JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Implications of the Irrelevant Sound Effect on Cognitive Performance – A Developmental Study

Bachelorarbeit

Gemäß § 13 der Ordnung des Fachbereichs 02
Sozialwissenschaften, Medien und Sport
der Johannes Gutenberg-Universität Mainz

Studiengang Psychologie

vorgelegt
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geb. am 28.09.1990
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Mainz, im September 2013

INHALTSVERZEICHNIS

ZUSAMMENFASSUNG

Während der Irrelevant Sound-Effekt (ISE) ein etablierter Effekt in kognitiven Erwachsenenstudien ist, existieren nur wenige Studien, die den Einfluss des ISE auf die Leistung von Probanden unterschiedlichen Alters in einem *Serial Recall Task* untersuchen. Da die Arbeitsgedächtniskapazität im Laufe der Entwicklung Veränderungen unterliegt, kann die Untersuchung von Altersunterschieden als eine zusätzliche Informationsquelle dienen und wichtige Einblicke in die Beziehung zwischen Arbeitsgedächtniskapazität, auditiver Ablenkung und kognitiver Verarbeitung bieten. Im Anschluss an bisherige Entwicklungsstudien (Elliott, 2002; Elliott & Cowan, 2005; Klatte et al., 2010; Elliott & Briganti, 2012), war das Ziel der folgenden Studie, den Einfluss von irrelevanten Störgeräuschen und kognitiver Belastung auf die *Immediate Serial Recall*- Leistung von Kindern und Erwachsenen zu untersuchen. Der Anteil der korrekten Ergebnisse (pc) und die Reaktionszeiten (RT) wurden gemessen. Die Ergebnisse der pc indizieren, dass Kinder und Erwachsene im gleichen Maße vom ISE beeinflusst wurden. Außerdem wurde die Leistung über die zwei Stufen kognitiver Belastung hinweg gleich von den Störgeräuschen beeinflusst. Die Reaktionszeiten zeigen robuste Alterseffekte und Effekte kognitiver Belastung, sie wurden jedoch nicht vom ISE betroffen. Die Ergebnisse wurden in aktuelle Theorien auditiver Ablenkung eingeordnet und können am besten von dem Duplex-Mechanismus erklärt werden, der von mindestens zwei unabhängigen Speicher- und Verarbeitungsprozessen im Arbeitsgedächtnis ausgeht (Hughes et al., 2007). Ein unitäres Erklärungsmodell, wie es in vergangenen Studien vorgestellt wurde (Elliott, 2002) ist somit unhaltbar.

Schlüsselwörter: Irrelevant Sound-Effekt, Arbeitsgedächtniskapazität, Aufmerksamkeit, Hintergrundschall, Entwicklung, Kinder

ABSTRACT

While the irrelevant sound effect (ISE) is a well-established effect in adult cognitive studies, there are only few studies that examine the influence of the ISE on the performance in a serial recall task of participants with differing ages. As working memory capacity underlies developmental change, studies of age differences may serve as an additional source of information and reveal important insights into the relationship between working memory capacity, auditory distraction and cognitive processing. Following up on previous developmental studies (Elliott, 2002; Elliott & Cowan, 2005; Klatte et al., 2010; Elliott & Briganti, 2012), the aim of the present study was to investigate the impact of irrelevant sounds and working memory load (WML) on the immediate serial recall performance of children and adults. Proportion correct (pc) and the reaction time (RT) were measured. The results of pc indicate, that children and adults were equally affected by the ISE. Moreover it influenced the performance similarly throughout the two levels of WML. The RTs show robust effects of age and WML, but they were not affected by the ISE. The results were classified into current theories of auditory distraction. The findings of the present study can be best explained by a duplex-mechanism account that implies at least two separate mechanisms in the storing process of working memory (Hughes, et al, 2007). A unitary account, as proposed in previous studies (e.g. Elliott, 2002) is untenable

Keywords: Irrelevant sound effect, serial recall, working memory capacity, attention, development, children

INTRODUCTION

It is commonly known that when trying to focus on a mental activity, e.g. reading, writing or remembering, background noise can have a distracting effect. Sensory input, e.g. from the eye while reading, seems to uncontrollably interfere with background noise that reaches the brain from the ear. In everyday life, cognitive tasks are often demanded and performed in the presence of background noise that consists of hybrid noise. This hybrid noise comprises irrelevant background speech and sounds which vary in their loudness and frequency. For instance, office noise includes sounds that result e.g. from copying, phones ringing, chats in the conference rooms and voices in the hallway. In schools, traditional ex-cathedra teaching is more and more replaced by modern teaching methods that contain phases of group work; students are then surrounded by background speech resulting from simultaneous discussing of the tasks within the groups.

