

2015

An Investigation of the Effect of Irrelevant Sounds on Serial Order Recall in Children and Adults

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AN INVESTIGATION OF THE EFFECT OF IRRELEVANT SOUND ON
SERIAL ORDER RECALL IN CHILDREN AND ADULTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Psychology

by
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B.S., Louisiana State University, 2013
May 2016

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ABSTRACT

Irrelevant sound is detrimental to performance on serial order recall for both adults and children. Many current models of the effects of irrelevant sound on serial order recall propose that the irrelevant sound interferes with rehearsal in adults. However a direct test of rehearsal on the irrelevant sound effect (ISE) had not been examined prior to the present study. Furthermore, the cause of the ISE in children remains unclear as children are less proficient at rehearsal, yet typically show larger effects. We examined how certain factors hypothesized to relate to the size of the ISE correlate to performance in both adults and children in order to investigate the underlying mechanisms causing the effect in the two populations. Results indicated that in adults, while rehearsal does significantly predict the size of the ISE, the size of the relationship is weak. In children, the relationship between rehearsal and the size of the ISE appears stronger, however further analysis leads to the conclusion that attention capture may be playing a unique role in causing the ISE in children despite being shown not to play a role in adults. The present study demonstrates the need for further investigation not only into the cause of the ISE, but also into developmental differences in auditory distraction.

CHAPTER 1 – INTRODUCTION

Imagine you are at a holiday party that your office mate is hosting. He introduces you to a friend of his wife and you two hit it off and talk the rest of the night. As the party begins to wind down you ask for her number, and she tells it to you over the noise of the other people leaving the party and the music in the background. You try to remember it as you fumble for the phone in your pocket, eventually pulling it out and typing in what you heard. The next day you give her a call, only to have a man pick up the phone, who clearly has no idea why you are calling looking for a “Charlotte”. You assume that as you were fumbling for your phone the night before you mixed up the order of the numbers in the phone number, and you never hear from her again. What you experienced in this scenario is the detrimental effect that irrelevant sound has on serial order recall, originally discovered by Colle and Welsh (1976). The detrimental effect has since been thoroughly demonstrated in adults. However, despite evidence that young children also show a similar effect, there has been little done to investigate if the proposed mechanisms causing the effect in adults apply to children. Thus, the current study included a direct measurement of the effect of irrelevant sound on serial order recall in children and adults, as well as other measures of rehearsal and attention control to investigate the underlying mechanisms causing the effect.

The most common method of testing the effects of irrelevant sound on serial order recall is to use a paradigm known as the irrelevant sound effect (ISE). In a typical ISE paradigm in the laboratory, participants are shown a series of stimuli (usually digits or letters) one at a time. After the items have been shown, the individual is asked to recall the items in the exact order they saw them either immediately after the last item has been presented or after a short retention period. During some of the trials irrelevant sound is presented during the presentation of the visual

stimuli, during a retention interval, during recall, or a combination of the three. Participants are asked to ignore the auditory stimuli. The presence of this irrelevant sound has been consistently shown to cause performance to worsen, compared to trials in which there are no auditory stimuli.

A second methodology for testing the effects of irrelevant sound on serial order recall is to compare irrelevant auditory stimuli with different characteristics. For the purposes of the current paper, the term “ISE” will be used to refer specifically to the comparison of serial recall performance in the presence of any sound, relative to serial recall performance in silence; however, the irrelevant sound stimuli may vary across studies (i.e., such as using a non-speech sound like a tone; Jones & Macken, 1993). As an example, the changing-state effect is defined as a comparison between performance during changing-state sounds (e.g. a list of words like “car–dog–hat–spring–tree”) and performance during steady-state sounds (e.g. repeating the word “car”; Jones, Macken, & Murray, 1993). The changing-state effect has also been shown to be robust, in that performance is significantly worse during changing-state irrelevant sound when compared to steady state irrelevant sound (Elliott, 2002; Jones et al., 1993).

Auditory Distraction Effects in Adults

Auditory distraction is not limited to paradigms employing serial recall. In fact, the ways in which auditory stimuli can worsen performance are multifaceted. Even though there is still debate within the field regarding the underlying causes of auditory distraction, the duplex model of auditory distraction proposes that there are two distinct and separable causes, attention capture and interference by process (Hughes, 2014; Hughes, Vachon, & Jones, 2007). Attention capture occurs when an individual rapidly disengages from the focal task and refocuses attention on a separate stimulus (Hughes, 2014; Hughes et al., 2007; Sörqvist, 2010). Sound can cause two types of attention capture effects, specific and aspecific. Specific attention capture occurs when

sound that the individual is not actively attending to has meaning to the individual, causing them to shift attention towards the source of the sound. For example, hearing one's own name in an unattended auditory stream has been reliably shown to cause some individuals to shift their attention away from the focal task (Wood & Cowan, 1995).

On the other hand, aspecific attentional capture, of which one example is the deviation effect, is due to unexpected auditory changes that cause a shift of attention away from the focal task (Hughes, 2014; Schröger, 1997). This is believed to occur because the cognitive system creates expectations about the auditory environment (Cowan, 1995; Vachon, Hughes, & Jones, 2012). If the current auditory input deviates from the expectations significantly, attention is recruited away from the focal task and towards the source of the deviation (Schröger, 1997). For example, if an individual is completing a task while attempting to ignore a spoken voice presented over headphones, and the speaker's voice changes unexpectedly from a male voice to a female one, the individual's task performance on the focal task will drop at the time of the change due to attentional recruitment away from the focal task and towards the changed stimulus.

Both specific and aspecific attention capture demonstrate a habituation response to repeated distractors. Habituation occurs when a novel stimulus no longer causes an attentional orienting response due repetition of the stimulus (Cowan, 1995). As a stimulus is repeated a neural model of the stimulus is formed and each new instance of the stimulus is compared to the model. Unless an instance is differentiated from the neural model, further processing resources are not allocated to the repeated irrelevant stimulus (Bell, Röer, Dentale, & Buchner, 2012).

Many theories of the effects of irrelevant sound on serial order recall originally included a role for aspecific attention capture in the cause of disruption (Cowan, 1995; Neath 2000).

Theories including aspecific attention capture as a cause of the detrimental effects assert that the unpredictability of the auditory stream results in small, but not insignificant, attentional orienting away from the relevant task. This attentional orienting account also attempted to explain the changing-state effect. The ISE and the changing-state effect have been demonstrated to be roughly equivalent in adults, as steady-state irrelevant sounds produce small and inconsistent effects on performance when compared to silence (Cowan, 1995; Elliott, 2002; Elliott & Briganti, 2012; Jones et al., 1993; Lange, 2005; Neath, 2000). Under the aspecific attention capture account of the effect of irrelevant sound, changing-state sound is consistently capturing attention away from the focal task, but steady-state irrelevant sound leads to a habituating response, in which the repeated auditory distractor during steady-state sound is quickly habituated to and thus no longer recruits attention away from the focal task. Performance becomes equivalent to performance in silence because of the lack of an attentional orienting response away from the task.

In addition to the attention capture mechanism, the second mechanism of auditory distraction in the duplex model is interference-by-process, or the interruption of specific processes by irrelevant sound (Hughes, 2014; Hughes et al., 2007). For example, semantically-related irrelevant speech during free recall of a semantically-similar list impairs performance greater than semantically-dissimilar irrelevant speech (Neely & LeCompte, 1999). An interference-by-process account for these effects proposes that during lists with both a length greater than the span at which individuals can rehearse (for example 15 items long) and with semantically-similar items, individuals use semantic-based storage (Marsh, Hughes, & Jones, 2009). Under this account, the semantic-based storage processes are interfered with, because individuals must select which set of information within the same semantic category to recall.

The interference-by-process account of the ISE posits that the controlled order processing involved in rehearsal of to-be-remembered items is interfered with by the automatic processing of order in the auditory stream. During serial order recall individuals are thought to be subvocally rehearsing the relevant to-be-remembered (TBR) items (Kattner & Ellermeier, 2014). As they mentally recite the TBR items, they are also rehearsing the relationship from one item to the next in order to reinforce the order cues used in the recall task (Elliott, 2002; Elliott & Briganti, 2012; Jones et al., 1993). Under the interference-by-process account, the changing-state effect is due to sound changing from one item to the next, creating order cues that an individual obligatorily processes in the auditory modality (Hughes, 2014; Hughes et al., 2007; Jones & Macken, 1993). It is these auditory order cues that interfere with serial order recall. The combination of order cues from the irrelevant sound and the rehearsed TBR items creates interference and causes the deleterious effects.

In order to further investigate the mechanisms underlying the ISE, Hughes, Hurlstone, Marsh, Vachon, and Jones (2013) tested the hypothesis that the ISE is affected by attentional factors, by manipulating the deviation effect and the changing-state effect. They asserted that if the changing-state effect is caused by aspecific attention capture then it would show similar moderating effects as the deviation effect, which is believed by most to be caused by aspecific attention capture. They found that the same conditions known to moderate the deviation effect had no effect on the size of the changing-state effect in a serial recall paradigm. For example, the deviation effect was eliminated when participants were forewarned of the deviating stimulus, and when encoding difficulty was increased, requiring the individual to focus more attention on the task-relevant stimuli. However, the changing-state effect persisted during forewarning and during increased encoding difficulty. These results were taken as evidence against the effects of

irrelevant sound being caused by aspecific attention capture because the effects of the irrelevant sound were persistent despite attentional mediating factors being introduced.

This finding is consistent with other findings from research examining the role of attentional factors in the ISE, such as examining the relationship between individual differences in working memory capacity (WMC) and the size of the ISE (Beaman, 2004; Elliott & Briganti, 2012; Sörqvist, Marsh, & Nöstl, 2013). WMC tasks require individuals to simultaneously store task relevant items and perform a processing task. This requires individuals to consistently switch their attention from completing the processing task to completing the storage component and vice versa, and is considered a measure of the efficiency of the control processes of working memory (Engle, 2002). Elliott and Briganti (2012) hypothesized that WMC would correlate to the size of the ISE because the ability to appropriately focus attention in WMC tasks would be similar to individuals focusing attention on the relevant task items and ignoring the irrelevant sound in the ISE paradigm, similar to the logic explored by Beaman (2004). However, their results indicated that individual differences in the magnitude of the ISE and WMC were not significantly related, providing further support for attentional control not contributing to the ISE.

