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Impact of Noise and Working Memory on Speech Processing in Adults With and Without ADHD

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IMPACT OF NOISE AND WORKING MEMORY ON SPEECH PROCESSING IN
ADULTS WITH AND WITHOUT ADHD

by

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ABSTRACT

IMPACT OF NOISE AND WORKING MEMORY ON SPEECH PROCESSING IN ADULTS WITH AND WITHOUT ADHD

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Old Dominion University, 2012
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Auditory processing of speech is influenced by internal (i.e., attention, working memory) and external factors (i.e., background noise, visual information). This study examined the interplay among these factors in individuals with and without ADHD. All participants completed a listening in noise task, two working memory capacity tasks, and two short-term memory tasks. The listening in noise task had both an auditory and an audiovisual condition. Participants included 38 young adults between the ages of 18-35 without ADHD and 25 young adults between the ages of 18-35 with ADHD. Results indicated that diagnosis, modality, and signal-to-noise ratio all have a main effect on a person's ability to process speech in noise. In addition, the interaction between the diagnosis of ADHD, the presence of visual cues, and the level of noise had an effect on a person's ability to process speech in noise. In fact, young adults with ADHD benefit less from visual information during noise than young adults without ADHD, an effect influenced by working memory abilities. These speech processing results are discussed in relation to theoretical models of stochastic resonance and working memory capacity. Implications for speech-language pathologists and educators are also discussed.

This dissertation is dedicated to my three wise, beautiful children Dionna Grace, Julia Marie, and Kayla Elizabeth whose inspiration provides me strength to persevere, whose laughter instills a peaceful joy, and whose tiny, unconditional hugs make life better.

“What we desire our children to become, we must endeavor before them.”

Andrew Combe

“Children are the bridge to heaven.”

Persian Proverb

“While we try to teach our children all about life, our children teach us what life is all about.”

Anonymous

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CHAPTER 1

Introduction

Central to human interaction is effective and consistent communication made possible by a rule-governed language system. Regardless of geographical region or societal dialect, language has many specific features. The English language is multi-modal and can be transmitted through auditory (i.e., speech), visual (i.e., written and sign), and tactile (i.e., braille) means. Although seemingly effortless and simple, the processing of spoken language is complex and influenced by specialized, hierarchical cognitive operations (i.e., internal listening conditions) (Larsby, Hullgren, Lyxell, & Arlinger, 2005; Wingfield & Tun, 2007) which are enhanced or degraded by external listening conditions.

During conversation, connected speech sounds are the sensory data which must be perceptually processed and interpreted through complex neural networks (Wingfield & Tun, 2007). Speech processing begins with an auditory speech signal. Initially, spoken language arrives through the auditory system at a rate of approximately 140 to 180 words per minute. The listener rapidly perceives auditory information which is then neurally encoded and transmitted to cortical areas for further processing. Phonological analysis and lexical identification are two linguistic operations required for the exact interpretation and use of the acoustic speech signal, resulting in accurate receptive language skills. These operations are dependent upon intact hearing acuity, the appropriate allocation of attentional resources, and the simultaneous manipulation and maintenance of the auditory information through working memory (Akeroyd, 2008; Pichora-Fuller, Schneider, & Daneman, 1995). It is through this combination of bottom-

up and top-down processing that an individual is able to understand spoken words, to comprehend syntactic markers, to recognize differences in sounds, and to converse orally with a communication partner.

An individual's cognitive-linguistic operations (i.e., internal listening conditions) used for speech processing are impacted by external listening conditions. The load and effort placed on the cognitive system is dependent upon the integrity and quality of the auditory signal (Arlinger, Lunner, Lyxell, & Pichora-Fuller, 2008). A degraded auditory signal or competing auditory signals increase the required listening effort (i.e., the attention needed to understand speech) (Fraser, Gagne, Alepins, & Dubois, 2010; Hicks & Tharpe, 2002; Lunner, Rudner, & Ronnberg, 2009; Stenfelt & Ronnberg, 2009; Wingfield & Tun, 2007). When listening in the presence of background noise, the allocation of attentional and working memory resources becomes challenged (Baldwin & Ash, 2011). As a result, more resources are needed for listening, thereby reducing the amount of working memory available for cognitive and linguistic processing (Pichora-Fuller et al., 1995). When an individual experiences difficulty interpreting the auditory signal through a single modality, he/she might seek out visual cues which will improve the recognition of speech in background noise (Schneider, Li, & Daneman, 2007).

Although the models outlining the relationship between listening in noise and cognition are based on empirical studies with typical adults or adult hearing aid users, it is reasonable to generalize those concepts to other populations. Schneider et al. (2007) explained that when listeners are required to process speech in complex listening conditions (i.e., background noise, multiple speakers, etc.), one of two things must occur: the listener must divide their attention and simultaneously process multiple pieces of

auditory information, or the listener must inhibit the irrelevant auditory information to focus on the target acoustic signal. This description is extremely relevant for adults with attention deficit/hyperactivity Disorder (ADHD). Researchers in cognitive psychology assert that inhibiting irrelevant acoustic information is facilitated by working memory. In an ADHD population whose core deficit is impaired inhibition (Barkley, 1997), listening in noise would not only increase the demands placed on working memory, but would also potentially require a higher signal-to-noise ratio (SNR) for effective processing of the signal (Schneider et al., 2007).

The interaction between auditory factors and cognitive factors is the focus of this research project. This study examined the effect of background speech noise on explicit cognitive operations, that is, speech processing, in adults with and without ADHD (Arlinger et al., 2008; Ronnberg, Rudner, Lunner, & Zekveld, 2010; Stennfelt & Ronnberg, 2009). In order to develop an appropriate rationale and make reasonable and logical theoretical predictions, the literature review provides a succinct explanation of complex cognitive constructs and their relationship to speech processing in noise for the target populations. The review is divided into the following broad sections: 1) internal listening conditions which include models of working memory and their relationship to attention and speech processing; 2) external listening conditions which include listening in noise and audiovisual cues; and 3) listening in noise for adults with ADHD.

CHAPTER 2

Literature Review

The ability to process speech accurately and efficiently in daily communication activities depends on a healthy language system as well as the integrity of several internal cognitive systems and acceptable external listening conditions. This review will introduce these internal and external listening conditions and discuss how they interact in the processing of a speech signal.

Internal Listening Conditions

Language: Central to human interaction is effective and consistent communication made possible by a rule-governed language system. Regardless of geographical region or societal dialect, language has many specific features. These features include a lexicon, semantics, syntax, morphology, phonology, and pragmatics. The first feature of the English language is that it has a lexicon or extensive list of words which represent specific concepts (e.g., objects, actions, adjectives, adverbs) (Wingfield & Tun, 2007). The second feature of the English language is that it is governed by a system of syntactic rules for combining those lexical elements (i.e., words) into sentences. Morphology refers to the composition of words, including inflection and the inclusion of suffixes and prefixes in rule-governed ways. Phonology is the sound system which provides the rules for combining speech sounds into meaningful and consistent units (i.e., words). Finally, pragmatics refers to the situational context and social standards understood and used by mutual communication partners. This language system is used to interpret speech signals around us and then to formulate responses to those

signals. In addition, accurate speech processing is dependent on the integrity of other cognitive operations such as attention and working memory.

Models of working memory. Working memory refers to a conceptual framework describing an individual's ability to store information temporarily for additional manipulation of that information; that is, a unique account of short-term memory (Baddeley, 2000; Gathercole, 1994). Originally, Baddeley and Hitch designed a three-component model of working memory, including: the central executive, the phonological loop, and the visuospatial sketchpad (Baddeley, 2000). The phonological loop and visuospatial sketchpad were described as subsidiary systems responsible for temporarily holding verbal and visual information. These subsidiary systems are active short-term stores which are aided and coordinated by the central executive (Baddeley, 1996a; Baddeley, 2000). In 2000, Baddeley added a fourth component, the episodic buffer, to the working memory model. The episodic buffer is described as a "temporary interface" (Baddeley, 2000, p. 421) between the phonological loop and visuospatial sketchpad responsible for the transfer of information between the two subsidiary systems and long-term memory. Like the phonological loop and the visuospatial sketchpad, the episodic buffer has limited-capacity and is controlled by the central executive (Baddeley, 2000). In general, Baddeley's working memory model represents the neurological system's ability to simultaneously store and manipulate information (Baddeley, 1992; Baddeley & Hitch, 1994; Baddeley, 1996b).

In 1988, Cowan proposed a similar information-processing system. Cowan (1988) suggested that a human processes information as a result of a small repertoire of coordinated mechanisms. These mechanisms include a very, very brief sensory store,

long-term memory, a short-term store, and a central executive. Within this system, the short-term store consists of activated long-term memories. That is, the short-term store is a subset of long-term memory. Once an individual's long-term memory has been activated by incoming stimuli, a temporary file becomes the focus of attention in the short-term store and can then be manipulated and controlled by the central executive. Cowan (1988) described this system as encompassing a combination of active and passive processes which occur in a "parallel" or "cascade" manner (p. 180).

Cowan (1988) argued that the Baddeley phonological loop and visuospatial sketchpad are simply unique instances of the short-term store. Essentially, Cowan (1988) proposed a more holistic and unified description of working memory. In this system, the distinction between processing and storage is made by separating the short-term store from the central executive; however, he made no further separations of specific processes or capabilities. Cowan's model appears to be more consistent with Oberauer, Heinz-Martin, Wilhelm, and Wittman (2003) who suggested that working memory can be fractionated along the functional dimension, that is, that the storage of information happens within the context of processing that information.

Like Baddeley (2000), and Cowan (1988), Engle, Tuholski, Laughlin, & Conway (1999) suggested that working memory results from a system of related processes which are dependent upon each other. Unlike Baddeley (1996b, 1998a), who suggested working memory is fractionated into distinct sub-processes, Engle et al. (1999) proposed that working memory is a global cognitive resource. Within this global cognitive resource are domain-specific storage and rehearsal processes (i.e., the short-term memory or store according to Cowan, 1998; the phonological loop and visuospatial sketchpad according to

Baddeley, 2000) and domain-general executive control processes (i.e., the central executive according to Cowan, 1988; the central executive according to Baddeley, 2000) (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004). Together the domain-specific and domain-general processes form the working memory system (Kane et al., 2004). Separately, the domain-specific processes reflect short-term memory and the domain-general processes reflect working memory capacity (Kane et al., 2004). Engle et al. (1999) argued that it is the engagement of the central executive, responsible for the maintenance of, the activation of, and the attention to information, which makes short-term memory and working memory different psychological constructs.

Research using individual differences supports the separation between the supervisory or control processes of the working memory system and the storage processes (Baddeley, 1996b; Buehner, Krumm, & Pick, 2005a; Cowan, 1988; Engle et al., 1999; Kane et al., 2004; Oberauer et al., 2003). In 2004, Kane et al. recruited 236 college students from several universities to complete a series of six short-term memory, six working memory, and thirteen reasoning tasks. Over the course of several weeks, participants were asked to recall verbal and visual information, to recall and process verbal and spatial information, and to complete standardized verbal-reasoning, spatial-visual reasoning, and inductive-reasoning tasks. Once collected, individual scores were analyzed using confirmatory factor analysis and structural equation modeling. In addition to supporting the division of the working memory system into short-term memory and working memory capacity, researchers identified a relationship between working memory capacity and general cognitive ability measures. Specifically, the data indicated that a moderate correlation exists between an individual's general fluid intelligence

(represented by the reasoning tasks) and working memory capacity (represented by the working memory tasks). This relationship between working memory and general fluid intelligence has been confirmed by several other researchers through experimental studies (Buehner et al., 2005a; Colom et al., 2008; Engle 2002; Matzel & Kolata, 2010; Mogle, Lovett, Stawski, & Sliwinski, al., 2008).