The distracting effect of unattended (i.e. irrelevant) speech on short-term memory was first described by Colle & Welsh (1976) as the irrelevant speech effect. The phenomenon was extended to the irrelevant sound effect (ISE) by Jones and Macken (1993). They demonstrated that the ISE is not necessarily bound to speech; recall performance is also impaired by nonspeech sounds. Therefore not speech but the changing state, i.e. the variance in the frequency and amplitude of the distractor items, applies as a necessary condition for the ISE. The effect even occurs through alternate presenting of two different distractor items (Tremblay & Jones, 1998). Steady-state distractor items, which do not show changes in the frequency and amplitude, impair the performance only to a minor degree (Jones, Madden & Miles, 1992; LeCompte, 1995). If the task requires order processing, changing-state sounds are more disruptive than silence (Jones & Macken, 1993). The impact of the ISE is therefore most often examined using a serial recall task. Performing a serial recall task in the presence of irrelevant sounds implies an active storage process of order information in working memory. Simultaneously, irrelevant background noise has to be inhibited. It is recognized that auditive distractors limit the short-term storage process of information in working memory (Jones, Macken & Mosdell, 1997; Miles, Jones & Madden, 1991; Norris, Baddeley & Page, 2004). Noise impairs storage even when it is presented in a moderate volume (Colle, 1980; Ellermeier & Hellbrück, 1998).

In literature, the origin of the ISE is the source of a long-standing debate. For a long time it has been assumed that theories of the ISE can be divided in two groups. These studies support a unitary account of auditory distraction. The first group describes the ISE as a conflict in working memory between serial information of the to-be-remembered stimuli and the irrelevant sound or speech. The ISE occurs when inhibition fails to keep the irrelevant serial information away from entering the rehearsal process in working memory (Jones & Macken, 1993; Macken, Tremblay, Alford, & Jones, 1999; Marsh, Hughes, & Jones, 2008). The second group describes it as a result of a depletion of attentional resources by the sound. Attention is distracted away from the focal task (the rehearsal of the information held in working memory) and toward the irrelevant sound. Therefore the ISE occurs when attentional control is hindered and attention-switching cannot be successfully conducted (Cowan, 1995; Lange, 2005; Elliott, 2002; Elliott & Cowan, 2005).

Hughes, Vachon and Jones (2007) proposed a duplex-mechanism approach that compromises these two groups of theories. This approach suggests that the ISE is triggered by *interference-by-process* (Jones & Macken, 1993; Jones & Tremblay, 2000). *Changing-state* distractor stimuli, which contain irrelevant order cues compete with, and thus impair, serial rehearsal of the to-be-remembered stimuli. The *deviation effect* (Cowan, 1995; Schröger, 1997) however can be attributed to attentional capture. The deviation effect occurs when new sounds in a sound sequence cause orienting reactions that deviate attention away from the focal task to the irrelevant sounds. It is caused by a more general process of attention-capture. Based on this, irrelevant distracting sounds trigger two processes: Changing-state and deviation effects, which are functionally different forms of auditory distraction and of which only the changing-state effect is susceptible to the ISE. The deviation effect underlies developmental change.

Sörqvist (2010) supports this view. He suggests that distraction by background noise is a result of at least two different mechanisms. The first mechanism is responsible for individual differences in processing serial-order tasks. This mechanism implies an inhibition process which avoids confusion between the irrelevant sound and the to-be-remembered items; it is susceptible to the changing-state effect. The second mechanism has a connection to working memory capacity (WMC). Researchers suggest that as WMC reflects a general pool of attentional resources (Kane, Hambrick, Tuholski, Wilhelm, Pane, & Engle, 2004), it is related to susceptibility to interference and attentional capture (deviation effect) but not to the changing-state effect (Ellermeier & Zimmer, 1997; Beaman, 2004; Sörqvist, 2010; Elliott & Briganti, 2012). Sörqvist, Marsh & Nöstl (2013) conclude, that WMC is unrelated to the ISE and that the two mechanisms (inhibition of irrelevant information and attention-switching between two tasks) function independently. Thus high WMC should reduce the deviation effect and WMC should not predict the susceptibility to the changing-state effect, triggered by the ISE.

Although the ISE is well documented in adults (for a review see Neath, 2000; Jones, Hughes & Macken, 2010), the performance-reducing effects of irrelevant changing-state sounds have just been recently examined in studies on children. Hitherto, there are only few developmental studies that have examined the influence of the ISE on the performance in a serial recall task of children and adults.

Elliott (2002) was the first developmental study that investigated the impact of the ISE on the performance of participants from four age groups (M = 8, 9, 11, 19 years). The serial recall performance of numbers (out of four list lengths: highest digit span, span -1, span -2, span -3) was measured. Five auditory conditions were used (changing-state words, steady-state words, changing-state tones, steady-state tones, and silence). The presented words were in the participant's native language. The results show an increase in working memory span with age, whereas the impact of the ISE decreased with age, being the highest for young children and the lowest for adults. Children, but not adults, showed a difference in performance between the speech and tones conditions. Performance in tasks which had the highest demand for attentional control (irrelevant native speech) was more impaired by the ISE compared to the tone and silence conditions. Elliott (2002) assumed from the results, that task-irrelevant speech is more attention deviating to children than tones or silence.

Klatte, Lachmann, Schlittmeier, & Hellbrück (2010) examined the effects of the ISE on the serial recall performance of children and adults. For this, two experiments were conducted in which the recall performance of common nouns, presented pictorially, was measured. The irrelevant sound conditions were silence, classroom noise and irrelevant speech in an unknown foreign language (Danish). In the first experiment, fixed list lengths were used for children (first graders) and adults.