Due to the lack of strong empirical support for a clear role of attentional processes in the effects of irrelevant sound in adults, the ISE and changing-state effect are generally attributed to interference-by-process (but see Röer, Bell, & Buchner, 2013; Röer, Bell, & Buchner, 2014). However, the extent to which rehearsal can account for the effects of the ISE has not been directly tested. Individual differences in rehearsal are difficult to measure. There has been no direct test of individual differences in rehearsal in the literature, only proxy measures like articulation rate. Articulation rate, while it has been shown to predict memory span through a proposed relationship with rehearsal (Cowan et al., 1998), is an exceptionally indirect method of

measuring rehearsal. The idea behind speeded articulation is as follows: the rate at which you can articulate is related to the rate at which you can rehearse, and the rate at which you can rehearse is related to your memory span. It has been demonstrated that memory span and articulation rate correlate. Thus, rehearsal is the assumed manner by which these two measures correlate. Furthermore, research has demonstrated an inability to model the effects of rehearsal as they are assumed to affect short-term memory (Lewandowsky & Oberauer, 2015) which presents an additional challenge to rehearsal-based views of the ISE. As such, the present study adopted a novel approach to directly assess individual differences in rehearsal and used these individual differences to predict the size of the ISE in adults, thus testing the interference-by-process account of the ISE.

Auditory Distraction Effects in Children

Despite the large number of studies investigating the causes of auditory distraction in adults, and specifically on serial recall, there is very little literature on the effects in children. Elliott (2002) was one of the first to test the changing-state effect in children, in order to test the hypothesis that attention capture plays a role in the ISE. Children of different ages (2nd grade to 6th grade) performed serial order recall in silence, as well as with changing-state and steady-state irrelevant sounds. Their performance was then compared to adults' performance. Each participant was first tested for their own personal digit span, and that span was used for the list length during the ISE tasks. Elliott (2002) predicted that if children did show an effect in a typical ISE task then attention capture would have to play a role in the ISE, because young children had previously been shown to exhibit significant developmental changes in rehearsal (Flavell, Beach, & Chinsky, 1966). Thus, if young children typically do not rehearse, the changing-state effect should not occur, and the distraction in children should be either

nonexistent or very small. However, the results not only demonstrated that children showed significant distraction effects, the size of the effects was significantly larger in younger age groups than in older children and adults. This pattern was true for comparisons between changing-state words and silence (a general ISE) and also for comparisons between changing-state and steady-state words (a changing-state effect). These results were taken to support the role of attention capture in the ISE because there was no explanation for the effects in children being larger, unless interference with rehearsal was not the only cause of the ISE.

Despite later research by Klatte, Lachmann, Schlittmeier, and Hellbrück (2010) who found a different pattern of developmental change in the size of the ISE than the one demonstrated in Elliott (2002), many questions about the underlying mechanisms causing the ISE in children remain. Their results showed that the size of the ISE was the same in all age groups. However, despite the methodological differences between the two studies, the existence of the ISE in children too young to appropriately rehearse remains unexplained by factors other than attentional capture. Elliott et al. (2016) demonstrated that rehearsal interference alone could not account for the ISE in children. When the focal task required children only to recall the items presented and not the order they were presented in, the ISE persisted in children but not adults. Similarly, when the order importance was removed from the auditory stimuli (i.e. steady-state sounds), the ISE persisted in children but not adults. This pattern of findings was taken to implicate additional interference beyond order rehearsal interference in child participants that adults are not subjected to. The pattern of results in Elliott (2002), Klatte et al. (2010), and Elliott et al. (2016) indicated that despite a general knowledge about how the ISE affects adults there are likely additional factors that play a role in the ISE in children. The present study examined the patterns of correlations for measures of rehearsal, attention control, and the ISE in both adults

and children, and made comparisons of the relationships across experiments to examine the possible implications of the developmental comparisons.

As mentioned above, in order to more accurately identify the factors that play a role in the ISE, the present study used multiple measures and examined the relationship between the size of the ISE, attention control, and rehearsal. By using an individual and developmental differences approach to measure immediate memory span performance, working memory capacity, rehearsal abilities, attentional control abilities, and the size of the ISE in a sample of adults and children, we assessed the causes of auditory distraction and how these causes may change with age. Although many researchers have attributed the changing-state effect in adults to processes related to the order information in the two streams of relevant and irrelevant information, a direct measure of rehearsal abilities of individuals has not been assessed in relation to the ISE. Thus, the current study included measures of rehearsal as a means of determining the relationship between an individual's rehearsal abilities and the size of the ISE.

The Present Study

The first rehearsal measure, the use of multiple speeded articulation tasks, has been linked to verbal short-term memory and memory span (Cowan et al., 1998; Hulme, Thompson, Muir, & Lawrence, 1984). Hulme et al. (1984) found the speed at which both children and adults could repeat a set of words was related to the number of words the individual could remember in serial order recall tasks. In addition, Cowan et al. (1998) had children verbally recite lists in speeded articulation tasks and measured the speaking duration and the time between each word in a list (interword pauses). They found that the interword pauses and the task completion time were independent of each other, but both accounted for variance in span. When adults were studied using internal verbal rehearsal, the same pattern of results were found (Cowan et al,

1998). Jarrold, Hewes, and Baddeley (2000) also found that duration and interword pauses accounted for at least some unique variance in span tasks in both adults and children. In adults, a variant of the speeded articulation task, the number of times an individual could recite a set list in their head sub-vocally, correlated with the ability to rehearse as well. Cowan et al. (1998) concluded that the ability to sub-vocally recite critical stimuli allowed for more rehearsal, thus improving the effectiveness of rehearsal, which in turn improved performance on memory span tasks.

Another way to measure an individual's reliance on rehearsal is to require concurrent articulation during a serial recall task. This is known in the literature as articulatory suppression, and it is thought to interfere with an individual's ability to rehearse TBR stimuli (Murray, 1967; Peterson & Johnston, 1971). The use of concurrent articulation to block subvocal rehearsal has consistently been the most direct method of blocking the ability to rehearse in an experimental paradigm in the literature (Bhatarah, Ward, Smith, Haynes, 2009; Camos, Lagner, & Barrouillet, 2009; Grenfell-Essam, Ward, & Tan, 2013; Larsen & Baddeley, 2003). By performing a serial order recall task under articulatory suppression while assessing span length, individuals would not be able to rehearse as effectively, thus providing a span measure without the full benefit of rehearsal. By comparing individuals' span performance both with and without concurrent articulation, one can assess the relative contribution of rehearsal to span performance.

The present study also examines the role of attention control on the ISE. The visual anti-saccade paradigm in Kane, Bleckley, Conway, and Engle (2001), has been shown to correlate with WMC (Chein & Weisberg, 2014). The task requires individuals to immediately look away from a distracting visual stimulus to perceive the critical stimulus on the opposite side of the screen. The ability to override the natural instinct to look towards the distraction is believed to

rely on inhibiting attention capture to minimize or eliminate the effect of the visual distractor. Any relationship between visual anti-saccade and the ISE would provide strong support for the role of attention in the ISE because of the separate modality of the antisaccade task. Measures of auditory attention capture, such as the deviation effect, might correlate to performance on the ISE because of task similarities unrelated to attention capture. However the visual anti-saccade task is distinct from the ISE paradigm, and evidence of a relationship between those two tasks could only be explained through a cross-modal role of attention control being important in both tasks.

The present study correlated performance on several cognitive tasks across two experiments. Experiment 1 included adult participants completing measures of WMC, rehearsal, and the ISE to identify possible causes of the ISE. In adult participants it was predicted that the correlational analysis would reflect the current literature on the ISE, in which (1) WMC and the size of ISE are not correlated (Elliott & Briganti, 2012), (2) that the size of the effect of rehearsal measures and the size of the ISE would be positively correlated (Baddeley, 2000; Cowan et al., 2005; Elliott & Cowan, 2005; Hughes et al., 2007; Jones & Macken, 1993), and (3) that performance on anti-saccade tasks will be positively correlated with WMC (Chein & Weisberg, 2014), but not with the size of the ISE. In Experiment 2, similar comparisons were made in a sample of young children, to determine if the patterns of correlations observed in adults would be replicated in children.

CHAPTER 2 – EXPERIMENT 1

Participants

143 undergraduate psychology students at Louisiana State University aged 18 to 30 ($M = 20.09$, $SD = 1.70$) with 109 females and 32 males participated in the present study for course credit. Exclusion criteria included uncorrected vision, hearing loss, and being a non-native English speaker. Of the 143 participants, 45 were run in two 1 hour sessions and 90 were run in a single two hour session.

Materials

Working Memory Measures

The first test of working memory administered to adults was the WMC battery from Unsworth, Heitz, Schrock, and Engle (2005). The battery consisted of three separate span tasks which were used to create a composite measure of WMC. The first task was Operation Span (OSPAN) in which participants performed simple mental arithmetic, and then responded using the mouse. A second screen appeared with a number that was either correct or incorrect and the participant was asked to record if the number was the correct answer by clicking “TRUE” or incorrect by clicking “FALSE”. Then a letter appeared on screen that the participant was asked to remember, and another arithmetic problem appeared on screen. This presentation of letters for recall, interspersed with the processing component, continued until there were between four and seven letters presented. Then the participant input the serial position of the letters from a set of 16 letters with a mouse click. The second task was the Symmetry Span (SSPAN) measure, which was similar to OSPAN. The first mental task required the participant to judge a ten by ten grid with black and white squares, for vertical symmetry. Once they made a decision they clicked the mouse, and as before, were asked to click “TRUE” if they believed the image was symmetrical

or “FALSE” if they believed it was not symmetrical. Following this, a four by four grid with one red square appeared on screen and the participant was to remember its location. After the sequence of symmetry judgments and spatial recall was completed three to six times, the participant was shown a blank four by four grid and was asked to click on the squares to indicate the order in which the red squares were shown to them. The final task was Reading Span (RSPAN), which included having participants read a sentence that either did or did not make sense. After reading the sentence, participants clicked the screen, and then were asked to click “TRUE” if the sentence made sense or “FALSE” if it did not. Then a letter appeared on screen that participants were to remember. After a sequence of four to seven sentence processing and letter recall screens were shown, participants clicked the letters in the order they originally appeared.

Attention Control

Attention control was measured with an anti-saccade task adapted from Kane et al. (2001). Trials began with a screen prompting the participant to press any key to begin the trial. Immediately after pressing a key, a fixation cross appeared on screen for a random interval between 200 and 2200 ms. After the fixation, the screen was blank for 50 ms, then on one side of the screen a “=” flashed twice for 100ms with a 50 ms blank screen between each flash. Then, 50 ms following the second “=” either a “B”, “P”, or “R” flashed for 100 ms on the opposite side of the screen, which was then masked by an “H” for 100 ms, and an “8” until a response was provided. Participants initiated the next trial when ready. There were six practice trials before the experiment, and 24 critical trials. See Figure 1 for a visualization of an anti-saccade trial.

Verbal Speeded Articulation Rate Task

The articulation rate task was derived from the speeded articulation task used in Cowan et al. (1998). Participants were recorded while reciting the numbers one to ten, aloud, three times in a row as quickly as possible. Each duration of a recitation from the beginning of the word “one” to the end of the word “ten” were recorded. Cowan et al. (1998) used a similar method in children, and that method was applied here in the adult sample.