Kane et al. (2004) did not find a strong correlation between tasks representing short-term memory (i.e., recalling digits, letters, words) and reasoning tasks.

Remembering that working memory capacity reflects central executive responsibilities, it appears that higher level cognition is a reflection of an individual's ability to select information and maintain that information actively while ignoring distracting stimuli. It is through recognizing the difference between short-term memory and working memory capacity that it becomes necessary to discuss working memory capacity and its relationship with other cognitive processes, such as attention.

Working memory and attention. As stated previously, working memory capacity works in coordination with short-term memory as a component of the working memory system. In Cowan's (1988) model of information-processing, stimuli are activated from long-term memory and are attended to selectively. Selective attention is the cognitive process responsible for the allocation of attention to relevant and/or irrelevant stimuli (Baddeley, 1996a; Cowan, 1988; Lachter, Forster, & Ruthruff, 2004). Consistent with Broadbent's (1958) selective filter theory, a stimulus entering the nervous system is only identified and recognized when attention is directed to that stimulus. A slippage of attention from an important stimulus to an unimportant stimulus may occur intentionally or unintentionally (Lachter et al., 2004). This attentional control is a significant factor in

effective information-processing and is conceptualized differently per professional discipline. In the literature, neuropsychologists use the terms *executive functioning* while experimental psychologists use the terms *working memory capacity* synonymously with attentional control (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

Working memory capacity reflects the supervisory and control processes of the central executive. When explaining and specifying the central executive, Baddeley (1999) relied on the Supervisory Activating System (SAS) component of Norman and Shallice's model of attentional control (Baddeley, 1996a). As with his model of working memory, Baddeley (1996b, 1998b) described the central executive in terms of its fractionated functions. These functions included dual-task performance, random generation, *selective attention*, and activation of long-term memory. Through this account, the central executive may also be used interchangeably with attentional control, executive functioning, and working memory capacity.

Miyake, Friedman, Emerson, Witzki, and Howerter (2000) studied the relationship of three proposed executive functions (i.e., shifting, updating, inhibiting). Miyake et al.'s (2000) results are pertinent to this discussion because, consistent with what was previously explained, their structural equation models supported both the unity and diversity of executive functions. That is, although distinct executive functions contribute differentially to performance on discrete tasks, there is commonality between shifting, updating, and inhibiting which could be explained by controlled attention. These findings are consistent with Engle et al.'s (1999) position that working memory capacity is directly about the "reliance on controlled attention" (p. 326) and only indirectly about the storage of information (i.e., memory) (Engle, 2002).

Remembering that working memory capacity has been correlated with general fluid intelligence and higher level cognitive abilities (e.g., reading) (Colom et al., 2008; Engle et al., 1999; Engle, 2002; Kane et al., 2004; Matzel & Kolata, 2010), the question becomes: does working memory capacity empirically equal attentional control (i.e., selective attention or the central executive or executive functions) through statistical evidence or are they simply semantically similar constructs? According to Engle (2002), it is not that an individual with high working memory capacity can remember more items, but that the individual is better able to control and maintain attention, especially in the presence of distracting and interfering stimuli. In this description, attentional control is a component of the working memory system working synergistically with the other components to facilitate an individual's ability to inhibit responses and to self-regulate. Several researchers provide empirical evidence supporting Engle's (2002) position (Kane, Bleckley, Conway, & Engle, 2001; Matzel & Kolata, 2010; McCabe et al., 2010; Redic & Engle, 2010).

In addition to supporting Engle's (2002) position, two of these studies support Miyake et al.'s (2000) conjecture that controlled attention or attentional control may be the underlying resource for executive functions. Matzel and Kolata (2010) provided a review of the data from animal studies supporting the idea that selective attention or attentional control is the primary component of working memory capacity. Furthermore, Matzel and Kolata contended that the prefrontal cortex is the neurological region activated during attentional control tasks. The prefrontal cortex has also been identified through imaging studies as the neurological structure activated during executive function tasks (Aron, 2008; Collette & Van der Linden, 2002).

Similarly, McCabe et al. (2010) administered a variety of working memory capacity tasks and executive functioning tasks to 260 adults between the ages of 18 and 90. The authors identified a very strong correlation ($r = .97$) between tasks measuring working memory capacity and tasks measuring executive functioning, indicating that these two constructs are functionally very similar, and proposed that the nature of this similarity is attentional control. These studies support the notion that attentional control represents the same concept as working memory capacity used among experimental psychologists and executive functions used by neuropsychologists (McCabe et al., 2010).

Kane et al. (2001) provide compelling evidence regarding the “controlled-attention view of working memory capacity” (p. 169 abstract). During prosaccade and antisaccade tasks in two experiments, participants with either high or low working memory span capacity had to actively maintain attention and goal information while being distracted by irrelevant external stimuli. That is, participants either had to identify targets found in the same location as the visual cue or in the opposite location. Individuals with high working memory spans significantly outperformed individuals with low working memory spans in the saccade tasks which require significant attentional control. These results support the idea that working memory capacity reflects an ability to control attention.

If controlled attention, working memory capacity, the central executive, and selective attention are terms for equivalent processes, then attention is a process which is facilitated by the working memory system. Consistent with this idea, working memory capacity becomes a valid predictor of attentional control (Kane et al., 2001) and performance on higher-level cognitive tasks, including reading and language (Engle,

2002). Subsequently, the relationship between the working memory system and language comprehension, specifically speech processing, is discussed.

Working memory and speech processing. Both experimental and imaging studies indicate that there is a relationship between language comprehension and working memory (Baddeley, 2003; Baddeley, Lewis, & Vallar, 1984; Gathercole, 1994; Jacquemot & Scott, 2006; Muller & Knight, 2006; Radanovic, Azambuja, Mansur, Porto, & Scatt, 2003; Rudner & Ronnberg, 2008; Shah & Miyake, 1996; Was & Woltz, 2007). In order to process speech, the acoustic signal must be transmitted, encoded, and bound with phonological representations and lexical units. The conversion of sensory input received by the auditory system into meaningful sound segments and words is facilitated by components of the working memory system. The phonological loop and the episodic buffer work together to maintain, rehearse, and bind speech sounds so that spoken language can be processed and understood (Baddeley, et al., 1984; Baddeley, 2000; Gathercole, 1994; Muller & Knight, 2006; Rudner & Ronnberg, 2008; Was & Woltz, 2007).

Within the working memory system is a subsystem called the phonological loop (Baddeley et al., 1984) which codes verbal information. Studies later support the subdivision of the phonological loop into the phonological short-term store and the articulatory subvocal rehearsal process (Gathercole, 1994; Muller & Knight, 2006). As a unit, the phonological loop is able to hold verbal material between 1.5 and 2 seconds (Baddeley 2003; Gathercole, 1994). Essentially, the subvocal articulatory rehearsal process is the silent repetition of recently received verbal information (i.e., speech sounds) so that those speech sounds do not decay but are maintained in the phonological

short-term store for effective and appropriate use (Baddeley 2003; Gathercole, 1994). Wilding and Mohindra (1980) demonstrated the importance of the phonological loop, specifically subvocal rehearsal, for the retention of sound sequences. When these researchers made subvocal rehearsal impossible, the participants had an increased number of recall errors for strings of letters. In addition to preserving information, the phonological loop engages in buffering processes with the episodic buffer (Rudner & Ronnberg, 2008).

The episodic buffer serves as an interface between the components of working memory and long-term memory (Rudner & Ronnberg, 2008). Although the phonological loop may underpin phonological processing, Was and Woltz (2007) argued that it is actually available long-term memory that mediates the relationship between working memory and speech processing. If Cowan's (1988) model of information-processing is accepted, then both Rudner and Ronnberg (2008) and Was and Woltz (2007) are describing theoretically similar processes using different terminology. Speech processing is comprised of the accurate rehearsal and maintenance of phonological information, effective mapping of that information to representations in long-term memory, and then relating that information to prior knowledge for effective use (Baddeley, 2003; Cowan, 1988; Pichora-Fuller, 2008; Ronnberg, Rudner, Foo, & Lunner, 2008; Ronnberg et al., 2010; Rudner & Ronnberg, 2008; Stenfelt & Ronnberg, 2009). That is, speech processing engages language and working memory systems.

External Listening Conditions

Listening in the Presence of Background Noise. Speech processing requires both the detection of the acoustic signal and the integration of that signal with stored

information so that meaningful sounds, words, and sentences can be interpreted during discourse (Larsby, Hallgren, & Lyxell, 2008; Pichora-Fuller et al., 1995). Speech processing, however, often takes place in the context of competing acoustic signals. Background noises may interfere with this process by either masking the physical properties of the auditory signal or distracting the listener (Larsby et al., 2008). When an individual is not able to integrate the current acoustic signal with stored linguistic representations during discourse, he/she cannot make a coherent interpretation (Pichora-Fuller et al., 1995).

In studying the relationship between an acoustic speech signal and cognition, Stenfelt and Ronnberg (2009) (see Figure 1, adapted from Anderson, 2007 as cited in Stenfelt & Ronnberg, 2009) developed a visual diagram outlining the continuous interaction between bottom-up (i.e., implicit or automatic) and top-down (i.e., explicit or deliberate) processing of auditory input. When the speech signal is undistorted, the process of decoding phonetic input and accessing lexical information from long-term memory is smooth, fast, and mostly implicit. When the speech signal is distorted, the process of decoding phonetic input and accessing information from long-term memory is strained, effortful, and mostly explicit. Therefore, it is the quality of the acoustic signal which determines how implicit or automatic speech processing is (Ronnberg, 2003; Rudner & Ronnberg, 2008).

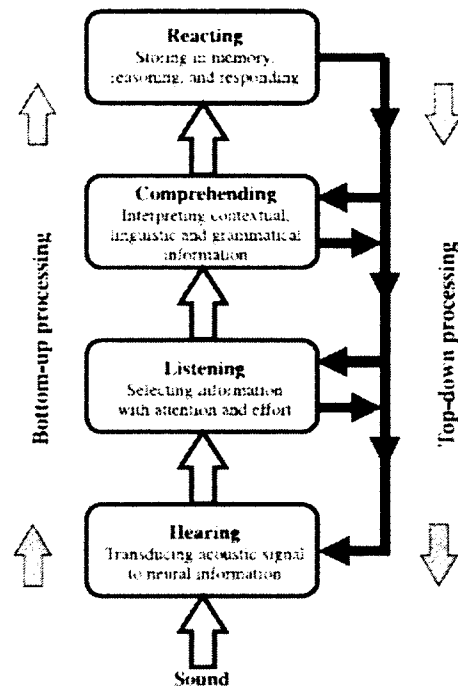


Figure 1. A model of bottom-up and top-down processing of an acoustic signal (adapted from Ewads, 2007, as cited in Stenfelt & Ronnberg, 2009)

The Ease of Language Understanding (ELU) model (see Figure 2) proposed by Ronnberg (2003, 2008) outlines a working memory system which considers both internal and external listening conditions. It outlines a model of working memory in which there is an interaction between the implicit capacity to recognize speech elements under adverse listening conditions and the explicit capacity to make sense of those elements for functional use (Ronnberg et al., 2010). In 2003, Ronnberg suggested a specific component of the ELU framework for the Rapid, Automatic, Multi-modality Binding of PHOnology (RAMBPHO) (Rudner & Ronnberg, 2008). The RAMBPHO is responsible for the rapid and automatic binding of the linguistic signal (i.e., multi-modal language) to the phonological and lexical information represented in long-term memory (Ronnberg et al., 2008). The function of the RAMBPHO is similar to that of the episodic buffer in that

it “mediates the rapid and implicit unlocking of the lexicon” (p.100). Essentially, the RAMBPHO matches the auditory input to appropriate linguistic representations in long-term memory.