In the second experiment, the list lengths were adjusted to the individual spans of the participants (second-third graders and adults). In contrast to findings by Elliott (2002), in this study, children and adults were equally impaired by irrelevant speech. Classroom noise had no effect on the performance. However, Elliott (2002) used native language distractors that included serial information. Klatte et al. (2010) presented an unknown language and classroom noise that both are perceived as a loose aggregation of unrelated auditory stimuli without serial order information. This differences in methodology could explain the discrepancy between the results of the two studies.

A recent study (Elliott & Briganti, 2012, Experiment 3) tested the hypothesis that children (M = 8 years) show a larger ISE than college students (M = 19 years) in a serial recall task. For children, the list length of the to-be-remembered words was determined individually, resulting in two list lengths (3 vs. 4 words). College students received a fixed list length (7 words). The sound conditions were: Silence (as baseline condition), and native language distractor words of differing word frequency (high vs. low). The manipulation of word frequency of the distractors had no effect on the overall performance. The ISE impaired the performance of all participants, however there was a larger magnitude of the ISE in children than in adults, which supported previous findings (Elliott, 2002).

Thus, previous developmental studies showed contradictory outcomes concerning the magnitude of the ISE on the serial recall performance of children and adults. Moreover, the developmental differences in the ISE have been explained by theories implying a role of attention in the emergence of the ISE (Cowan, 1995; Neath, 2000). However, there are limits in explaining differences in the susceptibility to the ISE only by increased attentional resources. Not just top-down inhibitory control mechanisms (i.e. attention capture; Bjorklund and Harnishfeger, 1990; Pearson & Lane, 1991), but also working memory capacity (WMC) is improving during the childhood (e.g., Chi, 1977; Case, 1985; Henry & Millar, 1991). WMC is the quantity of information (working memory load) that can be stored for a short period of time while processing. There is general agreement that WMC is limited and that the amount of items that can be held in short-time memory varies between 4 and 7 items (Cowan, 2001). In a serial recall task with background sounds, WMC is believed to be responsible for the ability to control attention (Heitz & Engle, 2007) and to inhibit irrelevant stimuli (Rosen & Engle, 1998; Conway, Cowan, & Bunting, 2001). Indeed, the WMC seems to be relevant at least for some aspects of the ISE in adults, although there are also contrary results (Beaman, 2004; Engle, 2002; Elliott & Briganti, 2012; Dalton, Santangelo & Spence, 2009; Lavie, 2005). Children, compared to adults, are not just less able to inhibit irrelevant information, but also have fewer WMC. Thus, the influence of attention and WMC on the strength of the ISE might be mistakenly confounded with an effect of age.

Elliott & Cowan (2005, Experiment 2) investigated individual differences in the working memory span of children (M = 8 years) and adults (psychology students). Working memory span was measured in five tasks, of which the irrelevant sound condition that included speech and tones is of interest for the current study. Participants received two list lengths (individual maximum span and this span minus 1). A correlational relationship between measures of visual span (of the digits 1-9) and the susceptibility to the ISE was found in adults. However the relationship was in an unanticipated direction (i.e. higher spans corresponding to a larger ISE). The ISE decreased the ability of high-span adults to correctly recall longer lists. For children, no such correlation was found. The results constitute a contradiction to the study of Elliott (2002) by finding a larger ISE for participants with higher memory spans. Elliott & Cowan (2005) suggest that high span individuals tend to adopt a latent verbal rehearsal strategy that may be adverse in the presence of irrelevant speech.

The present study investigated the impact of the ISE on cognitive performance at high (6 items) and low (3 items) cognitive load of children (mean age 9) and adults (mean age 22) in an immediate serial recall task. To exclude visual mnemonic strategies in the storage process of the items, this study used written visually presented common nouns as stimuli. A text in German (native language of the participants) about squirrels, read by a male voice, served as irrelevant background speech. In the present study pink-noise was presented as a baseline condition. According to Jones et al. (1992), pink noise (or 1/f noise) involves the least impairment of processing of visual information. Answers were given on a computer, this way not only the proportion correct (pc) but also the reaction time (RT) could be measured. In previous studies (see Szalma & Hancock, 2011 for a meta-analysis), little evidence was found for a speed-accuracy trade-off as a result to noise-effects in adults. When effects were observed, response accuracy was more affected than response speed. Concerning the current study, it was of interest whether there would be developmental differences at the expense of the irrelevant speech on both, the RTs and pc measures.

Importantly, in the present study, the WML was systematically varied for both age groups. Thereby, the increase of WML was expected to lead to the decrease in pc/ and to the increase of RTs. The drop of performance was also expected to be stronger in children than in adults. However, the most important question addressed in the present study was whether there is a relation between the ISE and WML. If WMC affects the strength of the ISE, it can be expected that ISE would be stronger in the high than in the low load condition. Moreover, since in general, children have a lower WMC, it can be expected that the influence of the WML on the ISE should be stronger for children than for adults. On the contrary, if WMC does not affect the ISE (as suggested by the previous studies – see Elliott & Briganti, 2012), then no interactions between WML and the ISE or between WML, the ISE and age are expected.

The last aim of the present study was to classify the results into current models of auditory distraction.

Support for a unitary account (e.g. Elliott, 2002) would exist when the deviation effect and the changing-state effect could both be explained by *attentional capture.* The unitary model supposes that distraction which is produced by changing-state speech should be controllable by attention. If it is so, high WMC individuals would be expected to be less susceptible to the ISE.