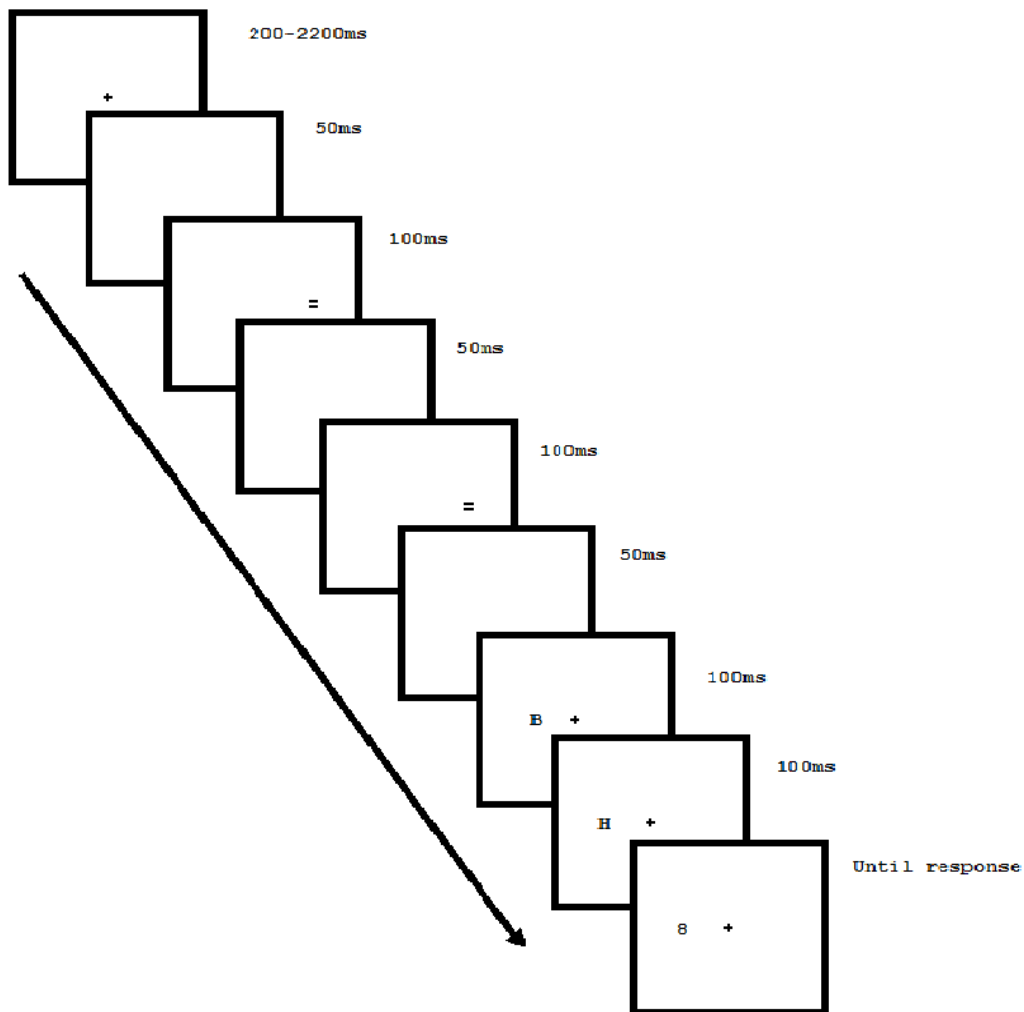


Figure 1. Example of anti-saccade trial in adults in Experiment 1

Sub-vocal Speeded Articulation Rate Tasks

Adapted from Cowan et al. (1998), individuals were asked to sub-vocally recite the alphabet from “A” to “Z” as rapidly as possible when the experimenter instructed them to begin. The participant then placed a tally mark on a sheet of paper every time they got to “Z” and the number of times individuals completed a recitation were recorded for a period of 60s. The second sub-vocal articulation task was the same except the participant recited the digits “1” to “10” sub-vocally for 30s.

Silent Digit Span

The silent digit span task was the same task used in Elliott (2002). Participants were shown digit lists at the rate of one digit/s, each starting with a block of four lists that were three digits in length. Digit lists included the digits one through nine, and digits would not appear twice in the same list. If participants recalled two or more of the lists completely correctly, the list length would increase by one for an additional block of four trials, up to a maximum list length of nine digits. If the participant recalled less than two of the lists correctly, or the participant completed the list length nine trials, the program ended. The participant’s integer digit span was recorded as the last list length at which the participant recalled two or more of the lists correctly, using a strict serial order criterion.

Articulatory Suppression Digit Span

In order to get an additional measure of rehearsal, participants completed a modified version of the digit span task that required them to recite the word “the” aloud, at a rate of twice per second. This articulation task was done throughout the presentation and recall portions of the digit span task. In order to ensure participants understood the task, they completed a practice session at the beginning of this task. The practice session presented a list of three digits as many

times as needed, until participants could perform the articulation during the recall task without stopping. The experimenter provided feedback during this portion to ensure that the participant knew not to slow their articulation during recall. After four trials without experimenter feedback on articulation, the practice session ended and the articulatory suppression digit span was started. The participant's integer articulatory suppression digit span was recorded as the highest list length at which the participant recalled two or more of the lists correctly, using a strict serial order criterion. The effect of rehearsal was calculated as the individual's integer digit span minus the integer articulatory suppression digit span.

ISE task

The ISE task consisted of 64 trials run at the participant's digit span length as determined by the silent digit span task. During the task individuals were presented with one digit/s (from the set of digits one to nine) until the number of digits in the list was equal to the individual's span. Participants typed their recall of the digits in order from first to last. During a randomly-selected half of the trials, the participants heard words over headphones, presented simultaneously with the onset of each digit. The words were from a closed set of nine different words that were not repeated within the trial. The possible words included *big*, *long*, *short*, *tall*, *blue*, *green*, *white*, *red*, and *yellow*. During the other randomly-selected half of the trials, no sound was presented over the headphones. The size of the ISE was calculated as the percent of correct recall (using strict serial position scoring) in silence minus the percent of correct recall with irrelevant sound.

Procedure

For the first 45 participants the WMC and the anti-saccade tasks were completed during the first session. Participants were run in groups of up to six at a time in personal computer

stations. Participants had as much time as they needed to complete each task. After everyone in the session had finished a task, the experimenter would start the next task on all of the computers. The first session lasted from 50 min. to 75 min. During the second session, participants were run one at a time on a personal computer and participants were given as much time as needed to complete each task. The second session lasted from 45 min. to 60 min.

The other 90 participants completed all tasks in a single session lasting from 90 min. to 100 min. All participants were run individually at a personal computer and were provided as much time as needed to complete each task. The order of tasks was the same as for the original 45 participants except for the addition of the sub-vocal speeded articulation tasks. The sub-vocal speeded articulation tasks were added to attempt to replicate adult data from Cowan et al. (1998). While child participants performed verbal speeded articulation adults only performed sub-vocal speeded articulation. As such the additional articulation rate tasks were added to allow for a more direct comparison to previous literature on articulation rate and memory span. The order of tasks can be found in Table 1 (Note. the first 45 participants did not complete the sub-vocal speeded articulation tasks).

Table 1. Tasks by session for Experiment 1

Part 1	Part 2
Operation span	Speeded articulation
Symmetry span	Sub-vocal speeded articulation tasks
Reading span	Silent digit span
Anti-saccade	Articulatory Suppression Digit Span
	Irrelevant sound effect

Note. Tasks are listed in order of administration for Experiment 1.

First, all participants completed the three measures of WMC one at a time. After all of the WMC tasks were completed, the experimenter provided verbal instructions on the antisaccade

task. The experimenter then started the anti-saccade task while instructing the participant(s) to ask as many questions as they needed before moving past the practice trials. Participant(s) were told not to move past the practice trials until they felt confident they understood the instructions. Participants were then either dismissed from the first session and asked to come back to the second session, or provided a break to use the restroom and/or stretch before continuing the experiment.

Participants were instructed to say on the verbal speeded articulation task. The experimenter then played an example over the headphones for the participant to hear what was asked of them. After the example was played, the experimenter began recording and the participant was told to start when they were ready. If the experimenter felt as though the participant did not understand the instructions (such as reciting the numbers at a normal rate instead of rapidly) they would be asked to rerecord their responses again. Only twice were participants asked to repeat themselves, both of which were because they did not understand the instructions.

The 90 participants who completed the experiment in a single session then completed the sub-vocal speeded articulation rate tasks, while the original 45 participants continued to the silent digit span task. During the sub-vocal speeded articulation task, the experimenter instructed the participant to on completing the alphabet sub-vocal speeded articulation task. The experimenter would indicate to the participant to start and begin a timer. Once the appropriate amount of time passed, the experimenter would stop the participant and count and record the number of tally marks. This was then repeated for the digit sub-vocal speeded articulation task.

Next, the experimenter started the silent digit span task, which instructed the participant to read the list of digits that would be presented one at a time and remember the numbers in

order. After the list was presented, participants were asked to type the numbers in order using the keyboard. If the participant mistyped they were given one opportunity to start over from the beginning of that particular list.

For the articulatory suppression digit span task, participants were told they would complete a similar task to the one they had just completed, while simultaneously reciting “the” at a rate of twice per second. After the participant indicated that they understood the task, the experimenter played an example of “the” spoken at a rate of twice/s to allow the participant to hear the rate they needed to use to recite the word. Before the critical trials began, a practice task was started. During the practice trials the participants were informed that the experimenter would provide feedback to help the participants correct any mistakes. Articulation mistakes included starting to recite after the trial had begun, slowing the rate of recitation at any time, stopping recitation, or hesitations. Whenever the participant made a mistake the experimenter was to make sure the participants knew what they did incorrectly. After the participant completed four trials with no errors, the experimenter ended the practice task, began recording, and the critical trials were started. The critical trials were the same as the digit span task, with the addition of articulatory suppression. In order to ensure participants continued articulating throughout the task, the experimenter provided input through mouse clicks to indicate if an articulation error was made during each individual trial. If the experimenter indicated there was an articulation error, the trial would be counted as incorrect. Furthermore, the recordings from the task were later reviewed to ensure the participant was articulating at a sufficient frequency.

The final task of the session(s) was the ISE task. The experimenter entered the participant’s span from the silent digit span program to determine the list length of the critical ISE trials. In the ISE task, participants were instructed to remember the order of digits presented

one at a time on the screen. Once the list was completed the participant was instructed to enter the digits in order using the keyboard, and was again given one chance to start over if a mistake was made. The participant was told to ignore any sounds they heard over the headphones during the ISE task.

