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ATTENTION TO TELEVISION IN PRESCHOOLERS WHO EXHIBIT ADHD
SYMPTOMS: AN ERP INVESTIGATION

A Dissertation Presented

by

LINDSAY B. DEMERS

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
Of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

ATTENTION TO TELEVISION IN PRESCHOOLERS WHO EXHIBIT ADHD SYMPTOMS: AN ERP INVESTIGATION

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Children with ADHD suffer from low and high order attention deficits. Work by E.P. Lorch and colleagues shows that these attention deficits affect televised narrative comprehension. The purpose of this research was to determine the extent to which the televised narrative comprehension deficits are the result of an inability to inhibit processing of irrelevant information. To achieve this, data were collected from 16 healthy adults and 37 preschool age children who varied in their ADHD symptoms. Participants were instructed to attend to one of two simultaneously presented audio tracks from children's television shows. For all participants the video that matched the target audio track was presented on a screen in front of them. Throughout viewing, white noise probes were played from the same locations as the attended and unattended audio tracks. Each participant sat through two different televised narratives. Narrative comprehensibility was manipulated within-subject such that each participant saw one comprehensible narrative and one incomprehensible narrative. Throughout both, EEG was recorded and subsequently time-locked to the presentation of the auditory probes from the attended and

unattended locations. After each narrative, participants were asked to recall aspects of the story that were either central or peripheral to the causal chain of events. The morphology of the participants' auditory evoked potentials followed the expected pattern (a positive-negative-positive complex for adults and a broad positivity for children during the 300ms after stimulus onset). All participants showed greater processing of the probes from the attended location during the incomprehensible narrative than during the comprehensible narrative, which suggests that participants were processing more information from the attended location when the sequence of events in the narrative was unpredictable. Only children with relatively higher levels of ADHD symptoms showed processing of the probes during the comprehensible narrative. This pattern of results suggests that children with ADHD symptoms were as capable as the typically developing children and adults at the spatially selective attention task, but that they had difficulty engaging in selective attention within the target channel. Contrary to our hypotheses, the amount and type of information recollected did not differ by ADHD status.

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CHAPTER I

INTRODUCTION

Children with Attention-Deficit Hyperactivity Disorder (ADHD) exhibit behavioral and electrophysiological evidence of selective attention deficits (Brodeur & Pond, 2001; Barry, Johnstone, & Clark, 2003). A parallel line of research examining narrative comprehension and attention to television in ADHD children suggests that these children also suffer from high-order cognitive deficits that can impair academic performance (e.g., Bailey, Lorch, Milich & Charnigo 2009; Kendeou, Lynch, van den Broek, Espin, White, & Kremer, 2005). The purpose of the current research was to determine the extent to which the narrative comprehension deficits observed in ADHD children are the result of their inability to inhibit processing of irrelevant information or a result of their inability to make online judgments about content relevance. Data from a sample of typically developing adults were also collected in order to make qualitative age comparisons.

To provide a context for the current study, research findings from a variety of areas are discussed. To start, the theoretical impetus for this research will be provided with a review of the literature on ADHD, television viewing, and narrative comprehension. Then, relevant research on electrophysiological indices of selective attention will be discussed along with a particular focus on differences in auditory evoked potentials (AEPs) in adults, typically developing children and ADHD children.

ADHD: An Overview

Although the specific symptoms vary with subtype, in general, ADHD is characterized by seemingly inadequate endogenous attentional control, restlessness,

impulsivity and a difficulty with tasks that require sustained vigilance. According to Barkley (2006), approximately 2-12% of children in the United States meet the DSM-III criteria for ADHD. Although ADHD can be diagnosed into adulthood, the youngest age at which symptoms of ADHD can be distinguished from other behavioral disorders is three years (Achenbach, Edelbrock, & Howell, 1987).

The DSM-IV defines three subtypes of ADHD: PI (predominantly inattention), PHI (predominantly hyperactivity and impulsivity), and C (combined-type; inattention, hyperactivity, and impulsivity). In order for a diagnosis of ADHD-PI to be made, six out of nine diagnostic criteria of inattention must be met with symptoms having persisted for at least six months. For a diagnosis of ADHD-PHI to be made, six out of nine measures of hyperactivity and impulsivity must be met and have persisted for at least six months. If a minimum of six items is endorsed in both the inattention and hyperactivity categories, then the diagnostic criteria for ADHD-C type have been met (APA, 2000). In addition to meeting these criteria, patients must also have exhibited some symptoms of ADHD prior to age seven, must have evidence of impairment in two or more settings (e.g., school and home), and there must be clear evidence of impairment, whether it be social or academic (APA, 2000). For a listing of the DSM-IV diagnostic criteria, see Appendix A.