The duplex-mechanism account (Hughes et al., 2007; Sörqvist et al., 2013) suggests that auditory distraction cannot be explained only by a differing ability to control attention. Based on the duplex-mechanism account, high WMC individuals should score higher at a serial recall task, particularly for longer lists than low WMC individuals, without the presence of changing-state speech (Beaman, 2004). However both will be equally susceptible to the ISE. Distraction by the ISE is believed to be an automatic effect that cannot be modulated by WMC resources. Therefore high WMC individuals should be able to relocate deviated attention to the focal task (deviation effect), but they should not be able to withstand disruption that interferes with the processing mechanisms in working memory (changing-state effect).

METHOD

Participants

The group of adults consisted of 21 psychology students (18 female, M = 22) from the University of Mainz, who received course credit for participation. In addition, the group of children comprised 15 children (8 female; ages 8-10 years, M = 9 years, 1 month, SD = 6 months). None of the participants had impairments in vision, hearing or cognitive functions. They took part in the study voluntarily, were highly engaged and completed all tasks. All participants were native German speakers.

Design

In this 2x2 mixed independent groups design, the performance of children and adults was investigated in an immediate serial recall task. The independent variables were background sound, which was either speech or pink-noise (baseline condition) and working memory load (WML), which was manipulated by the number of to-be-remembered words in the word list. Word lists comprised either 3 (low WML) or 6 (high WML) words. The dependent variables were proportion correct (pc) of correctly identified as wrong/right-ordered word lists and participant’s reaction times (RTs). The word lists comprised 3 or 6 items (list length varied randomly), representing low (set size 3) or high (set size 6) WML. The number of word lists in the right and wrong order was equal (i.e. 4 right vs. 4 wrong ordered word lists in the practice round and 32 vs. 32 word lists in the following rounds).

Procedure

Participants were tested individually. They were told that the presented sound was irrelevant for their task and that it should be ignored. Also participants should answer as fast as they could. Additionally, they were told that only the order of the items had to be remembered and no item would be added or omitted. Each participant completed two immediate serial recall tasks, comprising 72 trials. Each of both tasks comprised 8 practice trials without background sound, followed by 64 trials with either German speech or pink-noise as background sound condition, presented through headphones. The starting condition varied quasi-randomly.

The to-be-remembered words were presented one at a time at the center of the laptop-screen at a distance of 50-55cm to the eye. The words were shown at a frequency of 3 seconds per item. A fixation cross appeared in the center of the screen for 750 msec prior to each new stimulus. After the last item of each trial, a word list was presented and participants had to decide whether the word order was right or wrong, regarding the previously shown stimuli (Fig. 1). The keys (left/ right) of the External Response Pad served for the input of answers (right/ wrong). The keys (left/right) were randomly assigned to represent right/wrong. They were shown at the center of the laptop-screen.

Materials

Memory materials. The stimuli comprised 30 common nouns (animals) consisting of 1, 2 and 3 syllables, presented as text in the font 'Calibri" in the font size 60. All stimuli are listed in Appendix A. The set size was 3 or 6 items for both children and adults, it varied randomly.

Irrelevant sounds. Two different background sounds were used to measure the ISE in the serial recall performance: Pink-noise (1/f noise) as a baseline condition and a German text about squirrels, read by a male voice, as irrelevant speech (see Appendix B). Participants received the background sounds through headphones (*Sennheiser, HD 201).* The sound level of the recording was stable (65dB) and it contained no reverberation or changes in intonation. The recording repeated after 60 seconds.

Apparatus. The experiment was conducted with the aid of the program *Inquisit 4.0.* The tasks were presented on the screen of a notebook (Dell Latitude D505) with Windows XP as operating system.