Scoring

The WMC measures were each scored in a similar fashion. The storage components of each task were scored using a strict serial order criterion, and individuals were awarded one point for each item correctly recalled, regardless of whether the overall list was correct or not. Then the scores for each individual task were converted into z-scores and added together to create an individual's overall WMC score. The anti-saccade task was scored as the mean number of trials each individual was able to correctly identify the target. For the verbal speeded articulation rate measure, the minimum time to recite one set of the numbers 1-10 was recorded. Silent digit span and articulatory suppression digit span were both scored as the highest list length at which the participant recalled two or more of the lists correctly, using a strict serial order criterion, and the difference in the two scores was recorded as rehearsal. Finally the size of the ISE was calculated using two separate scores, which were the percentage of digits correctly recalled in silence and the percentage of correctly recalled digits during simultaneous irrelevant sound. These two scores were used to create a difference score to indicate the size of the ISE, with a higher score meaning performance deteriorated more during irrelevant sound.

Results

Descriptives (see Table 2) and preliminary correlations (see Table 3) were analyzed for the three complex span measures of WMC, OSPAN, SSPAN, RSPAN. In addition, the antisaccade task, alphabet speeded sub-vocal articulation, digit speeded sub-vocal articulation,

speeded verbal articulation, silent digit span (see Figure 2 for silent digit span frequencies in adults), articulation span tasks, and the two measures from the ISE, serial position in silence, and serial position with irrelevant sound, were analyzed .

Table 2. Descriptive statistics for raw measures of WMC, rehearsal, and serial order recall in adults

Task	<i>N</i>	Mean score	Min	Max
Operation span	135	55.69 (13.01)	14	75
Symmetry span	135	27.84 (7.63)	9	42
Reading span	135	51.17 (14.20)	15	73
Antisaccade	135	.55 (.19)	0.17	1.00
Verbal speeded articulation	135	1.82 (0.34)	1.11	2.51
Alphabet sub-vocal articulation	90	12.70 (2.47)	7	19
Digit sub-vocal articulation	90	17.30 (3.45)	8	26
Silent digit span	135	6.75 (1.19)	5	9
Articulatory suppression digit span	135	4.27 (0.94)	2	7
Serial position score in silence	135	.87 (.10)	0.57	1.00
Serial position score in irrelevant sound	135	.76 (.15)	0.34	1.00

Note. Std. in parentheses.

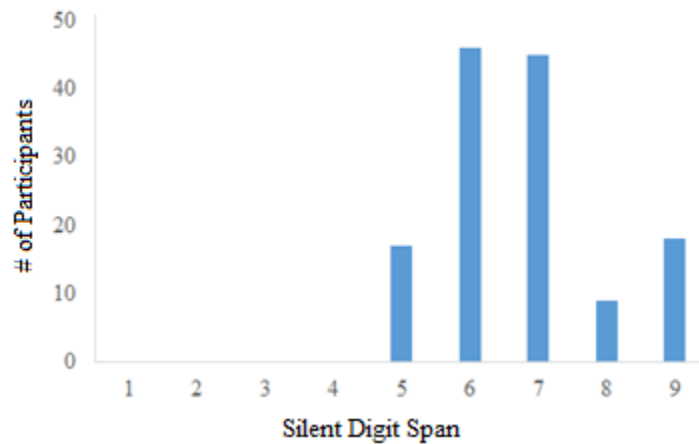


Figure 2. Frequency of silent digit span for adult participants.

With the exception of the speeded sub-vocal articulation tasks, the tasks were completed by 135 participants. A total of 90 participants completed all of the tasks. Significant, positive correlations between OSPAN, SSPAN, and RSPAN supported the creation of a working memory

composite score. This composite was created by converting raw scores to z -scores for all three measures, and adding the z -scores together. The same composite score procedure was used with the two sub-vocal speeded articulation tasks, and was also supported by their high correlations. The two digit span measures (digit and articulation) were examined for a significant effect of articulatory suppression using a within-subjects ANOVA for ease of reporting effect size measures and making comparisons across Experiments 1 and 2. The within-subjects ANOVA indicated a main effect of articulation, $F(1,134) = 514.34, p < 0.01, \eta_p^2 = .79, MSE = 0.81$, with performance without articulation significantly better than performance with articulatory suppression. The two digit span variables were then transformed into a rehearsal score by calculating the difference of silent digit span and articulatory suppression digit span. The proportion correct (using serial position scoring) on the ISE during irrelevant speech and silence was compared in a similar manner. A within-subjects ANOVA indicated a significant main effect of auditory condition, $F(1,134) = 151.55, p < 0.01, \eta_p^2 = .53, MSE = 0.01$, with performance in silence being significantly higher than performance in irrelevant speech. An ISE score was then calculated by subtracting proportion correct during irrelevant sound from proportion correct during silence ($M = .11, SD = .01$).

A second correlational analysis was done on the transformed and untransformed variables (see Table 4). These results indicated that the only significant correlate to the size of the ISE in adults was the rehearsal difference score, $r_{(133)} = .27, p < 0.01$. However neither the verbal ($r_{(133)} = -.06, ns$) nor the sub vocal ($r_{(88)} = .06, ns$), speeded articulation rate tasks significantly correlated to the rehearsal difference measure. Previous research has demonstrated the significant and positive relationship between memory span and speeded articulation tasks, attributing the relationship to a shared effect on rehearsal (Cowan et al., 1998). In the present study, digit span

Table 3. Raw correlations of measures of WMC, rehearsal, and serial order recall in adults (N = 135 unless stated otherwise)

Task	1	2	3	4	5	6	7	8	9	10	11
1 Operation span	-										
2 Symmetry span	.53**	-									
3 Reading span	.57**	.37**	-								
4 Antisaccade	.22*	.28**	.20*	-							
5 Verbal speeded articulation	.01	.03	.03	-.17*	-						
6 Alphabet sub-vocal articulation (N = 90)	.00	.13	.11	.33**	-.32**	-					
7 Digit sub-vocal articulation (N = 90)	.10	.13	.09	.18	-.32**	.66**	-				
8 Silent digit span	.34**	.29**	.48**	.15	-.08	.14	.11	-			
9 Articulatory Suppression Digit Span	.25**	.32**	.36**	.23**	-.03	.12	.04	.30**	-		
10 Serial position score in silence	.14	.00	.11	.19*	.02	.02	-.05	-.37**	.13	-	
11 Serial position score with irrelevant sound	.13	.05	.05	.112	.05	.08	.05	-.45**	.08	.77**	-

*. Correlation is significant at the 0.05 level.

** . Correlation is significant at the 0.01 level.

showed no relationship with any of the verbal speeded articulation ($r_{(133)} = -.08, ns$), alphabet sub-vocal speeded articulation ($r_{(88)} = .14, ns$), or digit sub-vocal speeded articulation ($r_{(88)} = .11, ns$). The present data show no relationship between the rate at which numbers can be recited either verbally or sub-vocally, and memory span. Antisaccade performance did, however, correlate to both the WMC composite ($r_{(133)} = .30, p < 0.01$) and the sub-vocal speeded articulation composite ($r_{(88)} = .28, p < 0.01$). The significant relationship between WMC and antisaccade performance indicated that both tasks measured attention control. The relationship between sub-vocal speeded articulation and antisaccade performance has not been demonstrated in previous literature.

Table 4. Transformed variable correlations in Experiment 1

Measure	1	2	3	4	5	6
1 Working memory composite	-					
2 Antisaccade	.30**	-				
3 Verbal Speeded Articulation	.03	-.17	-			
4 Sub-vocal articulation composite	.09	.28**	-.35**	-		
5 Rehearsal difference score	.14	-.03	-.05	.06	-	
6 Size of the ISE	-.02	.02	-.05	-.12	.27**	-

*. Correlation is significant at the 0.05 level.

** . Correlation is significant at the 0.01 level.

Further exploration was done to confirm that the lack of an expected relationship was not due to methodological problems. A third party listened to the audio recordings used in the verbal speeded articulation task. The third party subjectively determined whether participants were reciting the digits as fast as they could (i.e., following directions). The data were then split based on those who completed the task correctly ($N = 70$) and those who recited the numbers, but not as rapidly as they could ($N = 66$). Correlations were again run on the speeded articulation tasks

and their correlation to digit span (see Table 5). Individuals who were deemed to have followed directions showed a significant correlation to both the alphabet ($r_{(68)} = -.34, p < 0.01$) and digit ($r_{(68)} = -.37, p < 0.01$) sub-vocal articulation tasks. However, participants following directions still showed no significant correlation between verbal articulation rate and silent digit span, $r_{(68)} = .11, ns$.

Table 5. Articulation rate correlations in Experiment 1

Task	1	2	3	4	5
1 Alphabet sub-vocal articulation (N = 90)	-				
2 Digit sub-vocal articulation (N = 90)	.66**	-			
3 Followed directions verbal articulation (N = 70)	-.34**	-.37**	-		
4 Didn't follow directions verbal articulation (N = 65)	-.04	.00	-	-	
5 Digit span (N = 135)	.14	.11	.11	.12	-

*. Correlation is significant at the 0.05 level.

** . Correlation is significant at the 0.01 level.

Despite the current sample's close replication of the means and standard deviations of both sub-vocal articulation measures, digit span, and the correlation between alphabet and digit sub-vocal articulation from Cowan et al. (1998), no significant relationship with digit span was found for any articulation rate measure in the current study (see Table 6 for a comparison of the speeded articulation measures in Experiment 1 to Cowan et al., 1998). Furthermore, the individuals who were deemed to have followed instructions showed the expected significant relationships across all three articulation rate measures. The evidence leads to the conclusion that despite having accurately measured articulation rate, the current sample does not show the relationship between articulation rate and memory span that has been demonstrated previously. This lack of a relationship between memory span and articulation rates led to all measures of articulation rate being removed from further analysis.

Table 6. Comparison of the results of speeded overt articulation from present study to Experiment 2 of Cowan et al. (1998)

Comparison	Present Study	Cowan et al. (1998)
Mean sub-vocal alphabet speeded articulation	12.7	13.73
Standard deviation sub-vocal alphabet speeded articulation	2.47	3
Mean sub-vocal digit speeded articulation	17.3	18.18
Standard deviation sub-vocal digit speeded articulation	3.45	3.67
Mean digit span	6.75	7.1
Standard deviation digit span	1.19	0.87
Correlation between sub-vocal speeded articulation tasks	.68**	.67**
Correlation between alphabet speeded sub-vocal articulation and span	.11	.25**
Correlation between digit speeded sub-vocal articulation and span	.12	.23**

** . Correlation is significant at the .01 level

Hierarchical regression analysis was used to determine if the rehearsal difference score predicted the size of the ISE, as well as to determine if the other variables added significant variance in predicting the size of the ISE. The results of the regression indicated that the rehearsal difference score was a significant predictor of the size of the ISE, $R^2 = .06, p < 0.01$. However, the addition of the antisaccade measure and the working memory composite did not significantly improve the predictability, $\Delta R^2 = .01, p = 0.56$. This finding indicated that while the rehearsal difference score does not predict a large amount of the variance in the size of the ISE, it was significant. In order to further evaluate the role of rehearsal in the ISE, a second simultaneous regression was performed for the two components of the rehearsal difference score (digit span and articulation span) on predicting the size of the ISE. Digit span contributed a significant amount of variance to the size of the ISE ($\beta = .33, t = 3.76, p < 0.01$) while articulation span did not ($\beta = -.01, t = -1.02, p = 0.31$).

