative developmental changes in this age range. Furthermore, the exposure-related decrease in distraction has important implications for the interpretation of previous studies and the methodology of future developmental studies on attention control.

Distraction Control Increases with Age

The performance of children aged 4–7-years was initially more impaired by novel sounds than the performance of 9–10-year-olds and adults, demonstrating the ongoing quantitative development during middle childhood.

In the first block, RTs after novel sounds decreased disproportionately more with age (adults vs. 4–10-year-olds; 9-year-olds vs. 4–5- and 7-year-olds) than one would expect based on the age groups' respective standard RTs (cf. Supplement Ratio Model). Throughout the experimental sessions, we observed constant levels of RTs in standard trials in children aged 6–10-years and in adults. We conclude that the age-related decrease of distraction effects *cannot* be attributed to increased processing speed due to progressed brain maturation alone (Luna, Garver, Urban, Lazar, & Sweeney, 2004; see also Leiva et al., 2016; Wetzel et al., 2019; Wetzel et al., 2021). That is, changes in distraction effects throughout the experimental session reflect changes in distractor-specific cognitive processes such as attention control.

Decrease in Distraction Effects with Experimental Exposure depends on Age

We replicated the finding that distraction effects in children aged 6–10-years are reduced after the first experimental block in a larger, pooled sample of participants (Wetzel et al., 2021). For 6- to 9-year-olds, this decrease was significantly larger than the only descriptively observed decrease in adults. Overall, this decrease continuously declines with

age in children from 6 to 10 years approaching an adult-like results pattern. In contrast to the 6- to 10-year-olds, both youngest groups and the adult group showed no significant decline of the distraction effect from the first to the second and third block (cf. Figure 3).

The reduction of distraction effects with exposure in children aged 6–10-years reflects the presence of short-term learning mechanisms which enable children to reduce the costs of distraction. These learning mechanisms can interact with both aspects of selective attention, preferred processing of task-relevant events and inhibition of irrelevant events (Posner, 2012). Both aspects of selective attention develop during childhood and adolescence (Hoyer, Elshafei et al., 2021; Ridderinkhof & van der Molen, 1997; Ridderinkhof, van der Molen, Band, & Bashore, 1997; Thillay et al., 2015). Immature inhibitory control has been identified as an important factor contributing to distraction in childhood (Davidson et al., 2006; Hoyer, Elshafei et al., 2021). Inhibition mechanisms involved in attention control can act on the level of involuntary orienting of attention towards the novel sound (Bonmassar, Widmann, & Wetzel, 2020; Gumenyuk et al., 2004; Wetzel, 2015), on the level of reorienting of attention from the novel sound back to the task (Horváth et al., 2009) or on the level of motor responses (Hoyer, Elshafei et al., 2021; van den Wildenberg & van der Molen, 2004). Inhibition mechanisms are primarily linked to the frontal cortex (Ridderinkhof & van der Molen, 1997), that has a long developmental trajectory (Gogtay et al., 2004; Huttenlocher & Dabholkar, 1997), and matures in adolescence and not before (for review see Best & Miller, 2010).

In addition, the occurrence of sounds could provide information about the time and occurrence of the target (Hackley, 2009; Hackley & Valle-Inclán, 2003; Parmentier, Elsley, & Ljungberg, 2010). In our experiments, however, sounds remain irrelevant for the categorization task itself. Nevertheless, novel sounds captured attention in all age groups. While initial distraction effects differed between children and adults, children aged 6–10-years and adults showed similar distraction in the last block. It can be hypothesized that children successively learn that the novel sounds provide no relevant information in the

specific situation and then increasingly focus on task-relevant stimuli or increasingly inhibit an extensive evaluation of task-irrelevant stimuli. Statistical learning might support these learning processes. Statistical learning is a robust learning mechanism that facilitates the detection of statistical patterns in the environment (for review see Saffran & Kirkham, 2018). It has been shown that experience with a stimulus within an experimental session can influence learning results (Saffran & Wilson, 2003). This impact might be age-related (e.g., McNealy, Mazziotta, & Dapretto, 2010; but see Jost, Conway, Purdy, Walk, & Hendricks, 2015).