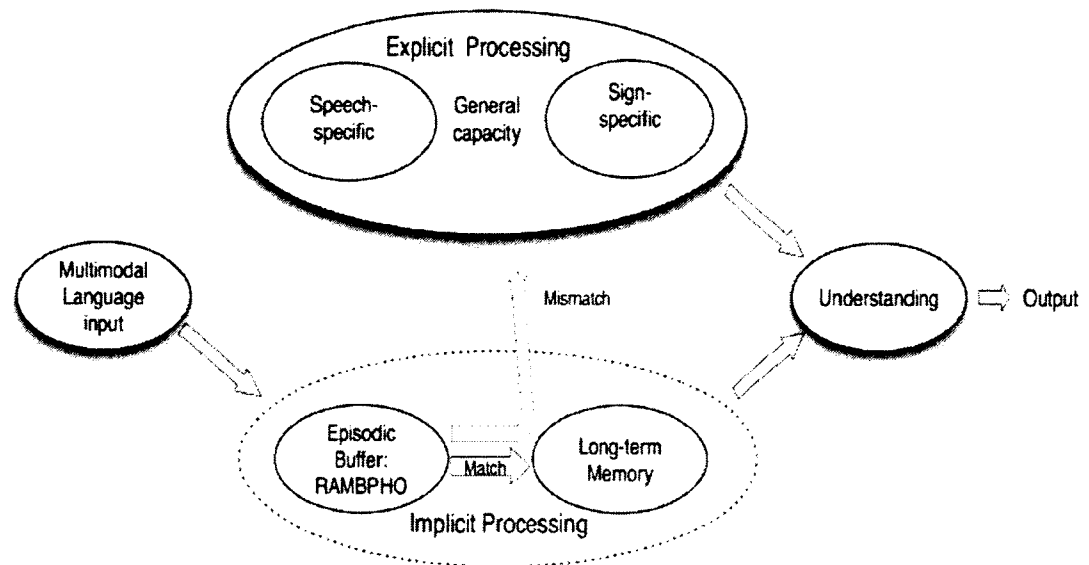


Figure 2. A working memory system for Ease of Language Understanding (ELU) (Ronnberg, 2003, 2010)

There are specific conditions which will determine if a match is made between the phonological representations of the RAMBPHO and the lexical representations held in long-term memory. For a match to occur, the acoustic signal must be clear and/or the individual must have adequate processing speed for lexical access and/or have precise phonological representations stored in long-term memory (Ronnberg, 2003; Ronnberg et al., 2008, Ronnberg et al., 2010; Rudner & Ronnberg, 2008). A mismatch occurs when the acoustic signal is degraded or distorted and/or when the individual has reduced processing speed and/or imprecise phonological representations stored in long-term memory. When a phonological mismatch occurs, explicit or deliberate processing and

storage is required to generate meaning based on previous knowledge (Ronnberg, et al., 2010; Rudner & Ronnberg, 2008). It is the deliberate component of the ELU model which seems similar to the notion of the supervisory attention system outlined by Norman and Shallice (as cited in Baddeley, 1996a) or the central executive outlined by Baddeley (2000) or working memory capacity/attentional control described by Engle (2002). That is, the harder it is to hear the acoustic signal the more working memory capacity is required to accurately extract meaning.

Researchers attempt to empirically demonstrate that ELU reflects the degree to which explicit, top-down processing functions are relied upon (Stenfelt & Ronnberg, 2009). When mismatch conditions exist, explicit, top-down processing functions will be repeatedly invoked to decode, interpret, and infer the contents of connected speech (Ronnberg et al., 2010). Therefore, individuals with a high working memory capacity will experience a more reduced cognitive load when listening in the presence of background noise than individuals with a low working memory capacity. This is empirically demonstrated through research designs which measure individual working memory capacity and speech processing under mismatch conditions (e.g., background noise), and that determine what kind of statistical relationship exists between these variables. Using this outline, several studies have demonstrated a strong correlation between measures of working memory capacity (e.g., reading span tasks, Visual Letter Monitoring Test) and speech recognition in noise (e.g., Hagerman sentences) (Foo, Rudner, Ronnberg, & Lunner, 2007; Lunner & Sundewall-Thoren, 2007; Runder, Foo, Sundewall-Thoren, Lunner, & Ronnberg, 2008; Rudner, Foo, Ronnberg, & Lunner, 2009). A high correlation between working memory capacity and the processing of speech in the

presence of background noise confirms the mismatch effect described by the ELU model. Therefore, robust internal listening conditions (e.g., working memory capacity) can mitigate the negative effects of poor external listening conditions (e.g. background noise).

Visual Speech Cues (Audiovisual speech perception). In addition to background noise, there are other external listening conditions which affect speech processing in adults. Accurate, functional, and timely comprehension of a spoken message is influenced by the location of the listener to the speaker (e.g., over the phone, face-to-face, from another room), by the background noise present, and by the presence of visual speech cues. These listening conditions can be isolated or can occur in combination, making the processing of speech for an adult either easy and accurate or difficult and inaccurate. In general, background noise weakens the auditory message while visual cues strengthen the auditory message.

The influence visual cues have on speech perception is evidenced in a variety of listening situations. Visual cues can be presented congruently with auditory speech cues, incongruently, and in combination with background noise. McGurk and MacDonald (1976) were the first to recognize and empirically demonstrate the influence visual input has on the perception of speech. In their classic study, participants watched a dubbed film in which a human face was seen to produce the syllable /ga/ while the voice said the syllable /ba/, leading participants to claim that the syllable heard was /da/. When participants watched the face say /ba/ but heard /ga/, they reported hearing /bagba/. In the trials in which the participants only listened to the human face without being given a visual cue or listened to the untreated film, they reported hearing the syllables accurately. The McGurk and MacDonald effect is a phenomenon which suggests that visual speech

cues can modulate the processing of auditory speech. When visual speech cues are presented incongruently with the auditory message, a distorted or inaccurate phoneme is perceived (Jasskelainen, 2010; McGurk and MacDonald, 1976).

During typical face-to-face conversation, individuals are congruently provided both auditory and visual input. In this way, human communication is basically audiovisual (Buchan, Pare, & Munhall, 2008; von Kriegstein, Dogan, Gruter, Giraud, Kell, Gruter, Keinschmidt, & Kiebel, 2008). Individuals are given an auditory stimulus consisting of specific phonemes and a visual stimulus consisting of dynamic facial movements. The facial movements have articulatory information which improves the individual's ability to detect (Grant & Seitz, 2000), interpret, and identify auditory input (Davis & Kim, 2004). The perception of the auditory stimulus is improved when simultaneously viewing the speaker because an appropriate phonetic representation (Bristow, Dehaene-Lambertz, Mattout, Soares, Gliga, Baillet, & Mangin, 2008) or speech motor schema is activated (Davis & Kim, 2004). The position of the lips, jaw, and tongue yield highly accurate visual speech cues creating visemes or basic visible speech units (Jaaskelainen, 2010). For example, when watching someone say /bed/, a listener not only identifies the initial phoneme, /b/, by its acoustic properties, but by seeing the speaker's lips compress and release to form the labial sound. Because visual speech cues provide constraints on the auditory stimulus the brain expects to receive, they have predictive power during the modulation of speech processing (Jasskelainen, 2010; van Wassenhove, Grant, & Poeppel, 2005; von Kriegstein et al., 2008) when combined with a congruent auditory message. Therefore, visual speech cues improve the rate of speech recognition (von Kriegstein et al., 2008; van Wassenhove et al., 2005), improve speech

perception (Jasskelainen, 2010), and improve performance on speech recognition tasks (Binnie, Montgomery, & Jackson, 1974; Erber, 1969, 1972; Grant, Walden, & Seitz, 1998; MacCleod & Summerfield, 1987, 1990; Sumbly & Pollack, 1954; Walden, Prosek, & Worthington, 1975) when simultaneously combined with auditory information.

It is the combination of visual and auditory speech cues which makes possible the perception and comprehension of spoken language (Szyzik, Tausche, & Munte, 2008). The adult's listening situation determines the extent to which this joint processing is required (Szyzik, et al., 2008). Because the brain has an "audiovisual integration mechanism" (Szyzik et al., 2008, abstract), adults might rely more heavily on visual speech cues when the auditory message is spoken in the presence of background noise. Buchan et al. (2008) demonstrated that when noise was present during face-to-face listening tasks, adults modified their fixation and location of eye gaze. Under noisy conditions, adults attended more frequently and longer to the nose and mouth of the speaker. These results suggest in part that when the intelligibility of the spoken message is reduced by background noise, adults seek and rely on the visual information provided by oral – motor movements.

Confirming this suggestion, adults with hearing loss who participate in lip reading courses report that it is easier to process and understand audiovisual speech than auditory speech alone in noisy situations (Fraser et al., 2010). In a noisy environment, listeners experience a reduction in listening effort and an increase in speech understanding when visual speech cues are provided (Bristow et al., 2008; Fraser et al., 2010; Larsby et al., 2005). In fact, speech recognition in the presence of background noise may be enhanced by more than 40% with the provision of visual speech cues (Fraser et al., 2010; Grant &

Braida, 1991; MacLeod & Summerfield, 1987, 1990; Sumbly & Pollack, 1954; Walden et al., 1975). According to MacLeod and Summerfield (1987, 1990), adding visual speech cues in the presence of background noise is like reducing that noise level by approximately 7-10dB.

Adults with ADHD

Attention deficit/hyperactivity disorder (ADHD) is a childhood psychiatric diagnosis which persists into adulthood. Like children, adults with ADHD may have difficulty concentrating, may be unorganized, may procrastinate, may be forgetful, and are impulsive (Adler, Spencer, Levine, Ramsey, Tamura, Kelsey, & Biederman, 2008; Searight, Burke, & Rottneck, 2000). Approximately 30% - 50% of children diagnosed with ADHD will grow into adults who continue to experience the unmitigated effects of the disorder (Barkley, 1997). The negative effects of ADHD span a lifetime and impact the individual's quality of life in that adults often experience lower academic achievement, difficulty with employment, poor driving behaviors, and difficulty with interpersonal relationships (Barkley, 2002). Because research has primarily focused on children with ADHD, there is limited empirical evidence for adults with ADHD regarding the cognitive processes which underlie this diagnosis and functional outcomes (Barkley, 2002; Miller, 2010).