Discussion

Prior literature on auditory distraction in the ISE in general has asserted that the cause of the effect can be attributed to an interference with rehearsal (Hughes, 2014; Hughes et al., 2007; Jones & Macken, 1993). Klapp, Marshburn, and Lester (1983) demonstrated that by removing the requirement to remember the order of a list of serially presented digits, the effect of irrelevant sound would be eliminated. If participants are presented a list of 8 digits containing the numbers 1-9 and asked to identify the digit that was not presented (e.g., a missing-item task) participants demonstrated no detrimental effect of irrelevant sound. If removing the importance of order can eliminate the ISE, then it stands to reason that order effects are the main cause. As rehearsal is the most overt and familiar order processing individuals utilize during a task, the ISE is generally attributed to rehearsal.

However, the present study calls into question just how much of a role rehearsal plays in causing the ISE. Our hypothesis asserted a strong relationship between the rehearsal difference score and the size of the ISE. While individuals with a higher reliance on rehearsal did show a significantly larger ISE and the amount they relied on rehearsal could significantly predict the size of the ISE, both effects were relatively small. Thus, it is important to investigate whether these results are due to inexact measurements of rehearsal or if some other form of order processing is implicated.

One indication that the present results might not accurately reflect the ability to rehearse is the lack of a correlation between the rehearsal difference score and the speeded articulation tasks. Our hypothesis predicted a relationship between the speeded articulation tasks and both the rehearsal difference score and the size of the ISE. However, neither relationship was shown to be significant. The results replicated those from Cowan et al. (1998) in means and standard deviations as well as correlations between speeded articulation tasks, but did not replicate the critical correlation to memory span that is used to explain the relationship between articulation rate and rehearsal. Despite the long established and well documented relationship between speeded articulation and memory span (Baddeley et al., 1975; Cowan et al., 1998; Kail & Park, 1994; Smyth & Scholey, 1996), the present studies' inability to demonstrate the same relationship with the rehearsal difference score or the ISE led to the conclusion that, in the current sample, speeded articulation tasks were not related to rehearsal. Thus, the lack of a correlation between the speeded articulation tasks and the ISE or rehearsal difference score does not indicate that the difference score fails to measure rehearsal.

Further support for the accuracy of a rehearsal difference score in measuring rehearsal is the persistent use of articulatory suppression to examine the role of, or prevent the effects of

rehearsal experimentally (Bhatarah et al., 2009; Camos et al., 2009; Grenfell-Essam et al., 2013; Larsen & Baddeley, 2003). However, the present study was designed to be a more direct test of rehearsal than articulation rate, to determine just how much of an effect rehearsal had on the size of the ISE by measuring individual differences in the reliance on rehearsal for serial order processing. It stands to reason that a putative measure of serial order processing with and without concurrent articulation provides a reasonable estimation of the amount a person relies on rehearsal to complete serial order processing. Thus, it can be concluded that interference with rehearsal does play a smaller than hypothesized but significant role in predicting the size of the ISE. However, this raises the question of if interference with rehearsal is not the sole cause of the ISE, then what else could be contributing to the effect?

The role of attention capture has been demonstrated *not* to have an effect on the size of the ISE during a traditional paradigm. For example, the size of the ISE is not in any way mitigated by forewarning or increased encoding difficulty, both of which are known to influence attention capture (Hughes et al., 2013). Furthermore, the ISE demonstrates no relationship with WMC nor does it demonstrate habituation (Beaman, 2004; Elliott & Briganti, 2012; Sörqvist et al., 2013). Both a relationship with WMC and habituation are hallmark indicators of some form of attentional processing, either capture or attentional control over disengagement (Hughes, 2014). The present study demonstrated no relationships between the size of the ISE and either WMC or antisaccade performance, both considered to be attention control measures. While neither WMC nor antisaccade performance are auditory attention control measures, the use of non-auditory measures assured that any correlations would be due to attention capture effects and not due to methodological similarities. These findings supported the hypothesis that attention capture was not playing a significant role in the size of the ISE.

According to the duplex mechanism account, if the effect is not driven by attention capture, it might be caused by interference-by-process. Normally the “process” in interference-by-process regarding the ISE is hypothesized to be rehearsal, but if another process is being interfered with it stands to reason that it is similar to rehearsal. While it cannot be said definitively that order processing is the process being interfered with, since the removal of order information from an ISE paradigm, such as in the missing-item task, eliminates the detrimental effect of irrelevant sounds on performance, the ISE is likely caused by interference with order processing. This additional order processing may be entirely separate from rehearsal since rehearsal accounts for so little of the ISE. As one example of this type of order processing, Smyth and Scholey (1996) found evidence for a role of order processing in spatial span tasks that was independent from rehearsal. The findings demonstrated that order played an important role in a spatial span task despite the non-verbal nature of the stimuli and the use of concurrent articulation to block rehearsal. Both the use of non-verbal stimuli and concurrent articulation are used as a means to block rehearsal, so the persistence of order effects indicates the persistence of obligatory order processing independent from the controlled sub-vocal rehearsal typically associated with order processes.

Furthermore, the present study supports the notion of order processing independent of rehearsal because the current findings, as well as many others in the literature, indicate that digit span under concurrent articulation was not zero or one. As articulatory suppression has been known to block rehearsal (Bhatarah et al., 2009; Camos et al., 2009; Grenfell-Essam et al., 2013; Larsen and Baddeley, 2003), the fact that individuals had a mean digit span with concurrent articulation of 4.27 indicates that there is an ability to maintain order information which seems relatively independent from the ability to rehearse. Prior studies using non-verbal stimuli that the

participant had no prior exposure to found that memory span was still high and that even under articulatory suppression order effects were maintained (Smyth, Hay, Hitch, & Horton, 2005). This was taken to indicate a domain general order processing mechanism, but also that this process was independent of long-term memory processes. Without any prior exposure to the stimuli, participants had no long-term memory representations to utilize to facilitate the order processing that was demonstrated.

Finally, as mentioned above, young children have demonstrated an ability to perform serial order recall despite not being able to efficiently rehearse the order of items at the age of 8 years old (Flavell et al., 1966). More interesting though, is the fact that despite not being able to rehearse item order efficiently, children still demonstrate an ISE (Elliott, 2002; Klatte et al., 2010). The pattern of results demonstrating a persistent ISE in children who cannot rehearse order information as efficiently as adults indicates that the ISE in children is caused by something different than in adults, or that the ISE is mainly caused by order information separate from rehearsal. If the ISE in children is fundamentally different than the ISE in adults, then the pattern of results from Experiment 1 should not be replicated in Experiment 2 with child participants. If instead of, or in addition to, rehearsal, WMC correlates to the size of the ISE in children, then it could be concluded that serial order recall is impacted differentially in children compared to adults. This could then explain the persistent ISE despite inconsistent rehearsal.

On the other hand, the non-rehearsal order explanation of the ISE might also help explain why children typically show a larger ISE than adults. During normal serial order processing adults can rely on a combination of automatic order processing and rehearsal to complete the task. If the ISE is caused by an interference with non-rehearsal order processing, then adults might be using the controlled order process of rehearsal to minimize the effects of irrelevant

sound on their automatic order processing. However, children do not have as developed rehearsal skills, so they would be less able to rely on the controlled process of rehearsal to minimize the effects of irrelevant sound during serial order recall. Thus, children may show a larger ISE despite not being able to rehearse efficiently because the ISE is not caused by rehearsal, but instead minimized by rehearsal.

CHAPTER 3 – EXPERIMENT 2

Young children have been shown to be at the very beginning of their development of rehearsal strategies, but they are not yet fully capable of rehearsing in the way that adults rehearse (Ornstein, Naus, & Liberty, 1975). Up through the third grade, children tend to rehearse the word being shown, or occasionally one or two other words in the list. This means that children at this age and younger are not rehearsing in a cumulative fashion; they are rehearsing the items themselves. Thus, it is unlikely an ISE would be due to an interference in their rehearsal processes. Drastic changes in the results of Experiment 2 from the results of Experiment 1 would indicate that the mechanisms causing the ISE are either different in children, or affect children differently than they affect adults.

Experiment 2 investigated the role of rehearsal in serial order recall in children, similar to the methods of Experiment 1 in adults. The results of Experiment 2 allowed for the evaluation of three separate hypotheses regarding the cause of the ISE in children. First, if the ISE in children is caused by a differential effect than that of adults it would show a relationship with attention control as measured by WMC or the steady-state effect, a stronger relationship with rehearsal, or no relationship with rehearsal at all.

Second, if the ISE in children is caused by blocking rehearsal in children then serial order processing in children should be impaired by articulatory suppression, and the difference in the two should predict the size of the ISE. As children are developing rehearsal, those more advanced in their rehearsal skills should demonstrate a larger ISE because they are more likely to be susceptible. Those who are not rehearsing cumulatively, or not rehearsing at all, would be rehearsing less efficiently and should therefore have a smaller ISE than their more advanced peers.

Third, if the ISE is caused by non-rehearsal order effects that are supplemented by rehearsal in adults but ineffective in children, then multiple relationships must be demonstrated. Children should first demonstrate no effect of articulatory suppression on digit span or a negative correlation between rehearsal and the size of the ISE. If children are not rehearsing effectively then the ability to perform serial order recall should not be impaired by the rehearsal blocking practice of articulatory suppression, and if children are able to effectively rehearse those who rehearse more effectively should demonstrate less of an effect of irrelevant sound. Additionally, the size of the ISE should be sizably larger in children than in adults, as they are unable to mitigate the effects of irrelevant sound with rehearsal. Lastly, the relationship with attention control as measured by WMC or the steady-state effect should be the same in adults and children.

Finally, there is support from Cowan et al. (2005), as well as in other developmental research, that children demonstrate greater variability in task performance than adults. In adults, performance may be restricted in range due to matured cognitive functions or ceiling effects within the adult population. The reduced variability can limit the ability to demonstrate relationships between different tasks in correlational research. However, children often demonstrate much wider variability due to their cognitive functions not being fully developed. This greater variability can allow for relationships between performance on different tasks to be stronger in child samples.