Since adults did not show reductions of distraction effects, it can be assumed that adult participants learn to categorize novel sounds as task-irrelevant within few trials or by effectively utilizing the instruction to disregard all sounds (Hughes & Marsh, 2020) and thus minimize attentional orienting and evaluation almost instantly. Reduced orienting of attention toward novel sounds and their evaluation in adults compared to children aged 7–10 years was also observed on the neurophysiological level (Bonmassar et al., 2020).

We observed qualitative differences between 6-year-olds (or older children) and younger children. The 4- and 5-year-olds remained on their initial high level of distraction effects (Figure 2) and showed no substantial or systematic reduction of distraction effects between the first and subsequent blocks. The large distraction effects in the youngest children might indicate their pronounced preference for new information (Meder, Wu, Schulz, & Ruggeri, 2020) and their generally less efficient inhibition and reorienting abilities (Hoyniak, 2017; Ridderinkhof & van der Stelt, 2000; Urben, van der Linden, & Barisnikov, 2011). This is supported by findings of an extension of distraction effects to the trial following a novel trial in 4- and 5-year-olds but not in older children in an auditory-visual oddball study (Wetzel et al., 2019). Moreover, the increase in distractor RTs in 4-year-olds in their third block indicate that young children struggle to maintain sustained attention (see also Hoyer, Elshafei et al., 2021).

the observed dynamic of distraction effects reflects qualitative and quantitative differences between the age groups. The 4- and 5-year-olds do not show sustainable effects of short-term learning on behavioral distraction and differ profoundly from adults, whereas children in middle childhood benefit from short-term learning. These observed patterns of distraction are line with the predictions made by the Dual Mechanisms of Control theory that describes two distinct mechanisms of cognitive control to handle events possibly interfering with one's current goal (Braver, 2012). Proactive control reflects the sustained and anticipatory maintenance of goal-relevant information and prevents interference with conflicting information while reactive control acts in response to an interference event (Braver, 2012). The mode of cognitive control of children shifts from predominantly reactive and to proactive control between early and middle childhood (3.5 vs. 8 years, Chatham, Frank, & Munakata, 2009; 5 vs. 9 years, Troller-Renfree, Buzzell, & Fox, 2020). Thus, the increasingly proactive mode of cognitive control, that facilitates the processing of task-relevant stimuli in older children, could contribute to the observed course of distraction effects. Furthermore, the observed developmental changes in distraction effects show remarkable similarities with the developmental course of executive functions. The supposed change in the structure of the executive functions (Huizinga, Dolan, & van der Molen, 2006; Wiebe, Espy, & Charak, 2008) and the observed change in the dynamic of distraction effects occur in the transition from early to middle childhood. This change coincides with admission into primary school in many countries. In Germany, most children are admitted to school at the age of 6 year. In fact, we observed larger distraction effects in 6-year-old kindergarten children compared to 6-year-old pupils (see poolability analysis, Table 3). This again demonstrates the sensitivity of the applied version of oddball paradigm to small developmental changes. We speculate, that the learning mechanisms observed in the present study also take place in the classroom and might contribute to long-term learning effects that improve executive control. One of the re-analyzed studies indicate long-term learning effects,

since participants, who participated in a previous experimental session, showed a trend toward reduced distraction effects in a second session after 6 days (see Table 4, Wetzel et al., 2016).

Overall, we found strong evidence that exposure to the task should be considered in all analyses of distraction paradigms. In our experiment, less than 102 standard and 30 novel trials were sufficient for most children aged 6–10 to reach distraction effects on (almost) the levels of adults. This observation would have been hidden in a “conventional” data analysis, that is, averaging across all experimental blocks within participants. Although differences in experimental design and age-range per group do not allow for direct transfer of these observations to other oddball studies (see Table 1), the present results indicate that at least for conditions similar to our re-analyzed data (i.e., environmental sounds, novel distractor sounds, visual categorization task) short-term dynamics are an important feature of attention control which is sensitive to developmental differences. It is important for future studies to acknowledge exposure to the experiment as a predictor in the analyses, because average distraction effects are an arbitrary mixture of initial distraction and exposure-related attentional processes despite their vastly different developmental trajectories.