Listening in Noise. The relationship between attention and audition has been acknowledged since early theories of cognitive processing (e.g., Broadbent, 1958). More recent studies have also supported the claim that an auditory distractor makes it difficult to focus sustained attention on the current task (Soderlund, Sikstrom, & Smart, 2007). From these results, it is logical to assume that adults with ADHD would be more

susceptible to auditory distracters than adults who do not have a diagnosis of ADHD. However, recent research investigating the phenomenon of stochastic resonance indicates that, in fact, noise may improve cognitive performance in some adults with ADHD (MacDonald, Li, & Backman, 2009; Sikstrom & Soderlund, 2007; Soderlund et al., 2007).

Stochastic resonance is described as a phenomenon that is essential to the performance of a variety of neurobiological systems (Li, Oertzen, & Lindenberger, 2006). Specifically, stochastic resonance refers to the positive response a nonlinear system has to an optimal level of external noise (Moss, Ward, & Sannita, 2004; Li et al., 2006; Soderlund et al., 2007; Usher & Feingold, 2000). That is, for the cognitive system, external noise enhances the system's ability to identify and respond to weak stimuli (Moss et al., 2004; Li et al., 2006; Usher & Feingold, 2000; Ward, Doesburg, Kitajo, MacLean, & Roggeven, 2006). From this phenomenon, the Moderate Brain Arousal Model of ADHD was developed (Soderlund et al., 2007). The Moderate Brain Arousal Model suggests that more noise is required by the neurological system of an adult with ADHD because of low levels of dopamine, the neurotransmitter responsible for regulating the signal-to-noise ratio (Li et al., 2006; Soderlund et al., 2007). Because individuals with ADHD have low levels of dopamine, they require more external noise to activate stochastic resonance thereby increasing the saliency of the signal perceived as weak by the neurological system (Soderlund et al., 2007; Ward et al., 2006). Ward et al. (2006) suggested that adding noise to the neural system actually allows that system to modulate neuronal activity more synchronously. When neurons fire simultaneously and

in order, then the processing of information for the decoding and encoding of information is successful, complete, and efficient (Ward et al., 2006).

Several studies have suggested that a positive relationship exists between noise and cognitive performance on a variety of tasks (Abikoff, Courtney, Szeibel, & Koplewicz, 1996; Aihara, Kitajo, Nozaki, & Yamamoto, 2008; Mayor & Gestner, 2005; Soderlund et al., 2007; Zeng, Fu, & Morse, 2000). Mayor and Gestner (2005) developed a computer generated neural network model which represented the same complex nonlinear functions of the human brain. During a variety of simulations, noise was introduced into this model and mathematical calculations of processing and communication between components were measured. Results indicated that the white noise introduced improved the speed of the signal, the amplitude of the signal, and the connectivity of the model, thereby confirming the theory of stochastic resonance. Furthermore, Mayor and Gestner (2005) suggested that these results would be comparable to the improvements experienced by the sensory and cognitive systems of humans. Consistent with Mayor and Gestner's assertions, Aihara et al. (2008) demonstrated that the addition of a visual distractor, described as visual noise, improves visual perception during a variety of visual detection tasks in adults. Although visual distractors do not equate with the white noise experienced by the auditory system, the influence of stochastic resonance is supported across a variety of tasks and sensory systems.

Zeng et al. (2000) reported that hearing thresholds were significantly improved with the introduction of white noise. A 2-6 decibel enhancement was observed across participants with cochlear implants and brainstem-implants. In this study, participants

were asked to push a button when they heard the acoustic signal presented electronically in a sound proof booth. All participants demonstrated a positive threshold shift when white noise was presented in conjunction with the acoustic signal.

Like adults with cochlear implants, children with ADHD can demonstrate improved cognitive performance when external noise is provided (Abikoff et al., 1996; Soderlund et al., 2007). Abikoff et al. (1996) facilitated improved mathematic performance by 33% for boys between the ages of seven and thirteen who had a diagnosis of ADHD when completing the tasks in noise compared to completing the same arithmetic tasks in silence. Consistent with these results, Soderlund et al. (2007) presented a variety of simple commands and recall tasks in the presence of white noise. All of the children diagnosed with ADHD demonstrated improved performance across tasks. There is a paucity of data on this topic in the extant literature. Both Abikoff et al. (1996) and Soderlund et al. (2007) were the only two studies found that examined the effect of noise in children with ADHD and no studies were found in the literature exploring the effects of noise on adults diagnosed with ADHD. Further, studies that examined the influence of background noise used white noise, not speech noise, which parallels typical listening conditions.

Purpose

The purpose of this study is to examine the impact of background speech noise on speech processing in young adults with ADHD as compared to healthy adults. Performance was compared in an auditory only versus auditory + visual processing condition. Through completion of this study, we aimed to:

1. Provide additional empirical evidence regarding the validity and reliability of the ELU model of working memory for young adults with and without ADHD.
2. Provide additional empirical evidence regarding the relationship between explicit cognitive processes and working memory capacity in adverse listening conditions for young adults with and without ADHD.
3. Provide additional empirical evidence regarding the relationship between working memory capacity and speech processing in noise for young adults with and without ADHD.
4. Provide additional empirical evidence regarding the relationship between speech processing in noise and audiovisual cues for young adults with and without ADHD.
5. Develop practical implications from theoretical constructs which are rooted in empirical evidence for clinicians and educators.

Research Questions and Predictions

In order to investigate how the working memory system (i.e., short-term recall and working memory capacity) contributes to the ability to process speech in noise for adults with and without ADHD, we measured each participant's working memory capacity through the reading span and operation span tasks, short-term recall through two digit recall tasks, and signal-to-noise ratio (SNR) through the QuickSIN (Killion et al., 2004).

The following research question is asked:

Based on the Moderate Brain Arousal Model of ADHD,

1. Will increased speech noise facilitate stochastic resonance thereby improving the ability of young adults with ADHD to process speech in the auditory condition as compared to healthy controls?

The following is predicted:

- a) Decreasing SNRs will negatively impact speech processing in both young adults with and without ADHD in the auditory condition.
- b) Decreasing SNRs will have a greater impact on performance in young adults without ADHD in the auditory condition.

Based on the theory that visual cues support speech processing in the presence of background noise the, following research question is asked:

2. Will audiovisual cues significantly improve speech processing in young adults with and without ADHD when listening in noise?

The following is predicted:

- a) Providing audiovisual cues will improve performance at all SNRs for both young adults with and without ADHD in the auditory+visual condition.
- b) Providing audiovisual cues will have an equal impact on performance for both young adults with and without ADHD in the auditory+visual condition.

Based on the ELU model of working memory, the following research question is asked:

3. Will top-down processing (i.e., explicit cognitive processes such as working memory) primarily contribute to an individual's ability to process speech in noise?

The following is predicted:

- a) For young adults with and without ADHD, working memory capacity will be the best predictor of QuickSIN performance at all SNR levels for both conditions (i.e. auditory and auditory+visual).
- b) For young adults with and without ADHD, digit recall will not predict QuickSIN performance at all SNR levels for both conditions (i.e. auditory and auditory + visual).
- c) For young adults with and without ADHD, there will not be a statistically significant relationship between performance on working memory tasks and short-term recall tasks.

Significance of the Study

Studying the relationship between listening in noise and cognition in young adults with and without ADHD is significant to the field of communication disorders, special education, and psychology for the following reasons:

- a) Studies related to the field of cognitive hearing science are relatively new suggesting that there is much that can still be learned regarding the relationship between listening in noise and working memory (Arlinger et al., 2009; Foo et al., 2007; Stenfelt & Ronnberg, 2009).
- b) Studies related to the field of cognitive hearing science support a multidisciplinary approach to investigating cognition which can facilitate functional treatment strategies for a variety of target populations.
- c) Studies which evaluate the reliability and validity of the ELU model contribute important information regarding the relationship between

theoretical cognitive constructs which underlie academic and clinical skills of target treatment populations.

- d) Studies which explain, describe, and empirically support working memory and speech processing facilitate a bridge from theory to practice.
- e) Research which explains the relationship between working memory and speech processing has practical implications for the design and delivery of treatment and educational models in schools and universities.

CHAPTER 3

Methods

Participants

Sixty-three young adults divided into two groups participated in this study. The experimental group consisted of 25 young adults between the ages of 18-35 (9 male; 16 female) who had received a diagnosis of ADHD at some point between the ages of 2 and 25 years. The control group consisted of 38 young adults between the ages of 18-35 (15 male; 23 female) with no diagnosis of ADHD. The experimental and control groups were matched on age (ADHD $M = 23.7$ years, $SD = 4.0$; non-ADHD $M = 23.5$ years, $SD = 4.0$) and educational level (ADHD $M = 14.6$ years, $SD = 1.32$; non-ADHD $M = 15.0$ years, $SD = 2.62$). Statistical analysis showed no significant difference between groups on age and education level (age: $t(61) = .151$, $p = .88$; education: $t(61) = -.798$, $p = .37$). The participants were recruited from a university and surrounding communities located in a southeastern state. In addition to posted fliers, participants were recruited through an approved email sent from the Office of Student Accessibility to enrolled students who met eligibility criteria, through speech-language pathology classes, and through the researchers' communication with co-workers and peers. To be included in this experiment, all participants were free from cognitive impairment (i.e., mental retardation), spoke English as their first language, and had a high school diploma with varying levels of college experience. To be included in the experimental group, the participants had a diagnosis of ADHD consistent with the criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders – IV - TR (DSM-IV-TR) according University's Office of Student Accessibility. If not a registered student,

documentation outlining the disorder was provided and certified by an appropriate and qualified professional (e.g., physician or psychiatrist) or through documentation of current treatment for ADHD. Any participants on ADHD medication were asked to refrain from taking that medication for 12 hours prior to the study. Participants in the control group verbally completed a questionnaire to assure no history of ADHD or other learning disabilities. Participants in both experimental and control groups took and passed a hearing screening demonstrating normal hearing at 20 decibels HL at 500, 1000, 2000, and 4000 kHz bilaterally. Finally, participants signed a consent form approved by the University's Institutional Review Board. Participants were given either a \$10 gift card to reimburse them for their participation in the study, or class credit.

Materials

Quick Speech-in-Noise (QuickSIN). During experimental trials, each participant's listening in noise abilities were measured using Quick Speech-in-Noise (QuickSIN) software (Killion et al., 2004), run on a standard Dell computer, during a designated testing session in the research lab (i.e., a quiet testing room). QuickSIN is a computer program which simultaneously presents a speech sentence repetition task in the presence of background noise. There were two presentation conditions generated by QuickSIN: (1) auditory and (2) auditory + visual. For each condition, the participant was asked to wear headphones and to verbally repeat 8 sentences with five key words at each of six signal-to-noise ratios: 25, 20, 15, 10, 5, 0. That is, while participants were repeating sentences, the background noise (i.e., speech babble) presented across sentences was gradually increased by increments of five decibels. In the auditory only condition, participants listened to a sentence through the headphones and repeated the sentence. In

the auditory + visual condition, the listener heard the sentences in the headphones and saw the speaker produce the sentence on a video monitor. Blocks of sentences were presented in counterbalanced order across participants across the two listening conditions. The examiner transcribed and scored repetition responses for QuickSIN online. The dependent measure in the task was the percent correct repetition of five key words per sentence (n=8 sentences). The number of words correct (max 40 words) were calculated for five SNRs: 0, 5, 10, 15, 20, and 25. Throughout all subtests, sentences were presented at a standard, comfortable hearing level, at approximately 60 dB HL. While the participants were completing the sentence repetition task, competing background noise was presented in gradually and systematically increasing increments of 5 decibels, from 40-60dB HL. Once the first presentation condition was completed (auditory or auditory + visual), then the participant completed the sentence repetition task in the presence of background noise in the second listening condition (auditory + visual or auditory only).