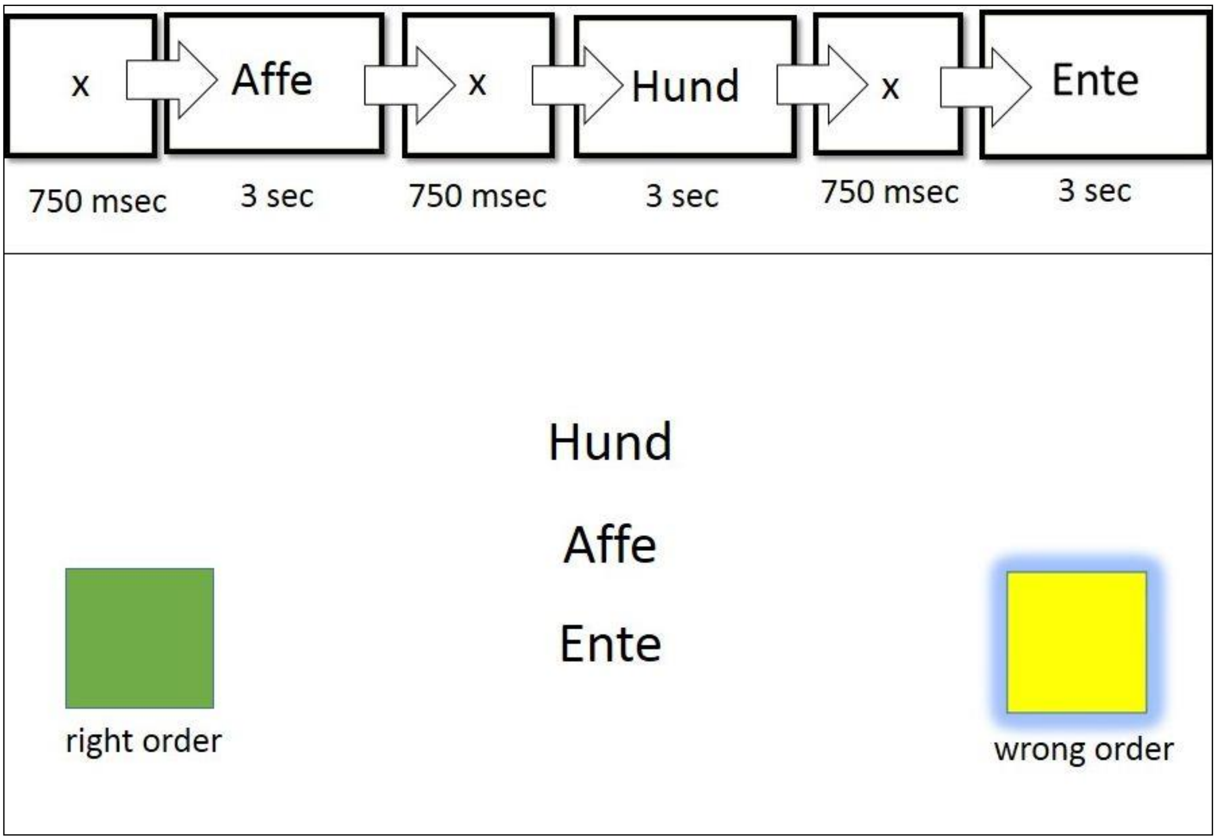

Figure 1. Exemplary trial used for children and adults. The participant correctly identified the wrong order of the items.

RESULTS

Proportion correct

A repeated measurements ANOVA with age as a within-subject factor was performed to examine the effects of sound (pink-noise vs. speech) and WML (set size 3 vs. 6) on the proportion correct (pc) of answers in an immediate serial recall task. Fig. 2 shows the means and 95% confidence intervals for the conditions of the design, divided by age.

The analysis revealed a significant main effect for age [$F(1, 34) = 24{,}49$, $p < .01$]. This effect indicates that there was a significant difference in recall performance between children and adults. Overall, adults achieved higher scores in the mean percentage of correct answers in the immediate serial recall task compared to children (see Fig. 2). Further, there was a significant main effect of sound [$F(1, 34) = 6{,}013$, $p = .01$], indicating that overall recall performance was affected by the sound-condition, being generally higher in the baseline condition (pink-noise) than in the speech condition. However, the interaction between sound and age was non-significant [$F(1, 34) = 1{,}865$, $p = .181$] showing that irrelevant speech has similarly affected performance in both age groups.

Additionally, a significant main effect for WML was found [$F(1, 34) = 34{,}724$, $p < .01$], which indicates that performance differed significantly between the two WML conditions. In general, children and adults scored higher in the low WML condition, than in the high WML condition. Furthermore, there was a significant interaction between WML and age [$F(1, 34) = 7{,}463$, $p = .01$]. That shows that age had an influence on the recall performance in the two WML conditions. LSD post-hoc tests show that children were more impaired by background speech in the high WML condition than were adults (both *ps* <. 001).

Importantly, there were no significant interactions between sound and WML [$F (1, 34) = .136$, $p = .715$] or between sound, WML and age [$F(1, 34) = .644$, $p = .428$]. Thus, the ISE did not depend on the WML, and it was true for both children and adults.

Summarised, the pc data showed main effects of age, sound and WML. Thus, pc was higher in adults than in children, also it was higher in a baseline condition than in the irrelevant speech condition, and pc performance was higher for the low WML than for the high WML condition. However, there were no significant interactions between age and the ISE suggesting that the ISE was equally strong for children and adults. Although children's' performance decreased stronger with the increase of the WML, there were no interactions between WML and the ISE or WML, the ISE and age. Overall, the data suggest that: 1) the ISE is equally strong in children and adults and 2) the ISE does not depend on the WMC.