Limitations

Although pooling multiple samples allowed for a more fine-grained comparison between adjacent age groups. In particular, the youngest group of children was underrepresented and could not be cross-validated by a second study. This outlines the need to collect larger samples in this young age range. Although our interpretation is supported by a review of relevant literature, we cannot rule out the possibility that distraction reduction might be limited to our specific variants of the active oddball paradigm. Furthermore, the current study was limited to behavioral measurements and thus provided only indirect conclusions about the underlying brain mechanisms. Further studies are required to establish the

generalizability of the presented findings and to identify the underlying mechanisms by using other dependent measures such as EEG, pupil diameter or eye blink rates.

Conclusion

Unexpected and task-irrelevant novel sounds impair the performance in a categorization task in 4 to 10-year-old children and adults. Our results demonstrate that the analysis of exposure to novel distracting events is an important, but widely neglected moderator of successful control of attention in children. The dynamic of distraction effects throughout the experimental sessions significantly differs between early and middle childhood as well as between children and adults. Children aged 6–10-years show strong initial distraction effects which considerably decrease to the levels of adults later in the experiments. These results demonstrate children's capability of flexible attention control, that can be improved up to the level of adults, if they have sufficient opportunity to learn to deal with task-irrelevant, but attention catching information. Throughout middle childhood, the increased ability to successfully shield against distraction reflects the continuous maturation of attention control, but their dynamics significantly differ from those of adults. These results contribute to the explanation of inconsistent findings of previous oddball studies with elementary school aged children. Younger children (4- and 5-year-olds) did not show effects of learning on attention control, indicating important qualitative developmental changes in attention control in the transition between early and middle childhood. Results indicate qualitative and quantitative differences in attention control mechanisms between age groups that fit well with the concepts of cognitive control and executive functions and their developmental trajectories.

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Table 1

Reported distraction effects in developmental auditory or crossmodal studies based on variations of the oddball paradigm

Type of task Publication	Standard (s) Distractor (d)	Minimum Number of Trials	Age Groups (n)	RT difference (d - s)	Comments
Visual categorization					
Gumenyuk et al. (2001)	600 Hz (s), EN (d)	600	7–10 (10) 11–13 (10)	Pooled 16	No group differences
Gumenyuk et al. (2004)	600 Hz (s), EN (d)	~ 847	8–9 (8) 10–11 (8) 12–13 (8)	33 53 57	Group differences not analyzed
Gumenyuk et al. (2005) [†]	600 Hz (s), EN (d)	700	8–10 (10)	55	Not applicable
Leiva et al. (2016)	600 Hz (s) White noise (d)	504	8–9 (37) Adults 18–36 (44) Adults 55–77 (39)	< 25 ¹ < 25 < 50	Group differences (8–9 and adults 18–36 < Adults 55–77)
Ruhnau et al. (2010)	<i>High cognitive load</i> ES (s), EN (d)	420	9–10 (14) Adults (12)	-31 15	Group differences (Sound Type × Age Group Interaction)
	<i>Low cognitive load</i> ES (s), EN (d)	420	9–10 Adults	-17 24	
Ruhnau et al. (2013)	ES (s), EN (d)	~ 448	9–10 (15) Adults (20)	30 33	No group differences
Van Mourik et al. (2007) [†]	600 Hz (s), EN (d)	498	8–12 (18)	33	Not applicable
Wetzel et al. (2016)*	<i>Environmental novels</i> ES (s), EN (d)	132	7 (16) 8 (10) 9–10 (12)	51 36 21	Group differences (Sound Type × Age Group Interaction)
	<i>Artificial sounds</i> 500 Hz (s)	132	7 8	14 15	
	400 and 600 Hz (d)		9–10	1	
Wetzel et al. (2019)*	ES (s), EN (d)	132	4 (17) 5 (37) 6 (18) 9–10 (18) Adults (13)	186 130 99 42 31	Group differences (4 and 5 > 6 > 9–10 and adults)