Reading Span (R-span) task. Originally developed by Daneman and Carpenter (1983), the R-span is a working memory span task that is widely used as a valid measure of working memory capacity because it reflects a participant's ability to both store and manipulate information (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). In 1999, Engle, Kane, and colleagues modified the design, administration, and scoring of the R-span. That updated version was used in this research project as a measure of individual differences in working memory capacity. During the R-span task, participants read aloud sentences viewed on a computer screen, determined the meaningfulness of each sentence, and verbally recalled capital letters from the end of each sentence in the sentence set. Sentence sets varied from 2-5 sentences in length and there were a total of

42 sentences. Each participant was scored on his/her accurate interpretation of the sentence and accurate recall of all capital letters in the designated number of sentences. Participant's total score was reported using partial-credit load scoring, which is calculated as the number of words correctly recalled averaged across each set of sentences (Conway et al., 2005).

Operation Span (O-span) task. Like the R-span task, the O-span task is a valid and reliable measure of individual differences in working memory capacity (Conway, et al., 2005). Engle et al.'s (1999) version of the O-span task was used in this research project. During the O-span task, participants read aloud mathematical equations viewed on a computer screen, determined the accuracy of the answer provided, and verbally recalled words from the end of each equation in the mathematical equation set. Equation sets varied from 2-5 equations in length and there were a total of 42 equations. Each participant was scored on his/her accurate solution to the equation and accurate recall of all words. Participant's total score was reported using partial-credit load scoring, which is calculated as the number of words correctly recalled averaged across each set of equations (Conway et al., 2005). For purposes of analyses, raw scores from both the R-span and O-span task were converted to z-scores and averaged in order to calculate a working memory capacity composite score.

Digit Span. A digit span task reflects short-term memory or storage because the participant is asked simply to recall numbers either forward or backward without a processing component (Conway et al., 2005). During experimental tasks, participants were asked to verbally recall digit lists presented orally by a female, English speaking experimenter. The Digits Forward and Digits Backward subtest of the Clinical Evaluation

of Language Fundamentals (CELF-3) was used to calculate a digit span score for each participant.

Procedure

The entire testing session took approximately one hour to complete for participants without a diagnosis of ADHD and an hour and fifteen minutes for those participants with a diagnosis of ADHD. Initially, the consent form was reviewed and signed. Participants were then asked to verbally complete demographic information providing their age, perceived visual acuity, medication use, and perceived level of academic achievement/performance. Next, participants completed the hearing screening. Participants then completed the reading span, operation span, digit recall, and QuickSIN tasks in the department's research lab. The order of those tasks was counterbalanced across participants and depended upon the group into which the participant was randomly placed. For all experimental tasks, participants were given practice trials. As data were collected, they were stored in a secure, electronic database and locked in a file cabinet by the primary investigator of this research project. The database was created using SPSS.

Once all of the data were collected, the researcher used SPSS to calculate descriptive statistics for the participants and to examine within-subject and between-subject differences on each variable (i.e., performance with a visual cue or without a visual cue, working memory capacity, short-term memory) using a multivariate analysis of variance (MANOVA). MANOVA was chosen because there were more than one dependent variables and because a MANOVA does not require an assumption of sphericity of group variances. A MANOVA compares the between-group variances and the within-group variances to determine if the difference is statistically significant

(Maxwell & Delaney, 2004). In addition, follow up analyses were completed using independent t-tests and correlational analysis between the covariates and percent correct performance at each SNR level on the experimental QuickSin tasks.

CHAPTER 4

Results

A 2 x 2 x 6 mixed design was used in which the modality of presentation (auditory only vs. auditory + visual), and SNR level (25, 20, 15, 10, 5, 0) were the within subject manipulations and the between grouping variable was ADHD vs. NON-ADHD. In addition, data were collected on two covariates (working memory capacity, short-term memory) which measured individual differences that were expected to relate to performance on the QuickSIN or relate according to the grouping variable (Maxwell & Delaney, 2004). Results (means and standard deviations) for each condition are shown for each group in Table 1. In order to determine the distinct effects of modality, level of background noise (signal-to-noise ratio; SNR), and the diagnosis of ADHD on speech processing, we analyzed the mean QuickSIN scores using a multivariate analysis of variance (MANOVA).

Table 1

Accuracy of performance (means and standard deviations) on QuickSin across listening conditions for ADHD and control groups

	Group			
	Non-ADHD		ADHD	
	Mean	SD	Mean	SD
Auditory				
SNR 25	99.01	1.70	98.02	3.50
SNR 20	97.96	2.52	95.92	5.67
SNR 15	96.58	3.77	95.30	5.12
SNR 10	94.67	4.16	91.24	6.22
SNR 5	81.18	12.12	80.94	12.82
SNR 0	15.20	4.41	12.40	7.92
Total	80.56	4.85	78.42	4.56
Audiovisual				
SNR 25	98.62	1.81	99.10	2.15
SNR 20	98.75	2.08	96.02	6.62
SNR 15	99.08	2.36	98.60	2.18
SNR 10	96.51	3.80	94.50	6.17
SNR 5	94.34	6.54	91.92	10.02
SNR 0	51.45	23.64	38.02	15.48
Total	87.45	13.17	85.82	6.37
Overall	84.87	4.60	85.71	19.12

QuickSin Results

Results of the MANOVA are reported as significant at the $p < .05$ level and are provided in Table 2. There was a significant main effect of group, $F(1, 61) = 5.41, p < .05$, partial eta squared = .081, indicating that individuals with ADHD performed significantly lower than normal controls on speech processing scores. There was a significant main effect of modality, $F(1, 61) = 347.14, p < .001$, partial eta squared = .85, indicating that the inclusion of an audiovisual cue made a significant difference on listening in noise performance as compared to the auditory only condition for both individuals with and without ADHD. There was also a significant main effect of SNR ,

$F(5, 57) = 306.46, p < .001$, partial eta squared = .96, indicating that the level of background speech noise had a significant impact on speech processing scores as SNR approached 0 for both individuals with and without ADHD.

Table 2.

Results of MANOVA for Main Effects and Interaction Effects

Effect	F - value	p-value*	partial η^2
Main Effects			
Group: ADHD or non-ADHD	5.41	.023	.081
Modality: audio or audiovisual	347.14	.000	.851
SNR: 25, 20, 15, 10, 5, 0	306.46	.000	.964
Interaction Effects			
SNR and Group	4.80	.001	.296
Modality and SNR	63.77	.000	.848
Modality and Group	3.40	.070	.053
Modality and Group and SNR	2.38	.050	.173

*p – value – results are significant at the $p < .05$ level

A number of significant interactions were also observed. There was an interaction effect of SNR and group, $F(5, 57) = 4.80, p < .001$, partial eta squared = .296, indicating that effect of the signal-to-noise ratio on the performance of speech processing differed according to the group variable (i.e., the diagnosis of ADHD). There was an interaction effect of modality and SNR, $F(5, 57) = 63.77, p < .001$, partial eta squared = .848, indicating that regardless of the group, speech processing in noise was influenced by the combination of the SNR and whether or not audiovisual cues were included. There was no interaction effect of group and modality, $F(1, 61) = 3.40, p > .05$, partial eta squared = .053, indicating that although performance was influenced by the presence of

audiovisual cues, this performance was not different between individuals with a diagnosis of ADHD and without a diagnosis of ADHD. All of these significant interaction effects were subsumed under a significant three-way interaction effect of modality, SNR, and group, $F(5, 57) = 2.38, p < .05$, partial eta squared = .173, indicating that although the interaction of modality and diagnosis did not statistically impact speech processing in noise, the inclusion of various SNRs did make a difference on speech processing scores between young adults with and without a diagnosis of ADHD.

The nature of this three-way interaction effect was further investigated using a series of follow-up statistical analyses. A 2 X 6 MANOVA was conducted for each of the modality conditions. For the auditory condition alone, there was no interaction effect between SNR and the grouping variable, $F(5, 57) = 1.19, p > .05$, partial eta squared = .094, suggesting that for young adults with and without ADHD there is not a significant difference in their ability to process speech in noise (Figure 3). However, for the audiovisual condition, there was an interaction effect between the SNR and the grouping variable, $F(5, 57) = 4.38, p < .05$, partial eta squared = .28 (Figure 4). These results suggest that it is the addition of the audiovisual cue which creates the statistically significant difference between adults with and without ADHD to process speech in noise. To identify the effect of different SNR levels for this group difference, a series of univariate ANOVAs for both the auditory and the audiovisual condition were performed (Table 3). For the auditory condition, the only SNR level which resulted in a statistically significant group difference was SNR10, $F(1, 62) = 6.97, p < .05$, partial eta squared = .102. In the audiovisual condition, the only SNR levels which resulted in statistically significant group differences were SNR20, $F(1, 62) = 5.75, p < .05$, partial eta squared =

.66, and SNR0, $F(1, 62) = 6.29, p < .05$, partial eta squared = .69. Specifically, individuals with ADHD performed worse than control participants at these SNR levels when an audiovisual cue was provided.

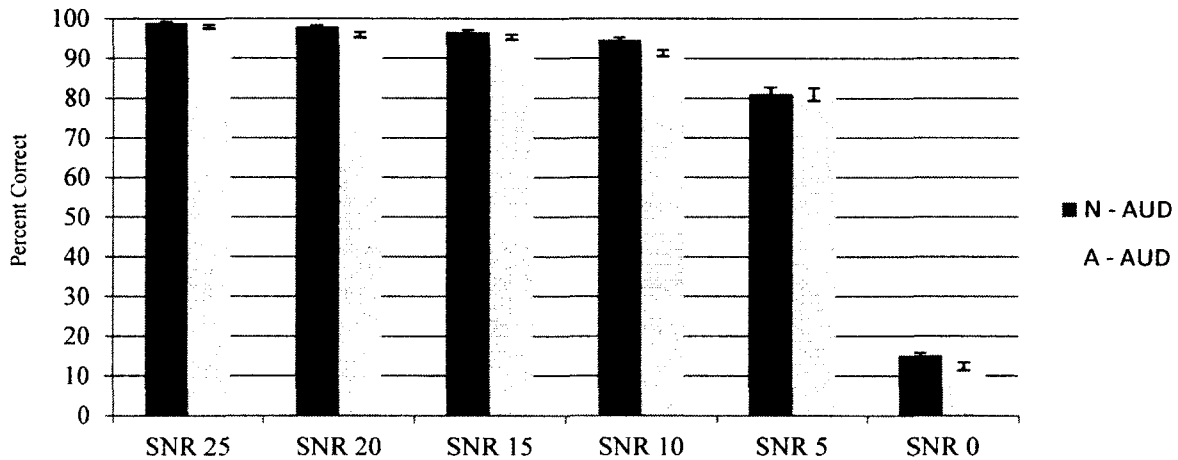


Figure 3. Graph showing the MANOVA results for the interaction between SNR and group in the auditory condition. The error bars indicate the standard error of the mean.