Participants

Thirty-five children ages 7 years and 2 months to 9 years and 4 months ($M_{age} = 7$ years and 11 months $SD_{age} = 5.73$ months), of which 18 were females and 17 were males, voluntarily participated in the experiment and received small rewards (toy cars, coloring books, etc.) for

participating. All children were told they could stop the experiment at any time for any reason and they would still receive a reward. All children were native English speakers, with the exception of one child who began learning English before age 4, had normal or corrected vision, and suffered no hearing loss.

Materials

Working Memory Measures

In order to assess working memory, a listening span task (LSPAN) and a counting span task (CSPAN) were used. Both tasks have processing and storage components similar to Experiment 1, but both components have been simplified for children. CSPAN was adapted from Cowan et al., (2003; this version was modeled on Case, Kurland & Goldberg, 1982). Children were presented with visual arrays with target shapes (blue squares) and distractors (red triangles). There were 2 to 9 targets and 2 to 9 distractors. Children counted the number of targets while ignoring the red distractors. Children then verbally reported the number of targets and the experimenter recorded the response. After two to five arrays, the child was asked to recall the responses they provided to the previous arrays in order.

LSPAN was adapted from Kail and Hall (1999) and Daneman and Carpenter (1980). Children heard 60 declarative sentences, half of which were clearly true (e.g. “Milk comes from cows.”), and half of which were clearly false (e.g. “Toads live in a couch.”). Each sentence was played over headphones at a subjectively comfortable volume. The child verbally indicated whether the sentence made sense or not, and then repeated the last word in the sentence. The experimenter immediately recorded the child’s answer and proceeded to the next sentence. After one to five sentences the child was asked to repeat the last words of each sentence in order.

Similarly to the WMC measures in Experiment 1, CSPAN and LSPAN were scored as the number of correctly recalled items from the storage component of each task. Then the two scores were converted into z-scores and added together to create an overall WMC score.

Speeded Articulation Tasks

The articulation rate tasks, both verbal and sub-vocal, were again used in Experiment 2. The only change from Experiment 2 is that during the sub-vocal speeded articulation tasks instead of writing tally marks themselves children tapped the table every time they completed a list (i.e. got to “Z” or “10”) and started over. The experimenter recorded the number of times the participant tapped the table themselves.

Silent Digit Span

Children completed the silent digit span task that adults completed in Experiment 1.

Articulatory Suppression Digit Span

Similar to Experiment 1, children completed a digit span task under articulatory suppression in order to have another measure of rehearsal. The articulatory suppression digit span task was slightly modified for children and adapted from the methodology used by Fatzer and Roebers (2012), in that children were asked to recite the non-sense word “da” instead of the word “the” that was used in Experiment 1. Furthermore, children verbally provided their answer to the experimenter instead of manually typing the response, so they stopped performing articulatory suppression when they were asked to recite the digit list instead of performing articulatory suppression through the recall phase like in Experiment 1. Once they were asked to recite the list of digits they could stop reciting “da” and recall the list verbally for the experimenter to type into the computer. Trials were not started until the child participant began

reciting “da” at a rate the experimenter deemed to be twice a second in order to ensure children were performing articulatory suppression.

ISE task

The ISE task for children was the same as the ISE task for adults except for the additional auditory distraction condition of steady-state sounds. In the steady state sound condition participants heard the same word (“red”) repeated at a rate of once a second, presented simultaneously with the presentation of each digit in the list. Furthermore, the same word was used for every steady-state sound condition. The inclusion of the steady-state condition allowed for an additional attention capture measure to replace the antisaccade task performed in adults. As order information is unimportant in the auditory environment during steady-state sounds, the steady-state effect is generally attributed to attention capture and not interference by process (Elliott, 2002). The duplex model of auditory distraction would propose that if there is no process to interfere with, then the effect of auditory stimuli is an effect of attention capture. Steady-state sounds by definition lack order information and would not interfere with obligatory order processing typically associated with the ISE. This additional comparison allowed for a more in-depth analysis of the role of attention capture in the ISE for child participants. While steady-state sounds have been shown to have no effect or a very weak in adults (Cowan, 1995; Elliott, 2002; Elliott & Briganti, 2012; Jones et al., 1993; Lange, 2005; Neath, 2000) it has been demonstrated in children (Elliott, 2002; Elliott et al. 2016). The task was run at each child’s individual span in order to ensure that no children were performing the task above their abilities.

Procedure

After receiving parental consent, the experimenter introduced themselves to the child and spend 2-5 min. talking with the child in order to build rapport. After initial introductions, the

experimenter explained to the child that they would complete some tasks on a computer with the help of the experimenter, and that they could stop at any time they wanted. If the child understood what they were told, they signed a child assent form to indicate such approval.

Once the child was ready the experimenter started the CSPAN task. The experimenter read all of the instructions to the child and answered any questions the child had about how to complete the task. The child was asked to view an array and count the number of squares in the array by pointing to each one individually and counting out loud. Once the child finished counting the squares they repeated the number of squares they counted, and the experimenter recorded the number using the number pad on the keyboard. After one to five arrays the child was asked to recall the number of squares from each array in order. The experimenter then recorded the numbers in the order the child recited them. There were five practice arrays and 60 experimental arrays.

After completion of the CSPAN task the experimenter engaged the child in small-talk for approximately a minute. Before beginning the LSPAN task, the child put the headphones on. Next, the experimenter started the LSPAN task. Again the experimenter read the instructions to the child and answered the child's questions. There were five practice sentences and 60 experimental sentences. The child heard the sentence over the headphones and verbally indicated whether the sentence made sense or not. The experimenter recorded the answer by pressing "T" if the child indicated the sentence made sense, and pressing "F" if the child indicated the sentence did not make sense. Then the child was asked to say the last word in the sentence out loud to facilitate later memory for the target word. After one to five sentences, children were asked to recite the last words of all of the sentences they heard since the last time they saw the prompt. The experimenter then typed the list of words as the child recited them in order.

After completion of LSPAN the experimenter again engaged the child in small-talk before starting the next task. Children were asked to recite the numbers “one” to “ten” as quickly as possible when the experimenter recorded their voice. Before beginning the experimenter provided an example of the task by reciting the numbers themselves three times. Afterwards children were instructed to “recite the alphabet from ‘A’ to ‘Z’ as many times as possible *in your* head in a single minute.” Children were asked to tap the table each time they reached the letter “Z” and begin again. The experimenter recorded the number of taps while timing the participant. After one minute the child was told to stop and no more taps were counted. Next, children were asked to repeat the procedure with the numbers “one” to “ten” instead of the letters “A” to “Z”, and for 30 seconds instead of a minute. The experimenter again counted the number of taps and timed the task. After 30 seconds the child was stopped and no more taps were recorded.

The final task was the ISE task. The experimenter entered the child’s silent digit span to determine the list length of the ISE task, and then read the child the instructions. Children completed the ISE task in the same manner as adults, except that the child would verbally indicate the order of the digits and the experimenter would type them for the child. The entire session took between 50 and 70 min.

Results

Descriptive statistics (see Table 7) were analyzed for CSPAN, LSPAN, verbal speeded articulation, alphabet and digit sub-vocal speeded articulation, silent digit span (see Figure 3 for silent digit span frequencies in children), articulatory suppression digit span, and proportion correct serial position scores for silence, steady-state, and changing-state sounds.

An initial within-subjects ANOVA was performed on proportion correct for the ISE task for serial order recall under the three auditory conditions. A significant main effect was found,

$F(2,68) = 54.81, p < 0.01, \eta_p^2 = .62, MSE = 0.01$, indicating a significant effect of auditory conditions. A Bonferroni correction post-hoc analysis indicated that all three auditory conditions were significantly different. Performance during silence was greater than steady-state auditory stimuli which was greater than under changing-state auditory stimuli. Due to the results of the post-hoc analyses, differences scores for the ISE, changing-state effect (CSE), and steady-state effect (SSE) scores were calculated. The ISE score ($M = .26, SD = .16$) was calculated as the proportion in silence minus proportion correct during changing-state auditory stimuli. The CSE score ($M = .18, SD = .13$) was calculated as the proportion during steady-state auditory stimuli minus proportion correct during changing-state auditory stimuli. The SSE score ($M = .08, SD = .15$) was calculated as the proportion in silence minus proportion correct during steady-state auditory stimuli.

Table 7. Descriptive statistics for raw measures of WMC, rehearsal, and serial order recall in children

Task	<i>N</i>	Mean score	Min	Max
Counting span	34	32.79 (7.40)	19	49
Listening span	31	17.19 (7.50)	5	31
Verbal Speeded Articulation	35	1.77 (0.25)	1.28	2.22
Alphabet sub-vocal articulation	35	9.25 (2.25)	5	15
Digit sub-vocal articulation	35	13.20 (3.31)	5	22
Silent digit span	35	4.71 (1.02)	3	7
Articulatory Suppression Digit Span	35	3.14 (0.69)	2	5
Serial position score in silence	35	.72 (.17)	.38	1.00
Serial position score in steady-state sound	35	.64 (.22)	.20	1.00
Serial position score in changing-state sound	35	.46 (.23)	.06	.87

Note. Std. in parentheses.

A second within-subjects ANOVA was performed on silent digit span and articulatory suppression digit span, to parallel the analysis approach taken with the adults. Results indicated a significant effect of articulation on digit span, $F(1,34) = 85.00, p < 0.01, \eta_p^2 = .71, MSE = 0.51$,

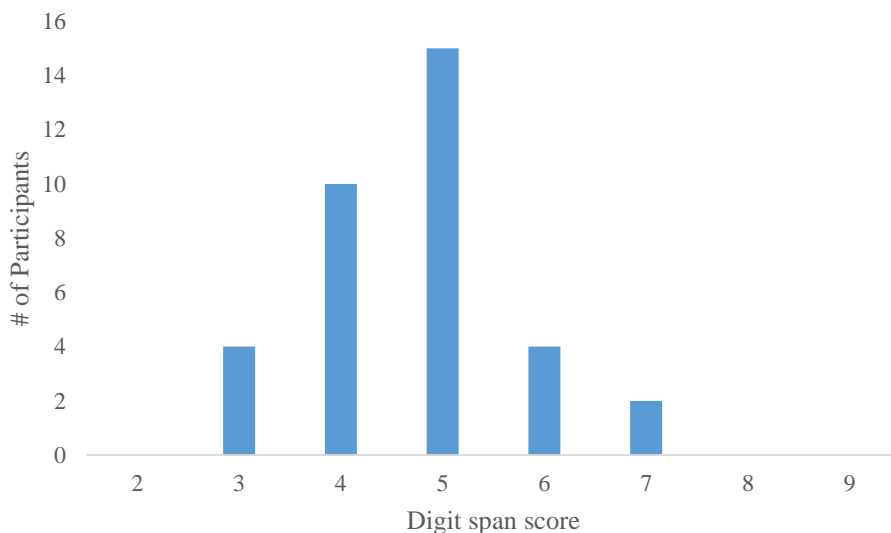


Figure 3. Frequency of silent digit span for child participants

with performance on digit span in silence ($M = 4.71$, $SD = 1.02$) being significantly better than digit span with articulatory suppression ($M = 3.14$, $SD = 0.69$). Participants' articulatory suppression digit span was subtracted from their silent digit span to create a rehearsal difference score.