Type of task Publication	Standard (s) Distractor (d)	Minimum Number of Trials	Age Groups (n)	RT difference (d - s)	Comments
Wetzel et al. (2021)*	<i>Environmental novels</i> ES (s), EN (d)	132	6–7 (54) 8 (37) 9–10 (50) Adults (38)	55 45 42 17	Group differences (6–7, 8, 9–10 > adults)
	<i>Repeated environmental distractors</i> ES (s), ES (d)	132	6–7 8 9–10 Adults	32 25 24 15	Group differences (6–7 > adults)
Sound direction categorization					
Wetzel et al. (2009)†	ES (s), EN (d)	648	7–8 (26) Adults (20)	17 29	No group differences
Wetzel (2015)†	Triangle Wave 500 Hz (s) Neutral ES (d)	620 ²	9–10 (18) Adults (18)	8 10	No group differences
	Significant ES (d)		9–10 Adults	-8 2	
Sound identity categorization					
Mikkola et al. (2010)†	AS on one side (s) AS on other side (d)	1944	5 (11)	22	Not applicable
Wetzel et al. (2004)	AS on one side (s) AS on other side (d)	648	5–6 (11) ³	51	Not applicable
Sound duration categorization					
Wetzel et al. (2006)†	<i>Deviant Strength High</i> 500 Hz (s) 400 and 600 Hz (d)	492	6–8 (16) 10–12 (16) Adults (16)	84 72 35	Group differences (6–8 > adults)
	<i>Deviant Strength Low</i> 500 Hz (s) 475 and 525 Hz (d)	492	6–8 10–12 Adults	51 48 36	
Wetzel & Schröger (2007)†	500 Hz (s) 600 Hz (d)	496	6–8 (14) 10–12 (16) 17–18 (13)	59 55 35	Group differences (6–8 > 17–18 when pooling both conditions)

Note. Within type of task studies are presented in alphabetical order of the first author and by year. Where the exact number of trials was not reported, minimum number of trials was calculated using the reported experiment duration, trial duration, and minimum number of valid distractor trials reported in ERP analyses. Response time differences are presented in milliseconds. Significant differences to zero are marked in bold. Asterisks mark studies providing data for the current study. Daggers mark studies including a condition or sub-sample

(e.g., atypically developing sub-samples) violating the inclusion criteria which are not reported in the table for reasons of comparability. EN = environmental novel, ES = environmental sound, AS = animal sound.

Inclusion criteria for studies: The study included at least a sub-sample of typically developing children aged 3–12, used an oddball paradigm with standard (frequent) and distractor (infrequent) sounds, reported unstandardized RTs as a dependent variable separated for sound type or as distraction effect values, used a simple categorization task (two categories; no Flanker-, no Go/NoGo-, cue- or similar more complex procedures) with response in every trial, and did not confound target-categorization of the task with sound type.

Literature-search strategy using Web of Science: As a starting point, we searched the core collection data base for the query “distraction oddball children”. The results of this query (18 studies) were analyzed regarding the inclusion criteria and if they fulfilled these, the study was included. The inclusion analysis was repeated for all studies mentioned in references or citations of all studies that fulfilled the inclusion criteria and this process was repeated whenever an additional study fulfilled the inclusion criteria.

¹ Distraction effects were reported in figure, hence not precisely determined.

² Plus ~1200 trials in previous passive or sound detection condition similar to the categorization task condition.

³ Excluding two children who showed no distraction effect.