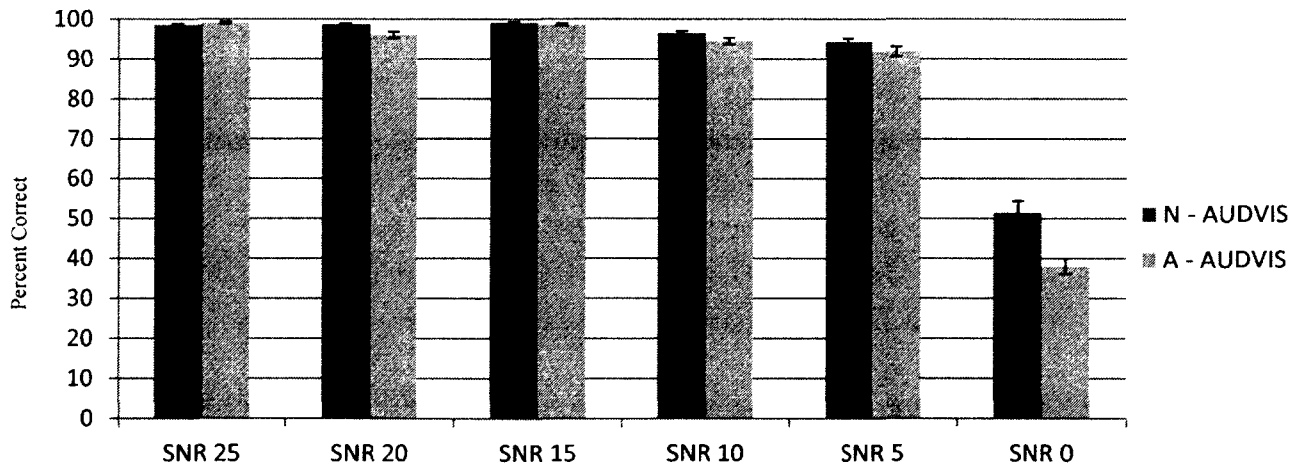


Figure 4. Graph showing the MANOVA results for the interaction between SNR and group in the audiovisual condition. The error bars indicate the standard error of the mean.

Table 3.

Univariate ANOVA Results for Group Differences at Specific SNR Levels

Condition	F-value	<i>p</i> -value	partial η^2
AUDITORY			
SNR_25	2.32	.133	.037
SNR_20	3.87	.054	.060
SNR_15	1.30	.259	.021
SNR_10	6.97	.011*	.102
SNR_5	.008	.929	.000
SNR_0	.784	.380	.013
AUDIOVISUAL			
SNR_25	.919	.342	.015
SNR_20	5.75	.020*	.086
SNR_15	.662	.419	.011
SNR_10	2.58	.113	.041
SNR_5	1.37	.247	.022
SNR_0	6.29	.015*	.093

* *p* – value – results are significant at the $p < .05$ level

Working Memory Relationships

In order to investigate how working memory capacity and short-term recall impacted performance for both groups of young adults on speech processing in noise, we first compared the ADHD and non-ADHD groups performance on the reading span task, operation span task, digit recall forward, digit recall backward, and the working memory capacity composite score through a series of independent *t* tests. Means and standard deviations for each group across tasks are reported in Table 4. Results revealed significant group differences only for the operation span task, $t(61) = -2.24$, $p < .05$, Cohen's $d = .58$, and working memory capacity composite scores, $t(61) = -2.13$, $p < .05$, Cohen's $d = .55$. Young adults without ADHD performed better on each of these

measures than individuals with ADHD. However, although young adults without ADHD also performed better on the reading span task, $t(61) = -1.61, p > .05$, Cohen's $d = .38$ recalling digits forward, $t(61) = -1.061, p > .05$, Cohen's $d = .28$, and recalling digits backward, $t(61) = -1.70, p > .05$, Cohen's $d = .43$, their scores were not significantly different from participants with ADHD.

Table 4

Means and Standard Deviations for each group across covariate tasks

	Group			
	Non-ADHD		ADHD	
	Mean	SD	Mean	SD
Digits Forward	11.18	1.71	10.60	2.40
Digits Backward	7.13	2.42	6.12	2.24
O-Span	.66	.11	.59	.130
R-Span	.72	.14	.67	.123
WM Composite	.21	.86	-.28	.909

Knowing that young adults with ADHD had a significant difference in scores on two measures of working memory capacity, a series of correlational analyses were completed to understand the relationship between working memory capacity and performance on speech processing in noise at each SNR level for both the auditory and audiovisual conditions. In addition, in order to understand the relationship between related cognitive constructs we ran correlational analyses were run between measures of working memory capacity and short-term recall. Table 5 provides a correlation table outlining the results of this analysis.

There was a significant relationship between the working memory composite scores and recalling digits backward, $r = .273, p$ (two-tailed) $< .05$. Specifically, there was a significant relationship between the OPSPAN task and recalling digits backward, $r = .197, p$ (two-tailed) $< .001$ for all participants. Although there was also a significant relationship between the OPSPAN and the RSPAN tasks, $r = .641, p$ (two-tailed), $< .001$, there was not a significant relationship between the RSPAN and recalling digits backward, $r = .098, p$ (two-tailed) $> .05$. These results suggest that the same underlying cognitive processes are responsible for the ability to repeat numerical digits in reverse order and solve mathematical equations while retaining information, but that the cognitive process responsible for determining meaningfulness of sentences while retaining information, although related, may be different. Finally, there was not a statistically significant relationship between recalling digits forward and working memory capacity, $r = .145, p$ (two-tailed) $> .05$, confirming that auditory recall reflects simple storage which is different than the ability to hold and manipulate information simultaneously.

In order to discuss the relationship between working memory capacity and listening in noise, the correlational analyses were run using the total working memory composite scores. There was a significant relationship between working memory capacity and three signal-to-noise ratios in the auditory condition. Working memory capacity was related to listening in noise in the auditory condition at SNR20, $r = .330, p < .01$; SNR15, $r = .276, p < .05$; SNR0, $r = .257, p < .05$. Working memory capacity was significantly related to listening in noise in the audiovisual condition at SNR10, $r = .322, p < .01$; SNR0, $r = .381, p < .01$. These relationships indicate that for all young adults,

with and without ADHD, working memory capacity related more to the ability to process speech in noise during the auditory condition. Young adults' ability to store and manipulate information was significantly related to their ability to discern speech sounds at three signal-to-noise ratios, including the hardest SNR ratio. For all participants, their ability to store and manipulate information was significantly related to their ability to discern speech sounds at two signal-to-noise ratios when visual cues were also provided, including the hardest SNR ratio. It is important to note that it was at SNR0 in the audiovisual condition which created significant between group differences in processing speech in noise, suggesting that it could be the relationship of working memory capacity under these conditions which influences performance.

Table 5

Correlation Table for All Measured Variables

Item	Item																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1) DF	1.00																
2) DB	.59***	1.00															
3) OS	.20	.39**	1.00														
4) RS	.06	.10	.64***	1.00													
5) WMC	.15	.27*	.91***	.90***	1.00												
6) A25	.30*	.12	.12	.14	.14	1.00											
7) A20	.27*	.13	.29*	.31*	.33**	.60***	1.00										
8) A15	.26*	.27*	.23	.27*	.28*	.35**	.32*	1.00									
9) A10	.17	.12	.02	.05	.04	.33**	.18	.15	1.00								
10) A5	.09	.12	.22	.15	.20	.15	.22	.05	.21	1.00							
11) A0	-.06	.11	.23	.24	.26*	.09	.17	.20	.18	.45***	1.00						
12) AV25	.36**	.16	.22	.19	.22	.60***	.51***	.47***	.22	.09	.02	1.00					
13) AV20	.38**	.14	.18	.23	.23	.66***	.66***	.36**	.20	.08	.05	.57***	1.00				
14) AV15	.15	-.06	.06	-.10	-.02	.19	.04	-.20	.07	.02	.04	-.01	.04	1.00			
15) AV10	.20	.12	.38**	.21	.32*	.16	.27*	.03	.06	.38**	.25*	.09	.13	-.54	1.00		
16) AV5	-.01	.02	.13	.20	.18	.32*	.35**	.09	.41**	.55***	.25*	.24	.33**	.08	.28*	1.00	
17) AV0	.17	.23	.36**	.33**	.38**	.14	.30*	.13	.38**	.59***	.59***	.12	.28*	.06	.33**	.62***	1.00

Note: Pearson's Product Moment Coefficients for all variables. Highlighted SNRs represent those levels of significant between group differences. DF = digits forward; DB = digits backward; OS = Operation Span Task; RS = Reading Span Task; WMC = working memory capacity composite; A25 – A0 = auditory subtest only SNR 25 – 0; AV25 – AV0 = audiovisual subtest only SNR 25 – 0

* p – value – results are significant at the $p < .05$ level

** p – value – results are significant at the $p < .01$ level

*** p – value – results are significant at the $p < .001$ level

CHAPTER 5

Discussion

Auditory processing of speech is influenced by internal (i.e., attention, working memory capacity, short-term recall, long-term memory) and external factors (i.e., background noise, visual information). In this experiment, we investigated how working memory capacity, short-term recall, and visual cues influence speech processing in the presence of background noise for individuals with and without a diagnosis of ADHD. Based on two theoretical models, the working memory model for ELU and the Moderate Brain Arousal Model of ADHD, and empirical evidence suggesting visual cues support speech processing, the following research questions were asked:

- 1) Will increased speech noise facilitate stochastic resonance thereby improving the ability of young adults with ADHD to process speech in the auditory condition as compared to healthy controls?
- 2) Do audiovisual cues improve speech processing in young adults with and without ADHD when listening in noise?
- 3) Will top-down processing (i.e., explicit cognitive processes) primarily contribute to an individual's ability to process speech in noise?

Young adults with ADHD did worse than controls in the presence of background noise in several conditions. For example, when the background noise was loudest (SNR0), and when a visual cue was provided, the ADHD group did poorer than healthy controls. This was a counterintuitive finding, as visual information typically assists processing of auditory signals. Rather, individuals with ADHD did not benefit from visual cues when they should have needed them the most as SNR became more difficult.

Analysis also indicated that there was a significant relationship between working memory capacity and listening in noise at the most difficult noise level for both modalities and that the relationship between recalling digits backward and working memory capacity was significant. There was not a significant relationship between recalling digits forward and working memory capacity. This discussion includes how these results relate to specific theoretical models, what these results mean to practitioners, the limitations related to these results, and potential future research projects.

The Working Memory Model for Ease of Language Understanding (ELU)

Results from this research project are consistent with findings of previous empirical studies (Foo et al., 2007; Lunner & Sundewall-Thoren, 2007; Rudner & Ronnberg, 2008; Rudner et al., 2009) supporting the relationship between working memory capacity and the ability to recognize speech in noise. The presence of background noise in the listening environment facilitates a cognitive mismatch between the phonological representations developed in the RAMBPHO and the lexical representations stored in long-term memory (Ronnberg, 2003; Ronnberg et al., 2008, Ronnberg et al., 2010; Rudner & Ronnberg, 2008). According to the working memory model for ELU, once a mismatch occurs, then speech processing becomes more deliberate or explicit, requiring higher levels of attentional control (i.e., working memory capacity) in order to maintain the incoming signal, while simultaneously activating representations in long-term memory, and ignoring irrelevant acoustic and visual information (Ronnberg et al., 2010; Rudner & Ronnberg, 2008). Correlations between working memory composite scores and speech processing at three noise levels in the auditory condition (i.e., SNR 20, 15, 0), including the most difficult noise level, and two

of the highest noise levels in the audiovisual condition (i.e., SNR 10, 0) empirically confirm a relationship between the presence of background noise and a young adult's cognitive load, making the processing of the acoustic signal more reliant upon higher level control processes (i.e., working memory capacity). It should be noted that these noise levels also correspond to a drop in speech processing scores across all participants.