Although the exact cause of ADHD is unknown, mounting evidence suggests that the disorder is highly heritable, with children of ADHD parents having a 2 to 8 fold increase in the probability of developing ADHD (Faraone & Biederman, 2001). In a meta-analysis of the research on ADHD in identical twins, Faraone & Biederman (2001) estimated ADHD heritability to be about .80, suggesting that the disorder is caused

primarily, but not entirely, by genetic factors. Some environmental factors that research suggests may potentially cause or exacerbate ADHD symptoms include maternal substance abuse during pregnancy, maternal age, maternal health, complications during pregnancy and delivery, and low birth weight. Another oft cited environmental factor of particular relevance to the present research is television viewing.

ADHD and Television

Much of the research examining ADHD and television viewing has been correlational. Nonetheless, these data are frequently interpreted as providing evidence for a causal relationship between television viewing and subsequent ADHD symptoms. As Levine and Waite (2000) put it: “We seem to ‘know’ that television is the cause of the shortened attention span about which teachers at every level of educational instruction are concerned.” (p. 667). Despite assertions such as this, researchers have been unable to provide sufficient data to substantiate their claims of causality.

In their study, Levine and Waite (2000) had fourth- and fifth-grade students complete a one-week long home viewing diary and collected estimates of each child’s daily television viewing from parents. To gauge attentional abilities, teachers were asked to complete the ADD-H Comprehensive Teachers Rating Scale (ACTeRS) (cf. Ullman et al. 1991) and parents were asked to complete the Distractibility/Hyperactivity scale (DI) of the Parenting Stress Index (cf. Abidin, 1995). Additionally, children were observed in the classroom, where researchers kept track of children’s behavior (e.g., getting out of seat, fidgeting, and excessive talking). Children were also given the Stroop Color and Word Test as a measure of impulsivity. The authors found that television viewing in the home was negatively associated with teachers’ ratings of students’ attentional abilities

but that no such relationship existed for parents' reports, classroom observations, or performance on the Stroop Color and Word Task.

Christakis, Zimmerman, DiGiuseppe and McCarty (2004) erroneously examined the relationship between early television exposure (i.e., prior to two years of age) and later attentional difficulties. Their data were collected from a nationally representative sample via telephone interviews. Parents were asked how many hours per day their children watched television on a typical weekday and weekend day. A few years later parents were re-contacted and asked to rate their children on five criteria of inattention and hyperactivity/impulsivity. In the initial report, the authors claimed that after controlling for a wide range of relevant variables (e.g., race, sex, maternal tobacco or alcohol use during pregnancy), the number of hours of television per day at the first interview significantly predicted endorsement of the five criteria of inattention and hyperactivity/impulsivity at the time of the second interview. However, reanalysis of this data set by Foster and Watkins (2010) showed that the findings of Christakis and colleagues were an artifact of improper analytic techniques. Despite the work of Foster and Watkins, the initial paper by Christakis and colleagues is still oft cited as providing strong evidence for a relationship between TV viewing and ADHD.

Miller, Marks, Miller, Berwid, Kera, et al. (2007) looked at the relationship between television exposure and symptoms of ADHD in preschool aged-children. In their study parents and teachers were asked to complete a checklist containing the DSM criteria for ADHD; television-viewing data were collected by asking parents how many hours of television their child watched on an average weekday and weekend day. The measure of hyperactivity was an actigraph that recorded the number of movements per

minute over the course of two hours. After controlling for relevant variables, the authors found that TV viewing significantly predicted teacher report of ADHD symptoms as well as scores on the actigraph. No such relationship existed for parent report of ADHD symptoms, however.