Table 2*Comparison of methodological characteristics of studies providing the subsamples*

	Wetzel, Schröger, & Widmann (2016)	Wetzel, Scharf, & Widmann (2019)	Wetzel, Widmann, & Scharf (2021)
Age Groups		4 years 5 years 6 years 7 years 8 years 9–10 years	6–7 years 8 years 9–10 years Adults
Conditions	Novel		
	High pitch deviant		Repeated environmental deviant
	Two sessions	One session	One session
	Within subject design		
Distractor Sounds	Uniquely presented environmental novels		
Standard Sounds	Environmental standard (same for all participants)	Environmental standard (same for all participants)	Environmental standard (differed between participants)
Location	After-school care center	Kindergarten	After-school care center
		Lab at the institute	Lab at the institute

Note. Number of trials per condition, sound duration and loudness, task and visual targets are identical across studies. Characteristics found in all studies span multiple columns. Conditions marked in grey are not included in the main analysis.

Table 3*Novel condition response time comparison between subsamples*

Age	Sound Type	Wetzel et al. (2016)		Wetzel et al. (2019)		Wetzel et al. (2021)		Test Statistics			
		<i>M</i> (<i>SD</i>)	<i>n</i>	<i>M</i> (<i>SD</i>)	<i>n</i>	<i>M</i> (<i>SD</i>)	<i>n</i>	<i>F</i>	<i>df</i>	<i>p</i>	η^2_G
4	Standard			790.29 (125.29)	17						
	Distractor			978.52 (166.57)							
5	Standard			693.76 (111.34)	37						
	Distractor			826.05 (140.18)							
6	Standard			663.90 (97.88)	18	653.54 (67.22)	17	0.132	1, 33	.719	.004
	Distractor			766.52 (121.39)		688.26 (100.72)		4.280		.046	.115
7	Standard	555.71 (88.58)	16			573.75 (74.34)	36	0.579	1, 50	.450	.011
	Distractor	606.93 (92.28)				638.75 (79.90)		1.846		.180	.036
8	Standard	546.97 (72.63)	10			557.78 (54.80)	38	0.268	1, 46	.607	.006
	Distractor	582.80 (88.31)				602.79 (71.25)		0.564		.457	.012
9	Standard	527.60 (62.53)	9	517.75 (67.61)	8	530.55 (58.70)	38	0.148	2, 52	.893	.006
	Distractor	546.89 (56.53)		564.27 (72.88)		567.70 (80.16)		0.273		.762	.010
10	Standard	443.07 (72.94)	3	491.75 (68.22)	10	523.92 (71.02)	12	1.754	2, 22	.196	.138
	Distractor	468.32 (86.13)		531.35 (56.85)		583.37 (81.93)		3.438		.050	.238
Adults	Standard			435.62 (40.65)	13	415.10 (42.84)	38	2.277	1, 49	.138	.044
	Distractor			466.14 (55.22)		431.78 (43.09)		5.324		.025	.098

Note. Responses are presented in milliseconds and are based on observed (in contrast to modeled) trials. Trials without any response, with an incorrect response, with a response later than 2000 ms or faster than 100 ms after target onset were excluded. RTs were compared separately for each sound type using one-way ANOVAs with the factor study. Significant differences in RTs indicate differential participant behavior across studies and are marked in bold. Responses are presented in milliseconds.

Table 4*Comparison table for randomization orders in the subsamples*

Study	Sound Type	Novel Condition First		Novel Condition Second		Test Statistics			
		<i>M</i>	<i>n</i>	<i>M</i>	<i>n</i>	<i>F</i>	<i>df</i>	<i>p</i>	η^2_G
Wetzel et al. 2016	Standard	555.77	18	521.74	20	1.717	1, 36	.198	.046
	Distractor	602.52		551.03		3.332		.076	.085
Wetzel et al. 2021	Standard	531.47	89	532.02	90	0.002	1, 177	.968	.000
	Distractor	594.47		551.93		7.162		.008	.039

Note. Response time comparison between participants for whom the novel condition was presented first and those for whom the novel condition was presented as second condition. RTs were compared separately for each sound type using one-way ANOVAs with condition as factor. Significant differences in RTs between studies are marked in bold. Responses are presented in milliseconds.