With regard to the auditory condition, the processing of speech becomes less automatic and more deliberate or dependent on working memory capacity when the increase in the signal-to-noise ratio exceeds the neurological system's innate threshold and ability to automatically compensate. Working memory capacity highly correlated with speech processing when the signal-to-noise ratio increased from 25 to 20 decibels and again from 20 to 15 decibels and again from 5 to 0 decibels. This pattern suggests that a person's neurological system adapts to a noise level and processes the acoustic signal more automatically, but once that noise level increases, then the neurological system must compensate again, making the processing of the acoustic signal deliberate and reliant upon working memory capacity. Essentially, it may not be that a young adult relies on working memory capacity or deliberate processing consistently under all noisy conditions, but that young adults go back and forth between implicit and explicit processing depending on the noise level.

Additionally, there was no correlation between young adults' short-term recall and working memory capacity, confirming several empirical studies (Baddeley, 1996b; Buehner et al., 2005a; Cowan, 1988; Engle et al., 1999; Kane et al., 2004; Oberauer et al., 2003) which identify a separation between the storage and control processes of the working memory system. Simple short-term recall correlated with SNRA25, SNRAV25,

SNRAV20, SNR levels which did not correlate with working memory capacity. These results suggest that the neurological system can compensate for low levels of background noise, maintaining bottom-up or implicit or automatic information processing. Because of the relationship between basic short-term recall and speech processing in low noise levels, it could be inferred that implicit decoding of the acoustic signal, under low noise conditions, is facilitated by the temporary storage of phonological information.

The Moderate Brain Arousal Model of ADHD

Results from this research project are not consistent with the empirically supported theory that there is a positive relationship between noise and cognitive performance (Abikoff et al., 1996; Aihara et al., 2008; Mayor & Gestner, 2005; Schneider, et al., 2007; Soderlund et al., 2007; Zeng et al., 2000). For both individuals with and without ADHD, the inclusion of background noise reduced speech processing at all noise levels. Based on the phenomenon of stochastic resonance, the Moderate Brain Arousal Model of ADHD explains that the provision of background noise activates a positive neurological response, thereby making a weak auditory signal more salient (Soderlund et al., 2007; Ward et al., 2006). This suggests that a person with ADHD would perform better on speech processing tasks in noise. Empirical results of this study indicated that mean speech processing scores were reduced for young adults with a diagnosis of ADHD when compared to young adults without a diagnosis of ADHD. Regardless of condition, the gradual increase of background noise was more detrimental to speech processing for young adults with a diagnosis of ADHD.

There are a few potential reasons why present results do not support the Moderate Brain Arousal Model of ADHD. Studies which demonstrated improved cognitive

performance with the inclusion of background noise used white noise as the type of background noise (Abikoff et al., 1996; Aihara et al., 2008; Mayor & Gestner, 2005; Soderlund et al., 2007; Zeng et al., 2000). The current project used increasing levels of speech babble as the type of background noise. The acoustic properties of babble and white noise are extremely disparate and therefore their impact on the sensory and neurological systems is different. Heinrich, Schneider, and Craik (2008) found that the presentation of continuous babble impeded a young adult's ability to recall word pairs. Secondly, stochastic resonance is made possible by an "optimal noise level" (Ward et al., 2006, p. 320) and the background noise in this study was not held constant, but increased throughout the task. The background noise accompanying the speech processing tasks was not provided in an effort to improve performance, but in an effort to determine how well an individual can accurately detect the acoustic signal in the presence of competing auditory information. Finally, there were only two studies identified (Abikoff et al., 1996; Soderlund et al., 2007) which examined the effect of noise on an ADHD population and those populations were comprised of children who have immature and underdeveloped neurological systems. The present study used young adults whose neurological systems are mature and almost fully developed. Thus, the stochastic model may need to address the type of background noise in its effect for auditory processing in individuals with ADHD.

Audiovisual Cues

Results from this research project are consistent with the empirically supported theory that visual cues strengthen the auditory message by reducing listening effort and improving speech recognition (Binnie et al., 1974; Erber, 1969; Grant et al., 1998;

MacCleod & Summerfield, 1987, 1990; Sumbly & Pollack, 1954; von Kreigstein et al., 2008; van Wassenhove et al., 2005; Walden et al., 1975), including speech recognition, in noise (Bristow et al., 2008; Fraser et al., 2010; Larsby et al., 2005). Mean speech processing scores for all young adults were significantly increased in the audiovisual condition. The provision of congruent visual cues allowed participants to effectively and accurately interpret the auditory stimulus as background noise systematically increased. Since the young adults were able to hear the acoustic signal while simultaneously viewing the speaker's facial movements, an appropriate phonetic representation was triggered allowing for improved speech processing (Bristow et al., 2008).

Although there was one significant group difference in the auditory condition, the overall pattern of performance for young adults with and without ADHD essentially demonstrates a commensurate ability to process speech in the presence of fluctuating levels of background noise without the presence of visual cues. This result aligns with a study finding that children with ADHD were able to control auditory interference as well as children without ADHD (van Mourik, Sergeant, Heslenfeld, Konig, & Oosterlaan, 2011). A young adult's ability to accurately process speech when fluctuating levels of noise are present improves with the inclusion of audiovisual cues. However, audiovisual cues had a more positive impact on speech processing for young adults without a diagnosis of ADHD, especially when background noise was at the highest level (SNRAV0). Unlike in the auditory condition alone, the inclusion of visual cues facilitated a significant, negative difference in speech processing skills for young adults with ADHD at SNRAV20 and SNRAV0. When it would seem a young adult with ADHD would need an audiovisual cue the most, they benefited less from its presence.

There are a few potential reasons why the presence of audiovisual cues does not improve speech processing performance for young adults with ADHD as much as normal, especially at the most difficult SNR level. Working memory capacity scores were significantly lower for young adults with ADHD when compared to young adults without ADHD in this study. As discussed earlier, one possibility is that a young adult's cognitive load increases as the SNR level increases, necessitating the young adult's neurological system to initiate the transfer from automatic speech processing, facilitated by short-term recall, to deliberate speech processing, facilitated by working memory capacity. It appears that, although numerically reduced when compared to their matched peers, a young adult with ADHD's working memory capacity or attentional control is sufficient enough to process speech as efficiently and accurately as their matched peers without ADHD. It is when another piece of information enters the stream of neurological data in the form of visual information, as in the auditory+visual condition, that the cognitive load is stretched. In that case, the reduction in working memory capacity for young adults with ADHD becomes detrimental. This theory is supported by the strong relationship between working memory capacity and speech processing at SNR AV0. Young adults with ADHD do not have sufficient executive control processes necessary to simultaneously maintain phonological input, ignore irrelevant acoustic information, AND integrate visual speech cues in order to retrieve accurate linguistic representations from long term memory. A reduction in working memory capacity limits the ability to effectively handle multiple streams of neuronal information in young adults with ADHD.

Another potential reason for the negative impact of audiovisual cues on speech processing in noise for young adults with ADHD is visual attention. It is not known

whether or not young adults with ADHD were able to sustain visual focus on the visual cue. If the young adult with ADHD shifted eye gaze frequently during the task, then the provided visual information was not salient enough to positively influence speech processing. In order for visual speech cues to be effective, they must be held in sight long enough to generate accurate sensory traces which can then be mapped onto stored phonetic representations. This possibility needs to be explored in other studies, possibly with the use of eye-tracking.

Practical Implications

Although this research project is rooted in conceptual theory, our theoretical results can be translated into practical and functional treatment strategies for practitioners (psychologists, special educators, speech pathologists, audiologists) who work with adults with ADHD. First, these results support the importance of selecting reliable and valid evaluation tools so that measured behaviors accurately reflect underlying cognitive constructs and linguistic skills. These results remind clinicians to be diligent in analyzing subtests to ensure individual tasks actually examine working memory capacity versus short-term recall. Language skills are facilitated by the interaction of cognitive processes and strong linguistic representations in long-term memory. A good assessment will include a variety of empirically based standardized and nonstandardized tests, the results of which can generate a unified and comprehensive representation of the client's language skills in relation to cognitive processes.

Second, results of this study indicate that background noise can be detrimental to auditory processing, particularly for individuals with ADHD. This suggests the need for practitioners to carefully monitor the educational and therapeutic environments for

students with ADHD, and provide quiet working conditions for these individuals as needed, particularly avoiding background speech noise.

In addition, these results support the importance of working memory capacity or attentional control during the completion of language based tasks. This confirms the use of self-talk, cognitive rehabilitation techniques, and empirically supported self-regulation strategies as educational and therapeutic interventions (Baddeley, 2003; Baddeley, Gathercole, & Papagno, 1998; Barkley, 2000; Gathercole, 1994; Graham, Harris, & Mason, 2005; Watson & Westby, 2003; Ylvisaker & DeBonis, 2000). Clinicians and teachers are encouraged to facilitate the use of self-talk in all of their clients in an effort to improve task performance. Speech-language pathologists like Lyn Turkstra, Mark Ylvisaker, Sarah Ward, and Jill Fahy in their published articles and continuing education courses promote and describe the use of specific therapeutic methods developed from cognitive rehabilitation techniques (Feeney & Ylvisaker, 2008; Richard & Fahy, 2005; Turkstra & Flora, 2002; Ward, 2012).

Finally, these results support the importance of facilitating an appropriate balance between verbal input and visual cues which is relative to the activity. It is clear that for individuals with reduced working memory capacity, a point of saturation may be reached whereby visual cues increase cognitive load and reduce performance. Practitioners should complete observations of clients with ADHD in order to determine how best to use visual cues as environmental supports. It will be important to monitor the balance between the provided visual cues and associated verbal instructions, explanations, and/or background noise.

Limitations

There are limitations which could have influenced the results of this study. The small sample size influences the power of generated statistical results. More participants could yield larger between group and within group differences. By having a larger representation of young adults with ADHD, an interaction effect between modality and group may have been generated. In addition, there may have been more conclusive results regarding the relationship between working memory capacity and speech processing at all noise levels for both groups of young adults.

Another issue is related to recruiting participants with a true and pure ADD/ADHD diagnosis. Although efforts were made to ensure young adults in the ADHD group had an accurate diagnosis, there was no way to ensure that the nature and severity of that diagnosis was identical or consistent across group members. Many of the ADHD participants had co-morbid diagnoses (i.e., anxiety disorder, executive function disorder, or a learning disability) making the connection between reported results and the diagnosis of ADHD more difficult. Furthermore, this study was limited to young adults and generalization of results to other age ranges is limited.

A final limitation is highlighted by Freyaldenhoven, Thelin, Plyler, Nabelek, and Burchfield's (2005) study regarding the link between stimulant medication and accepting background noise in adult females with ADHD. The authors reported that stimulant medication increased the level of background noise young adult women with ADHD were able to accept. The young adults in this research project were asked to be medication free for 12 hours prior to completing evaluation tasks. Results of this project may have been completely different if the young adults with ADHD were tested while medicated. Despite this limitation, the reported results are viewed to be representative

and valid reflections of cognitive performance absent of any pharmaceutical assistance and therefore valuable.