Preliminary correlations (see Table 8) were run on the raw variables. With the exception of CSPAN ($N = 34$) and LSPAN ($N = 31$), all tasks were completed by 35 participants. A total of 30 participants completed all of the tasks. Due to significant positive correlations between CSPAN and LSPAN ($r_{(28)} = .60$, $p < 0.01$), a WMC score was created as the summed z -scores for 30 participants. Unlike in adults, the lack of significant correlations in any of the speeded articulation tasks does not support the creation of a composite score for articulation rate.

After analyzing the data for outliers, five participants rehearsal difference scores were removed, one participant had the largest silent digit span score of all the children (7) but also had the lowest articulatory suppression digit span score (2). This large discrepancy between the two scores lead to their removal from the rehearsal difference score measures. The other four were not scored for their rehearsal difference score because they had the minimum digit span of three,

Table 8. Raw correlations of measures of WMC, rehearsal, and serial order recall in children (N = 35 unless stated otherwise)

Task	1	2	3	4	5	6	7	8	9	10
1 Counting span (N = 34)	-									
2 Listening span (N = 31)	.48**	-								
3 Verbal Speeded Articulation	-.11	-.25	-							
4 Alphabet sub-vocal speeded articulation	.23	.28	-.16	-						
5 Digit sub-vocal speeded articulation	-.05	.03	-.37*	.33	-					
6 Silent digit span	.01	.23	-.13	.21	.33	-				
7 Articulatory suppression digit span	.26	.23	.04	-.21	.10	.35*	-			
8 Serial position score in silence	.06	-.22	-.37*	-.27	-.20	-.70**	-.19	-		
9 Serial position score with steady-state sound	-.02	-.08	-.01	-.30	-.46**	-.78**	-.10	.73**	-	
10 Serial position score with changing-state sound	.10	.06	-.11	-.25	-.15	-.66**	.12	.70**	.81**	-

*. Correlation is significant at the 0.05 level.

** . Correlation is significant at the 0.01 level.

which meant the rehearsal difference score could only be zero or one, limiting the variance and possibly influencing the correlations.

Another correlational analysis was performed on the transformed and untransformed variables (see Table 9, but see Appendix C for the same correlations with no outliers removed). Once again the only significant correlate to the size of the ISE other than its two components was the rehearsal difference score, $r_{(28)} = .44, p < 0.01$. Interestingly, despite the changing-state effect being attributed to rehearsal and the steady-state effect generally being attributed to attention capture, the correlation between the rehearsal difference score and the ISE seems to be driven by both the changing-state component and the steady-state component of the ISE. While neither the changing-state effect ($r_{(28)} = .28, ns.$) nor the steady-state effect ($r_{(28)} = .22, ns.$) significantly correlated to the size of the ISE, the two were similar in magnitude. If the rehearsal difference score is accurately measuring rehearsal, and the difference between the steady-state effect and the changing-state effect is that changing-state sounds can interfere with order/rehearsal, then there should be a much larger relationship between our rehearsal difference score and the changing-state effect than the steady-state effect.

The speeded articulation tasks again failed to significantly correlate to silent digit span in our initial correlations, and only alphabet sub-vocal speeded articulation significantly correlated to the rehearsal difference score, $r_{(28)} = .45, p < 0.05$. This pattern of findings appeared to indicate that again participants' articulation rate was not predictive of memory span or rehearsal.

WMC did not significantly correlate to the size of the ISE, $r_{(28)} = -.25, ns.$ However, the steady-state effect, generally attributed to an effect of attention, did not significantly correlate

Table 9. Raw correlations of measures of WMC, rehearsal, and serial order recall in children (N = 35 unless stated otherwise)

Measure	1	2	3	4	5	6	7	8
1 WMC (<i>N</i> = 30)	-							
2 Verbal Speeded Articulation	-.20	-						
3 Alphabet sub-vocal speeded articulation	.28	-.15	-					
4 Digit sub-vocal speeded articulation	-.04	-.37*	.33	-				
5 Rehearsal difference score (<i>N</i> = 30)	.10	-.04	.45*	.12	-			
6 Size of the ISE	-.25	-.24	.06	.00	.44**	-		
7 Size of the SSE	-.24	.16	-.07	-.49*	.28	.51**	-	
8 Size of the CSE	-.04	-.41*	.13	.44*	.22	.62**	-.36*	-

*. Correlation is significant at the 0.05 level.

** . Correlation is significant at the 0.01 level.

with WMC, $r_{(27)} = -.04$, *ns*. Despite WMC being a measure of executive control of attention the lack of a correlation may indicate a need for further investigation into the steady-state effect.

To investigate these findings, a hierarchical regression was performed to determine if the rehearsal difference score significantly predicted the size of the ISE, and to determine if WMC significantly added variance in that prediction. The rehearsal difference score was again a significant predictor of the size of the ISE, $R^2 = .25$, $p < 0.05$. However, WMC again did not add significant variance to the size of the ISE, $\Delta R^2 = .078$, *ns*.

Finally, as in adults, a simultaneous regression with silent digit span and articulatory suppression digit span predicting the size of the ISE was performed. Differently than the adult participants, results indicated that only articulatory suppression digit span ($\beta = -.65$, $t = -3.79$, $p < 0.01$) contributed significant unique variance in predicting the size of the ISE. Silent digit span was not contributing significant variance to the model ($\beta = .27$, $t = 1.57$, *ns*). This finding indicates that while the unique rehearsal component in the adults was accounting for the rehearsal and ISE relationship, in children the rehearsal ISE relationship is caused mostly by variance unique to the articulatory suppression digit span task.

Discussion

The results of Experiment 2 indicated that while children showed a similar pattern as adults, there were important differences between the two. The first difference was the larger ISE in children compared to adults, and the second was the large steady state effect found in children that is found to be either non-existent or weak in adults (Cowan, 1995; Elliott, 2002; Elliott & Briganti, 2012; Elliott et al., 2016; Hughes, 2014; Jones et al., 1993; Lange, 2005; Neath, 2000). These two differences indicated that while children may be affected by auditory distractors similarly to adults, the effects were differential in magnitude. Initially the correlation and

regression analyses between the size of the ISE and the rehearsal difference score seemed to replicate what is demonstrated in adults. However, further investigation tempered those comparisons. First, the lack of a significant correlation between the size of changing-state effect and rehearsal indicated that the distinction between the steady-state and changing-state effects may be less clear in children than previously thought. As changing-state sounds change from item to item, the importance of order information in the auditory environment is magnified and the ability to rehearse the order of the TBR items may be affected (Cowan, 1995; Elliott, 2002; Elliott & Briganti, 2012; Hughes, 2014; Jones et al., 1993; Neath, 2000). Thus, the relationship between rehearsal and the changing-state effect would be expected to be significant (Hughes, 2014; Jones et al., 1993). This logic is problematic for the a priori assumption that the rehearsal score in the present study accurately measured rehearsal. Further investigation into the relationship between the rehearsal difference score and the size of the ISE led to a simultaneous regression of the two components of the difference score (silent digit span and articulatory suppression digit span) on predicting the size of the ISE. Again different from adults, it is clear that not only did the articulatory suppression task contribute significant variance into the model, the silent digit span task contributed no significant unique variance. As both the silent digit span task and the articulation digit span task shared a similar methodology with the ISE task, and with each other, it is unlikely that the regression was being driven by methodological similarities. The most satisfactory explanation for these results is that in children performing articulatory suppression, attention capture is playing a significant role that has been shown not to persist in adults. Despite prior evidence that children can complete articulatory suppression (Fatzer & Roebbers, 2012), it is possible that children found it more demanding to perform the dual task of completing the digit span task and performing articulation. This task demand is causing a split in

attention from the focal task toward the suppression task. It may be because the articulatory suppression task acts as a more demanding dual task in children but not in adults. This explanation provides a justification for why the steady-state effect seems to be driving the relationship. The attention capture component of irrelevant sound, normally considered to be the steady-state effect, is correlating to the attention control component of the articulatory suppression digit span task.

However, even that explanation has its limitations. The relationship between WMC and the ISE was shown to be non-significant, and even more damaging is that the relationship between the steady-state effect and WMC was almost null. WMC, having been demonstrated to measure executive control of attention in adults (Shipstead, Redick, Hicks, & Engle, 2012), has been shown to demonstrate similar relationships to attention in children (Conlin, Gathercole, & Adams, 2005). The fact that the present study showed no relationship between working memory capacity and either the ISE overall, or the steady-state effect indicates that the developmental differences in the ISE may not be caused by attention capture either.

Overall, the results found mixed support for the hypotheses of rehearsal interference and attention capture playing a role in the ISE in children. However, recent research has yielded support for both accounts of the effect occurring simultaneously in children. Elliott et al. (2016) proposed that children suffer from attentional deficits during serial order recall differently from adults because their under-developed order processing heightens attentional effects caused by their underdeveloped attentional control. One goal of the present study was to determine if these order effects could be attributed to rehearsal or other order processing. However, due to the inaccuracy of the rehearsal difference score in children, the ability to investigate the source of the order processing interference cannot currently be examined. The significant effect of articulatory

suppression on digit span performance indicated that if children were rehearsing in order the ISE would be negatively correlated to the rehearsal difference score. However, since the rehearsal difference score demonstrated a significant positive correlation with the size of the ISE the non-rehearsal order process explanation of the ISE would seem to be void. However, due to the inability to say that the difference in digit span was entirely attributable to rehearsal, it was impossible to evaluate the non-rehearsal explanation of the ISE in the present study.

CHAPTER 4 – GENERAL DISCUSSION

The present study found only a small relationship between rehearsal and the size of the ISE in adults despite prior research hypothesizing rehearsal as the cause of order interference in auditory distraction during serial order recall (Hughes, 2014; Jones et al., 1993). However, there is no support for an attention capture account of the effect in the adult sample. If neither rehearsal nor the attention capture can account for the size of the ISE, it is possible there may be another cause. As the importance of order has been demonstrated in the effect of irrelevant sound on serial order recall (Klapp et al., 1983), it stands to reason that the cause of the effect is due to an interference with order processing. Thus, if the effect is not wholly caused by rehearsal in adults it is likely caused by an interference with non-rehearsal automatic order processing. In fact, an automatic order process would more closely match the automatic order processing of auditory environment that is believed to be causing the interference (Hughes, 2014; Sörqvist, 2010).