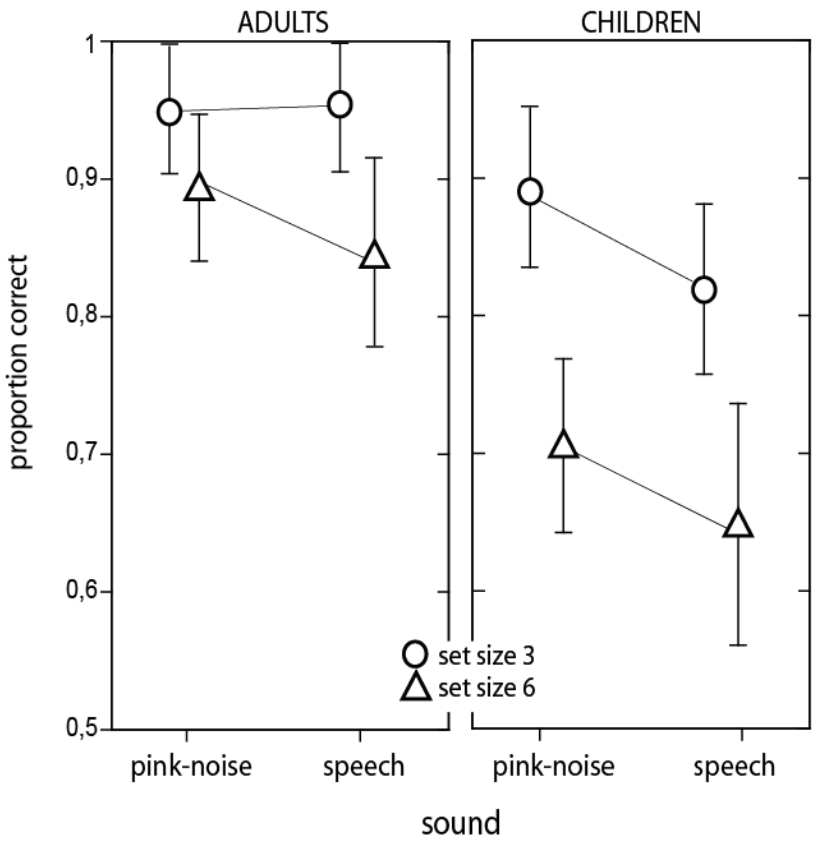

Figure 2. Means and 95% confidence intervals of the proportion correct of correctly categorised word lists, grouped by age.

Reaction times

A repeated measurements ANOVA was conducted with the same factors as in the analysis of the effects on proportion correct. Fig. 3 shows the RT means and 95% confidence intervals for the conditions of the design, divided by age.

Again, there was a significant main effect for age [$F(1, 34) = 19{,}587$, $p < .01$]. This effect indicates that children and adults differed in their RTs, whereby children answered slower than adults (see Fig. 3). The main effect of sound as well as the interaction between sound and age were not significant [$F(1, 34) = .088$, $p = .768$ and $F(1, 34) = .954$, $p = .336$ respectively]. This shows that the irrelevant speech condition had no significant impact on the RTs, and this was true for both age groups. Overall, the RTs remained fairly constant in both sound conditions (i.e. pink-noise vs. irrelevant speech – see Fig. 3). A main effect of WML was found [F (1, 34 = 74.817, $p < .01$], which shows that the RTs were significantly longer in the high than in the low

WML condition Further, there was a significant interaction between WML and age [F (1, 34) = 6,018, $p < .05$]. LSD post-hoc tests show that the raise in RT with increasing WML was significant in both age groups (both *ps* <.001), but stronger in adults than in children (see Fig. 3). Importantly, no significant interaction was found between sound and WML [$F(1, 34) = .02$, $p = .887$] and there was no significant interaction between sound, WML and age [$F(1, 34) = .14$, $p = .707$].

In summary, the RT data show very robust effects of age and WML, however the RTs were not affected by the ISE nor there were significant interactions between the ISE and WML or between the ISE, WML and age. Overall, the ISE seemed to be reduced only for accuracy measures, independent from age.

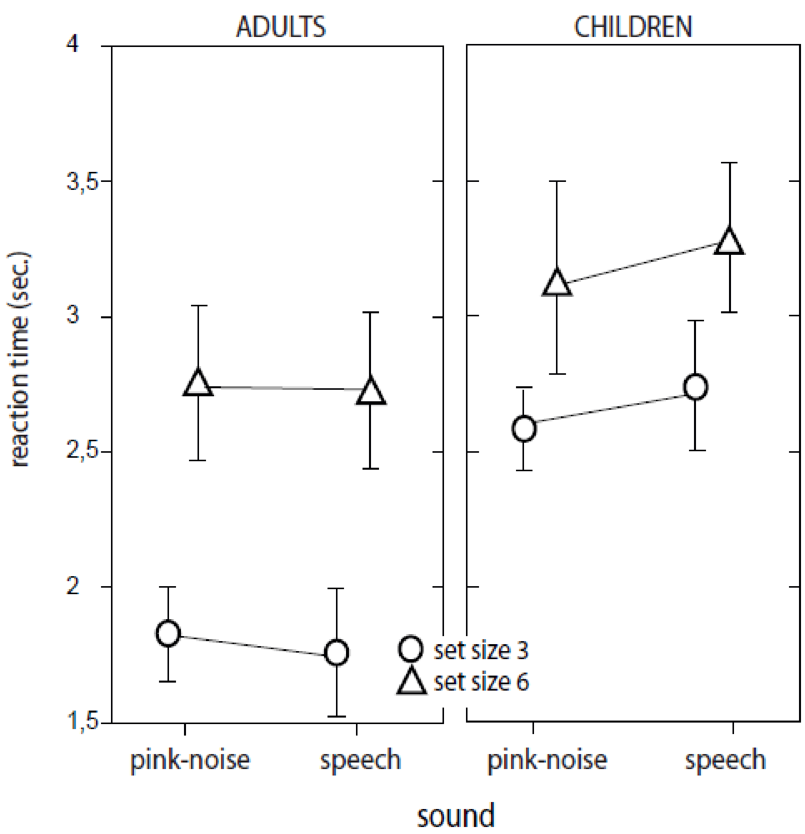

Figure 3. Means and 95% confidence intervals of the reaction times, grouped by age.