Future Research

Additional research is essential with regard to the interaction between audition and cognition in young adults with ADHD. A replication study is necessary which increases the sample size and includes the electronic monitoring of eye movements during the audiovisual condition of the listening in noise task. This would provide supplemental information regarding how young adults with ADHD process visual cues to improve speech performance compared to same age peers. The influence of ADHD medications on listening in noise also should be explored. It would also be valuable and interesting to determine how background noise impacts speech processing in young adults with related diagnoses that impact on learning (e.g., dyslexia and auditory processing disorders).

Future research is also needed with regard to the relationship between the working memory system and language skills in a variety of populations. This study only compared short-term recall and working memory capacity to speech processing in noise. Research is needed to determine how working memory capacity and short-term recall relate to phonological awareness, fluency, and discourse in adolescents and young adults with speech-language impairments. In addition, research is needed to determine if any combinations of interventions indirectly improves working memory capacity in those populations.

Conclusion

Background speech noise negatively impacts speech processing for young adults with and without ADHD. Although the inclusion of audiovisual cues improves performance for all young adults, young adults with ADHD do not benefit as much from the presence of visual cues as normal. As the level of background noise increases, so does the young adult's reliance on working memory capacity to accurately decode the auditory signal. Because the provision of visual cues increases the cognitive load and because young adults with ADHD have a reduced working memory capacity, visual cues actually may reduce speech processing performance at the highest noise levels.

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CURRICULUM VITAE

BIOGRAPHICAL

Name:	Anne M. P. Michalek	
Business Address:	Child Study Center Old Dominion University Norfolk, VA 23529-0136	Tel: (757) 683-4117
Home Address:	3437 Woodsman Lane Virginia Beach, VA 23452 Email: aperrott@odu.edu	Tel: (757) 409-1368

ACADEMIC DEGREES

In Progress	Old Dominion University Norfolk, VA	Ph.D. Special Education Concentration: Communication Disorders (Dr. Stacie Raymer)
1997-1999	Old Dominion University Norfolk, VA	M.S. Speech-Language Path (Dr. Nicholas Bountress)
1994-1997	Old Dominion University Norfolk, VA	B. S. Speech-Language Path Audiology; Minor Special Education (Dr. Nicholas Bountress)

PROFESSIONAL EXPERIENCE

Academic

2006-2010	Old Dominion University Norfolk, VA	Adjunct Instructor and GTA (Communication Disorders/Special Education)
2006-2010	Old Dominion University	Adjunct Clinical Supervisor (Child Study Center)

Non-Academic

2005-2007	Atlantic Speech Therapy, Virginia Beach, VA Speech-Language Pathologist
2004-2005	Children's Hospital of the Kings Daughters, Norfolk, VA Speech-Language Pathologist
2001-2004	Cumberland Hospital, New Kent, VA Lead Speech-Language Pathologist
2000-2001	Chesapeake Public Schools, Chesapeake, VA Speech-Language Pathologist
1999-2000	Special School District of St. Louis County, St. Louis, MO Speech-Language Pathologist

PUBLICATIONS

Journal Articles

*non-refereed

Raver, S., Bobzien, J., Richels, C., Hester, P., Michalek, A., & Anthony, N. (in press). Effect of parallel talk on the language and interactional skills of preschoolers With cochlear implants and hearing aids. *Literacy Information and Computer Education Journal*.

Raver, S. A., Michalek, A., & Gillespie, A. (2011). Major stressors and life goals of caregivers of individuals with disabilities. *Journal of Social Work in Disability & Rehabilitation, 10*(2), 115-128. doi: 10.1080/1536710X.2011.571536

*Raver, S. A., Bobzien, J., Richels, C., Hester, P., Michalek, A., & Anthony, N. (2011). Parallel Talk: Effects on the Language and Interactional Skills of Preschoolers with Deafness. *Proceedings from the Ireland International Conference on Education, Dublin, Ireland*, pp. 89-96.

Raver, S. A., Michalek, A., Michalik, J. & Valenta, M. (2010). Comparison of quality of life perceptions of caregivers of individuals with intellectual disabilities in the United States and the Czech Republic. *The Journal of the International Association of Special Education, 11*(1), 22-30.

Manuscripts Under Review

Childress, D., Raver, S. A., Michalek, A. M. P., & Wilson, C. (in review). Enhancing service coordination knowledge through effective professional development: An investigation of the kaleidoscope training. *Topics in Early Childhood Special Education*.

Raver, S. A., Hester, P., Michalek, A. M. P., Cho, D., & Anthony, N. (in review). Impact of activity mini-schedules on the attention and communication skills of preschoolers with cochlear implants. *Journal of Deaf Studies and Deaf Education*.

Watson, S., Raymer, A., Richels, C., & Michalek, A. M. P. (in review). Psychosocial Treatments for ADHD: A Systematic Appraisal of the Evidence. *Learning Disability Quarterly (LDQ)*.

Monographs

Raver, S. A., Michalek, A. M., Michalik, J., & Valenta, M. (in press). Quality of life of caregivers of individuals with intellectual disabilities in the United States and the Czech Republic: A comparison. In M. Valenta, & J. Michalik, *Quality of life of Caregivers (Kvalita života osob pečujících o osobu se zdravotním postižením)*.

Prague, Czech Republic: Czech National Research Agency.

PROFESSIONAL ACTIVITIES

Professional Workshops and Presentations

Raver, S., Bobzien, J., Richels, C., Hester, P., Michalek, A., & Anthony, A. (2011). Parallel talk: Effects on the language and interactional skills of preschoolers with deafness. Ireland International Conference on Education, Dublin, Ireland, October 5, 2011.

Raver-Lampman, S., & Michalek, A. "Caregivers perceptions in the United States and the Czech Republic." Presented to the International Council for Exceptional Children Conference (CEC); National Harbor, MD, April 26, 2011.

Michalek, A. M. P., Richels, C., Watson, S., & Raymer, S. M., "Psychosocial Treatments for ADHD: A Systematic Appraisal of the Evidence," 39th Annual International Neuropsychological Society Meeting, Boston, MA, February 4, 2011.

Michalek, A. M. P., & Watson, S., "Connecting the Pieces: Working Memory, Executive Functions, & Written Language," American Speech-Language Hearing Association Convention, Philadelphia, PA, November 19, 2010.

Watson, S., Gable, R., Michalek, A. "The Role of Attention and Working Memory in Student Learning," Second International Conference on Education Research, New Orleans, LA, September 27, 2010.

Raver, S. A., Hester, P., Michalek, A. M. P., & Cho, D., "Impact of Activity Mini-Schedules on the Communication and Attentional Skills of Preschoolers with Hearing Loss," The International Conference for Exceptional Children (CEC), Nashville, TN, April 24, 2010.

Local Workshops and Presentations

- Michalek, A. M. P., Watson, S. "Working Memory: What Does it mean for an SLP?", Annual Conference: Speech-Hearing Association of Virginia, Vienna, VA, March 17, 2012.
- Michalek, A. M. P. (invited lecturer) "Legal Aspects: Students with Learning Disabilities", Old Dominion University, Norfolk, VA, March, 2010, February, 2011, and October, 2011.
- Michalek, A. M. P., Watson, S. "Understanding Conceptual Models of ADHD for Improved Practice," Annual Conference: Speech-Hearing Association of Virginia, Portsmouth, VA, March 13, 2010.
- Watson, S., Michalek, A. M. P. "What does Brain Based Research Reveal about Learning Disabilities?" Annual Conference: Speech-Hearing Association of Virginia, Portsmouth, VA, March 12, 2010.
- Raver, S., Michalek, A. M. P. "Major Stressors and Life Goals of Caregivers of Individuals with Disabilities," Virginia State Council for Exceptional Children Conference, Virginia Beach, VA, October 17, 2009.
- Bountress, M., Fleming, K., Williams, L., Nicholson, C., Burris, C., Michalek, A. M. P., "What's Hot in Supervision: From Theory to Practice," Annual Conference: Speech-Language Hearing Association of Virginia, Richmond, VA, February 28, 2009.

Teaching

Courses Taught:

Articulation and Phonological Disorders
 Clinical Practicum I, II, III
 Orientation to Clinical Procedures
 Survey of Communication Disorders

Research

Completed Projects

- | | | |
|------|---|-------------------------|
| 2010 | Effectiveness of parallel talk on pragmatic skills of preschoolers with cochlear implants (data manager with Raver, S. A., Hester, P., Richels, C., Bobzien, J., and Anthony, N.) | Old Dominion University |
| 2010 | Using fMR brain imaging to compare regions-of-interest activations during motor and overt | |

- language tasks in adult stroke patients
(data manager with Chuang, N.) Old Dominion University
- 2010 Effectiveness of social stories on
communication skills of preschoolers with
cochlear implants (data manager with
Raver, S. A., Hester, P., Maydosz, A.,
and Bobzien, J.) Old Dominion University
- 2009 Effectiveness of mini-schedules on
communication skills of preschoolers with
cochlear implants (data manager with
Raver, S. A., Hester, P., Maydosz, A.,
and Bobzien, J.) Old Dominion University

Pending Projects

- 2011 Impact of noise and working memory on
speech processing in adults with and without
ADHD (dissertation project with Raymer, A. M.,
Watson, S. A., and Ash, I.) Old Dominion University

HONORS

- 2011 Recipient of the Kimberly Gail Hughes Research Award from Old
Dominion University, Norfolk, VA
- 2011 Selected to be spotlighted in the Office of Graduate Studies
monthly newsletter, Old Dominion University, Norfolk, VA
- 2010 Admitted Golden Key National Honor Society, Old Dominion
University, Norfolk, VA
- 2010 Nominated for the Outstanding Classroom Graduate Teaching
Assistant Award within Old Dominion University's College of
Education, Old Dominion University, Norfolk, VA
- 2005 Recipient of several GOTCHAS for excellence in service and
quality of care, Children's Hospital of the Kings Daughters,
Norfolk, VA

CERTIFICATION AND LICENSURE

Speech-Language Pathology License, Board of Audiology and Speech-Language
Pathology, Commonwealth of Virginia

Certificate of Clinical Competence, American Speech-Language Hearing Association

MEMBERSHIP IN PROFESSIONAL SOCIETIES

1999-Present	American Speech-Language Hearing Association
1999-Present	Speech and Hearing Association of Virginia
2010-Present	Council for Exceptional Children

PROFESSIONAL SERVICE

Michalek, A. M. P., "TBI and Communication Tools." Presented to acute care staff at Cumberland Hospital, New Kent, VA, May 9, 2005.

Michalek, A. M. P., "Neuroanatomy and Behavior." Presented to each orientation class for Cumberland Hospital, New Kent, VA, March 2003-January 2004.

Presenter, "Escape from Holland: Strategies for Facilitating Effective Communication." Presented to the rehabilitation department at Cumberland Hospital, New Kent, VA March 17, 2003.

Presenter, "Alert Group." Presented to all employees at Cumberland Hospital, New Kent, VA, September 10, 2003.

Presenter, "Dysphagia." Presented to all employees at Cumberland Hospital, New Kent, VA, October 23, 2003.