Support for an automatic order process comes from prior literature finding non-rehearsal order effects (Smyth & Scholey, 1996) as well as the ability for both children and adults to perform serial order recall above a span of 1 under articulatory suppression. Smyth and Scholey (1996) found persistent order effects (e.g. serial position curves) despite multiple methodological manipulations to eliminate rehearsal. Unnamable TBR stimuli and simultaneous articulatory suppression were simultaneously used, both of which can be used to prevent rehearsal. By using unnamable TBR stimuli the participants could not sub-vocally recite the items because there were no verbal labels to assign to the stimuli. Simultaneous articulatory suppression prevents the use of sub-vocal speech because participants cannot simultaneously produce two different speech streams. The fact that Smyth and Scholey (1996) found evidence for maintained order

information suggests that there might be additional order processing independent of rehearsal. Furthermore, the present study supports the findings of Smyth and Scholey (1996). Both children and adults produced articulatory suppression digit spans above 1, which without additional order processing independent of rehearsal, would be impossible. If articulatory suppression is preventing the sub-vocal speech needed for rehearsal, and rehearsal is the only order process, then participants should be unable to remember the order of lists longer than a single item in length above chance. The fact that adults remembered an average of 4.27 items, and that children remembered an average of 3.19 items indicated that order processing was persistent, despite the attempts to block or minimize rehearsal processes. Thus it remains possible that while the current explanation for the interference in serial order recall is valid, the mechanism being interfered with needs to be further examined. Future research into measuring and eliminating rehearsal and the effects it has on serial order recall need to be further examined.

Current investigations into the ability for rehearsal to explain experimental findings have been less fruitful than imagined. Lewandowsky and Oberauer (2015) demonstrated that the current model of rehearsal preventing decay within the working memory system cannot account for the experimental findings. The authors attempted to computationally model how decay of TBR items is combated by rehearsal. They found that none of the proposed models of decay and rehearsal computationally produce results similar to the experimental findings. The authors conclude that decay and rehearsal do not occur as the present literature assumes. Instead, it is hypothesized that while sub-vocal rehearsal happens, it does not affect experimental results. These conclusions support the notion that order processing separate from rehearsal might be the true cause of the ISE.

The child results also support the need to rethink the current literature on auditory distraction in serial order recall. Despite similarities in the results of Experiments 1 and 2 across the two samples, there are major differences that cannot be explained by the prior literature on the ISE. The findings of the large and statistically significant steady-state effect and the larger magnitude of the ISE both indicate a differential effect of irrelevant sound on children. However, very little has been done to actually investigate these effects in children. The present study is one of the few to investigate auditory distraction in children, and other recent investigations into auditory distraction in children and adults have found similarly distinct results (Elliott et al., 2016). The effect of steady-state sounds and the role of a “dual task” articulatory suppression digit span both point to a role of attention capture within the ISE that has been shown not to exist in adults.

The mere possibility that attention capture may occur in children during an ISE task indicates that there are unidentified developmental differences in auditory distraction. In adults, irrelevant auditory information does not capture attention unless there is a drastic change in the auditory environment (Hughes, 2014; Sörqvist, 2010), but the results of Experiment 2 indicated that in children, auditory attention capture might happen even when the irrelevant sound does not change from item to item. This steady-state effect in children could have broad implications. The current hypotheses of articulatory distraction imply that listening to changing-state sounds (e.g. music) will not negatively impact performance on tasks that do not require order. However, if the effect in children is not limited to order effects, as the presence of a significant steady-state effect suggests, then such things as playing classical music in a class room or while doing homework may be detrimental to the child’s ability to pay attention to the focal task. This is further supported by the results of Elliott et al. (2016), which found that eliminating both the need to

recall the order of TBR items to accurately complete the task, and the automatic order processing of irrelevant sound did not completely eliminate the ISE in children.

Taken together, the results of Experiments 1 and 2 demonstrate a need to rethink the framework of auditory distraction. While the present explanations for interference-by-process and attention capture are well founded within the duplex-model account, the mechanisms of interference need to be more clearly understood. The ISE has been hypothesized to be caused by rehearsal interference for a long time, however a direct test of the size of the relationship of the ISE and rehearsal abilities had not been performed. The present study attempted to confirm the prior literature on the process of rehearsal interference, but the results in Experiment 1 indicate that while the explanations for the interference are likely correct, the mechanism being interfered with may be different from rehearsal. Experiment 2 found further evidence for a need to reexamine current hypotheses of auditory distraction. The differential effects cannot be explained by the prior literature on the ISE, despite being applied within the duplex model differently for children and adults. Understanding the developmental changes in auditory distraction will allow for a better understanding of how the auditory environment affects us. By understanding the changes as we age we can not only better understand auditory distraction, but we can better tailor findings to be applied in a setting appropriate for children.

Future research should include a thorough investigation into the role of rehearsal in auditory distraction, as well as investigations into the existence of automatic order processes that persist independent of rehearsal. In the auditory distraction literature on children, future research is needed to investigate the role of attention capture in the ISE as well as to further investigate other paradigms in which differential results might be identified. Furthermore, the possibility that articulatory suppression in children is not only a rehearsal blocking mechanism but also a much

more demanding dual task in children than in adults needs to be further investigated. The possibility that articulatory suppression may be causing task performance decreases which are unrelated to rehearsal is vital to understanding the role of attention control in children.

In summary, the present study finds support both for and against the hypothesized mechanisms causing the ISE. While in adults, rehearsal did significantly predict the size of the ISE, the effect was small. This small effect size left open the possibility that while rehearsal is affected in the ISE and attention capture is not occurring to an extent that influences the size of the ISE, other mechanisms might be contributing to the cause of the ISE. In children the results were even less clear. Again the size of the ISE was shown to be predicted by rehearsal, however the purity of the rehearsal measure was called into question. The possibility that the ISE in children is fundamentally different than in adults remains a possibility, as the role for attention capture in children can be argued based on the present study. A thorough reexamination of the mechanisms behind the ISE and developmental changes have brought to light many more questions to be answered.

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APPENDIX A – IRB EXEMPTION APPROVAL (ADULTS)

Project Report and Continuation Application

(Complete and return to IRB, 130 David Boyd Hall, Direct questions go to IRB Chairman Robert Mathews 578-8692.)



Institutional Review Board
 Dr. Robert Mathews, Chair
 130 David Boyd Hall
 Baton Rouge, LA 70803
 P: 225.578.8692
 F: 225.578.5983
 irb@lsu.edu | lsu.edu/irb

IRB#: 2060 Current Approval Expires On: 2/21/2014
 Review Type: exempted Risk Factor: _____
 PI: Emily Elliott Dept: Psychology Phone: 578-7460
 Student/Co-Investigator: _____
 Project Title: An Investigation of Cognitive Processes
 Number of Subjects Authorized: 150

Please read the entire application. Missing information will delay approval!
 IRB Security of Data Agreement: <https://sites01.lsu.edu/wp/ored/files/2013/07/Security-of-Data-Agreement.pdf>

I. PROJECT FUNDED BY: _____ LSU Proposal #: _____

II. PROJECT STATUS: Check the appropriate blank(s) and complete the following:

- 1. Active, subject enrollment continuing; # subjects enrolled: 90
- 2. Active, subject enrollment complete; # subjects enrolled: _____
- 3. Active, subject enrollment complete; work with subjects continues.
- 4. Active, work with subjects complete; data analysis in progress.
- 5. Project start postponed
- 6. Project complete; end date: _____
- 7. Project cancelled: no human subjects used.

III. PROTOCOL: (Check one).

- Protocol continues as previously approved
- Changes are requested*
--List (on separate sheet) any changes to approved protocol.

IV. UNEXPECTED PROBLEMS: (did anything occur that increased risks to participants):

--State number of events since study inception: 0 since last report: 0
 --If such events occurred, describe them and how they affect risks in your study, in an attached report
 --Have there been any previously unreported events? Yes/No: no

V. CONSENT FORM AND RISK/BENEFIT RATIO:

Do new knowledge or adverse events change the risk/benefit ratio? Yes/No: no
 Is a corresponding change in the consent form needed? Yes/No: no

VI. ATTACH A BRIEF, FACTUAL SUMMARY of project progress/results to show continued participation of subjects is justified; or to provide a final report on project findings.

VII. ATTACH CURRENT CONSENT FORM (only if subject enrollment is continuing); and check the appropriate blank;

- 1. Form is unchanged since last approved
- 2. Approval of revision requested herewith: (identify changes)

Signature of Principle Investigator: Emily Elliott Date: 2/3/2014

IRB Action:	<input checked="" type="checkbox"/> Continuation approved;	Approval Expires: <u>2/14/17</u>
	<input type="checkbox"/> Disapproved	
	<input type="checkbox"/> File Closed	
Signed	<u>Robert C Mathews</u>	Date <u>2/19/14</u>

Print Form

APPENDIX B – IRB EXEMPTION APPROVAL (CHILDREN)

ACTION ON PROTOCOL CONTINUATION REQUEST



Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

TO: Emily Elliott
Psychology

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: August 20, 2015

RE: IRB# 2335

TITLE: The Development of the Ability to Ignore Distracting Sounds

New Protocol/Modification/Continuation: Continuation

Review type: Full Expedited Review date: 8/20/2015

Risk Factor: Minimal Uncertain Greater Than Minimal

Approved Disapproved

Approval Date: 8/20/2015 Approval Expiration Date: 8/19/2016

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 100

LSU Proposal Number (if applicable): 15912

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman 

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –

Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

*All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.lsu.edu/irb>

APPENDIX C – RAW CORRELATIONS IN EXPERIMENT 2 WITHOUT REMOVING OUTLIERS

	Measure	1	2	3	4	5	6	7	8
1	WMC ($N = 30$)	-							
2	Verbal Speeded Articulation	-.20	-						
3	Alphabet sub-vocal speeded articulation	.28	-.15	-					
4	Digit sub-vocal speeded articulation	-.04	-.37*	.33	-				
5	Rehearsal difference score ($N = 30$)	-.09	-.16	.36*	.26	-			
6	Size of the ISE	-.25	-.24	.06	.00	.46**	-		
7	Size of the SSE	-.24	.16	-.07	-.49*	.12	.51**	-	
8	Size of the CSE	-.04	-.41*	.13	.44*	.39*	.62**	-.36*	-

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

VITA

Corey Ian McGill, a native of Plano, Texas, is a third year student in the cognitive psychology program at Louisiana State University (LSU) under the mentorship of Dr. Emily Elliott. Mr. McGill received his Bachelor of Science degree from LSU in 2013. During his senior year at LSU he completed an honor thesis examining the role of stimulus presentation and recall method on auditory distraction. During his graduate career at LSU, Mr. McGill has further investigated the processes contributing to auditory distraction. He anticipates graduating with a Master of Arts in May 2016. He plans to continue his education at LSU in the coming years.