DISCUSSION

The aim of the present study was to investigate whether: 1) there is developmental change in the impact of distracting sounds, and 2) whether the ISE is affected by working memory load (WML). Therefore, an immediate serial recall task was conducted with two sound conditions (pink-noise and irrelevant speech) and two levels of WML (list of 3 or 6 common nouns). German speech, the native language of the participants, served as a changing-state distractor and pink-noise as baseline condition. A group of young children (mean age 9) and adults (mean age 22) took part in the study. Overall, the ISE has been found only for accuracy data (pc), but not for reaction times (RTs), which were also measured in the present study. This is concordant with previous findings (see Szalma & Hancock, 2011 for a meta-analysis). Most importantly, the results of the present study are in line with those reported by Klatte et al. (2010), where no differences in the ISE have been found for children and adults. Moreover, the results show that the ISE was not affected by the WML, although accuracy decreased with increasing WML. In the following, the findings of the present study are discussed and put into the context of current models of auditory distraction.

No developmental changes in the ISE

Overall, adults achieved higher pc scores than children and accuracy was higher in the pink-noise condition than in the irrelevant speech condition. Both findings are in line with existing evidence suggesting differences in the cognitive tasks at different ages (e.g. Chi, 1977; Bjorklund & Harnishfeger, 1990; Henry & Millar, 1991; Pearson & Lane, 1991; Elliott, 2002; Elliott & Briganti, 2012) and the disturbing effect of the irrelevant speech on serial recall (e.g. Jones, Madden, & Miles, 1992; LeCompte, 1995; Norris, Baddeley, & Page, 2004) However, as the interaction between sound and age was non-significant, an essential finding of this study was that children and adults were *equally* impaired by irrelevant speech. This is concordant with the findings of Klatte et al. (2010), but in contrast to the findings by Elliott and colleagues (Elliott, 2002; Elliott & Briganti, 2012) that have reported the decrease of the ISE with increasing age. The discrepancy between the results of the two studies (Klatte et al., 2010 and Elliott, 2002) was explained by differences in methodology. Namely, whereas Klatte et al. (2010) examined the effects of the ISE on the serial recall of pictorially presented common nouns, Elliott used digits as stimuli. Additionally, there were differences in the irrelevant sounds used in both studies. Klatte et al. (2010) presented an unknown language and classroom noise that both are perceived as a loose aggregation of unrelated auditory stimuli without serial order information. In contrary, Elliott (2002) used native language distractors that included serial information. And finally, Elliott (2002) adjusted list lengths for the individual working memory span, whereas Klatte et al (2010) reported partially different results for two experiments, whereby in the first experiment, fixed list lengths were used vs. adjusted list lengths in the second experiment.

With the respect to differences in methodology, the present study was partially similar and partially different from both previous studies (Elliott, 2002, Klatte et al., 2010). Firstly, the stimuli in the present study were nouns, but they were presented as written words (not pictures) and a set of 30 different animal names was used in contrast to 10 common nouns in the study by (Klatte et al., 2010) or 9 (1-9) digits used by Elliot (2002). Secondly, the irrelevant speech condition in the present study was native language as in the study by Elliot (2002). The speech condition in the study of Klatte et al. (2010) differed from the speech condition in the present study as Danish was a foreign speech distractor and in the current study, the German speech distractor was a native language distractor to the participants. Thirdly and lastly, only in the present study the working memory load was systematically varied, whereas in previous studies adjusted list lengths (to the individual working memory span) were used.

An important difference between present and previous studies was in the task requirements. Strictly speaking, the subjects in the present study did not have to recall items in their correct order (as in free recall), but to respond whether the order of the presented items was correct or wrong by pressing the corresponding button. Due to guessing probability, it can be questioned whether the present study captured the same serial recall performance as it was the case in the previous two studies (although there were also some differences in the response possibilities). However, the relatively long RTs and the overall accuracy level, reported in this study, indicate that subjects indeed tried to remember and to recall the serial order of the presented items.

Working memory load and the irrelevant sound effect

Performance differed significantly between the two WML conditions, and this was the case for both pc and RT measures. Overall, accuracy was higher and the RT was faster in the low WML condition. Moreover, age had an impact on performance throughout the WML conditions. Decrease in the accuracy data was stronger in children, adults showed a stronger increase in RTs. However, in the RT data showed no significant effect of the ISE, nor there were significant interactions of the ISE with age or WML. Thus, when asking about the relationship between WML and the ISE, accuracy data are much more relevant.

Based on the pc measures it can be concluded, that the ISE affected children and adults in the same way *and* importantly, the ISE influenced the performance throughout the WML conditions equally. This is suggested by the non-significant interactions between WML and the ISE and WML, the ISE and age. It indicates that irrelevant speech impaired performance in the same way throughout the WML conditions in both age groups. These findings are in line with previous findings from adult studies, suggesting that WMC does not affect the susceptibility to the ISE (e.g., Beaman, 2004; Hughes, Vachon, & Jones, 2007; Sörqvist, 2010; Sörqvist et al., 2013).