Table 5*Model comparisons*

Model	<i>df</i>	AIC	BIC	$R^2_{\text{conditional}}$	R^2_{marginal}
Model + AR	60	285024.8	285506.2	.288	.202
Model – AR	59	285164.9	285638.3	.291	.203
Model + Study as predictor	61	285167.4	285656.8	.290	.203
Model – Block as predictor	27	285324.5	285541.2	.284	.197

Note. The maximum likelihood estimation method was used. Likelihood ratio test compared against the first model with the predictors *Sound Type* $\times$ *Age* $\times$ *Block*. AR = autocorrelated residuals on the level of trials. AIC = Akaike-Information-Criterion. BIC = Bayesian-Information-Criterion. All models allowed for random slopes and intercept for *Sound Type*. Main model is marked in bold.

Table 6*F-tests for main effects and interactions of the Sound Type $\times$ Age $\times$ Block model*

	numDF	denDF	<i>F</i>	<i>p</i>
(Intercept)	1	22181	19351.39	< .001
Sound Type	1	22181	392.44	< .001
Age	7	312	84.80	< .001
Block	2	22181	23.23	< .001
Sound Type $\times$ Age	7	22181	19.54	< .001
Sound Type $\times$ Block	2	22181	49.72	< .001
Age $\times$ Block	14	22181	2.02	.013
Sound Type $\times$ Age $\times$ Block	14	22181	3.85	< .001

Note. The restricted maximum likelihood estimation method was used. Statistically significant results are marked in bold.

Figure 1. An auditory-visual oddball paradigm was presented. Participants were instructed to press the left or right button depending on the category of the visual target, e.g., a fish or a butterfly (symbolically displayed in the figure). Correct responses within 2,000 ms after target onset were followed by a 600 ms visual feedback. Task-irrelevant sounds preceded the visual targets. Sounds could be either standard sounds (e.g., fragment of a bell) or distractor sounds (e.g., breaking glass) and were presented with a probability of 78% and 22% respectively in experimental blocks.

Figure 2. Model implied response times of the *Sound Type* × *Age* × *Block* model. Error bars represent 95% confidence intervals. The figure shows a decrease of RT in novel trials with increasing block number in the 6–10-year-olds, while RT in standard trials did not change. Distraction effects of the 4 and 5-year-olds and of adults followed a different course.

Figure 3. Estimates for the contrast coefficient which compares distraction effects (i.e., $\Delta(RT_{\text{Novel}} - RT_{\text{Standard}})$) of first block against the average of the other two blocks, that is: $\text{DE contrast} = \frac{\text{DE Block 2} + \text{DE Block 3}}{2} - \text{DE Block 1}$. Negative estimates reflect a *reduction* of the distraction effect (i.e., $RT_{\text{Novel}} - RT_{\text{Standard}}$) between the first block and the average of subsequent ones. Error bars represent 95% confidence interval. Brackets represent statistically significant group differences on a 5% α -level. Differences to zero and pairwise comparisons are FDR-corrected (Benjamini & Hochberg, 1995). The confidence intervals are not visually adjusted for multiple testing, but where zero is not included in the confidence interval this remains statistically significant with FDR-correction. Distraction effects of 6–10-year-olds statistically significantly differ between the first and the remaining blocks.

Figure 4. Box plot of the model-implied individual distraction effects across blocks, that is, (“Mean” Distractor Trial – “Mean” Standard Trial RT). *Contrast* refers to the individual distraction effect contrast $= \frac{Distraction_j \text{ Block 2} + Distraction_j \text{ Block 3}}{2} - Distraction_j \text{ Block 1}$ with j being an indicator for each specific participant and $Distraction = \text{distractor RT} - \text{standard RT}$. Negative values in the contrast reflect a reduction in the DE from block 1 to the average DE of block 2 and block 3. Upper hinges correspond to the third quartile. Lower hinges correspond to the first quartile. Middle line marks the median. Whiskers reflect values up to $1.5 \times \text{IQR} \pm \text{median}$. Individual depicted values are outliers extending the whiskers’ range. Red diamonds correspond to means.