Classifying the findings into current working memory models

In the current study, the ISE impaired the pc of children and adults equally. This contrasts with the assumption of a unitary account of auditory distraction, which explains the ISE by attentional capture of the irrelevant sounds of the ISE (Elliott, 2002). Klatte et al. (2010) suggest, that due to automatic access of the irrelevant sounds to short-term memory, the changing-state stimuli directly interfere with the representations of the to-be-remembered stimuli in the rehearsal process. They propose that this mechanism operates equally in adults and children. Accordingly, the susceptibility to the ISE has to be due to the characteristics of the sounds and to the attentional abilities of the participants. This model explains the impairment of the performance of the first-graders and the unaffectedness of older children and adults by the ISE in their study. Klatte et al. (2010) therefore suggest that the ISE is susceptible to developmental change.

The results of the present study are mostly in line with previous theories on a duplex-mechanism account (Hughes et al., 2007; Sörqvist, 2010; Sörqvist et al., 2013). They suggest, that two separate mental processes are involved in the distraction of the storing process by changing-state speech: The changing-state effect, which is affected by the ISE and the deviation effect that is susceptible to developmental change. Children therefore should be more susceptible to the deviation effect than adults are, as attention capture and WMC are not fully developed until adolescence. According to the duplex-mechanism account the susceptibility to the ISE does not underlie developmental change, therefore the ISE should affect children and adults equally. This was the case in the present study; children and adults were equally impaired by the ISE and the ISE affected the performance throughout the WML conditions in the same way. Thus it can be assumed that the ISE is independent from WMC.

Conclusion

Adults and children were equally impaired by the ISE. Moreover, the ISE was equally strong in a high and low working memory load condition in both age groups. In conclusion, the results of the present study suggest no developmental change in the susceptibility to the ISE and no effect of the working memory capacity to the ISE. The data can be explained by a duplex-mechanism account of the distraction of attention (Hughes et al., 2007; Sörqvist et al., 2013). A unitary account, as suggested by Elliott (2002) is not consistent with the findings of this study.

Children and adults may be equally affected by the ISE, nevertheless the consequences of exposure to background noise are devastating, especially for children. Field studies have shown that chronic exposure to irrelevant sounds, i.e., indoor noise in classrooms, has enduring effects on children’s language, pre reading skills, and academic attainment (Maxwell & Evans, 2000; Shield & Dockrell, 2008). Based on this, measures should be taken by schools to provide a suitable learning environment with as little distraction as possible.

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APPENDIX A – Used stimuli

Affe	Biber	Biene	Delphin	Eichhörnchen
Ente	Esel	Eule	Fledermaus	Frau
Hai	Hund	Igel	Katze	Krokodil
Mann	Meerschweinchen	Nilpferd	Panda	Pferd
Regenwurm	Reh	Schaf	Schildkröte	Schmetterling
Seepferdchen	Storch	Tiger	Wal	Wespe

APPENDIX B – Distractor text

„Das Eichhörnchen ist eines der populärsten Geschöpfe unserer einheimischen Tierwelt. Der ursprüngliche und wichtigste Lebensraum des kleinen Nagetiers sind Nadelwälder, aber auch in Laubwäldern, in Feldgehölzen, Parkanlagen und Obstgärten findet es sich zurecht. Eich-hörnchen verbringen den größten Teil des Tages hoch oben in den Baumkronen. Für diesen Lebensraum ist das Eichhörnchen ausgezeichnet angepasst. Das Eichhörnchen ist ein vorzüglicher Baumkletterer. Sein Körper ist schlank und leicht. Mit den spitzen Krallen der Zehen, kann sich das Eichhörnchen in der Baumrinde so fest einhaken, dass es auch mit dem Kopf nach unten klettern kann. Die Vorderfüße mit den stummelförmigen Daumen, kann es als Greifhände gebrauchen. Die Hinterbeine sind länger und kräftiger als die Vorderbeine. Sie dienen als Sprungbeine. Mit ihnen stößt sich das Tier ab und springt von Baum zu Baum oder von Ast zu Ast.“

Erklärung für schriftliche Prüfungsleistungen

gemäß § 13, Abs. 2 und 3 der Ordnung des Fachbereichs 02 Sozialwissenschaften, Medien und Sport der Johannes Gutenberg-Universität Mainz für die Prüfung im Bachelorstudiengang B.Sc. Psychologie vom 11. Febr. 2011, StAnz. S. 460

Hiermit erkläre ich,

____

Name, Vorname   Matrikelnummer

dass ich die vorliegende Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen oder Hilfsmittel (einschließlich elektronischer Medien und online-Quellen) benutzt habe.

Mir ist bewusst, dass ein Täuschungsversuch oder ein Ordnungsverstoß vorliegt, wenn sich diese Erklärung als unwahr erweist.

____________________   ____________________

Ort/Datum   Unterschrift

§ 19 Abs. 3 habe ich zur Kenntnis genommen („Versucht die Kandidatin oder der Kandidat das Ergebnis einer Prüfung durch Täuschung oder Benutzung nicht zugelassener Hilfsmittel zu beeinflussen, oder erweist sich eine Erklärung gemäß § 13 Absatz 2 Satz 5 als unwahr, gilt die betreffende Prüfungsleistung als mit „nicht ausreichend" (5,0) absolviert.")