Zimmerman & Christakis (2007) looked at the association between type of content and later attentional problems. Data were collected from a nationally representative sample using ‘time use’ diaries which parents were asked to complete on one randomly chosen weekday and one randomly chosen weekend day. Measurement of inattentive and hyperactive/impulsive behaviors was later collected from parents using an inventory of traits derived from the Achenbach Child Behavior Checklist (cf. Achenbach, 2000). The authors found that viewing of educational content prior to age three was not associated with subsequent ratings of inattentional/hyperactive behaviors. However, viewing of entertainment-based content was positively associated with subsequent ratings of inattentional/hyperactive behaviors.

Perhaps the most thorough examination of the relationship between television viewing and ADHD symptoms is provided by Miller, Miller, and Halperin (2009). In their study, which is ongoing, preschool age children who exhibit early signs of ADHD are being assessed annually with regard to their symptoms and their television viewing patterns. Using structural equation modeling, the authors have found that at baseline assessment, television viewing and ADHD symptoms are predictive of each other (a feedback loop). However television viewing at baseline is not predictive of ADHD symptoms observed at subsequent assessments whereas ADHD symptoms at baseline are predictive of television viewing at subsequent assessments. Although it is impossible to

unequivocally determine the direction of the relationship given that the data are correlational, by employing advanced statistical methods the authors make a strong case for the notion that television viewing does not cause ADHD symptoms, but that children with ADHD symptoms are more likely to watch television.

The possibility that children with ADHD are more inclined to watch television is not surprising when one considers the social and cognitive circumstances that can accompany the disorder. For example, children with ADHD may watch more television than typically developing children because they have difficulty engaging in other leisure activities due to co-morbid disorders. Although estimates vary, research suggests that somewhere between 8% and 39% of ADHD children are likely to have a reading disability (Barkley, 2006). For obvious reasons, the prevalence of these disabilities would make reading an unlikely pastime for children with ADHD. Also, some research suggests that children with ADHD face higher rates of peer rejection and report having fewer friends than their typically developing peers (e.g., Bagwell, Molina, Pelham & Hoza, 2001). An increase in peer rejection may make children with ADHD more prone to engage in solitary activities, such as television viewing.

Moreover, research suggests that children with ADHD are easily bored and have difficulty persevering through their boredom (Barkley, 1996). There is evidence to suggest that viewers can become engaged with a television program in as little as 15 seconds (e.g., Anderson, Choi & Lorch 1987; Lorch and Castle 1997; Richards and Turner, 2001), which could provide ADHD children with an opportunity to become engaged in an activity using relatively little effort and requiring virtually no conscious perseverance. However, given that these children do have cognitive deficits relative to

their typically developing peers, it cannot be assumed that children with ADHD watch television for the same reasons as typically developing children or that these children extrapolate the same information from televised narratives. In order to better understand how children attend to television and how the presence of ADHD symptoms might affect comprehension of televised narratives, the next part of this literature review considers research on attention to and comprehension of television in typically developing and ADHD children.

Attention to Television

Children first exhibit interest in television at about 9 months of age (Linebarger & Walker, 2005). From then until about age 5 there is a steady increase in attention to television, with apparently purposeful viewing and comprehension by about 2.5 years and a peak in visual attention occurring at about 11 years (Anderson, Lorch, Field, Collins & Nathan, 1986; Anderson and Levin, 1976; Anderson and Lorch, 1983). Huston and Wright (1983) argued that early in life, children's television viewing is driven by the perceptual salience of formal features. Formal features are attributes of television programming that result from a variety of production and editing techniques. These attributes include different camera techniques such as pans and zooms, varying editing techniques (e.g. the pacing of cuts), and also different auditory events such as music, sound effects, and voices. These attributes function independently of content, though typically certain types of content utilize certain formal features (e.g., several fast-paced cuts in an action sequence). According to Huston and Wright, with increased exposure to television as well as cognitive maturation children begin to rely less on perceptual salience of formal features to guide their looks to and from the television and begin to

more heavily weight the comprehensibility of the content conveyed by the program.

One way to determine the extent to which attention to television is driven by perceptual salience versus content comprehensibility is to manipulate a televised narrative such that the density of the formal features is maintained, but the comprehensibility of the content is reduced. Anderson, Lorch, Field and Sanders (1981) showed 2-, 3-, and 4-year-old children comprehensible and incomprehensible versions of *Sesame Street*. The incomprehensible segments were distorted in one of three ways: (1) the clips were randomly edited within each segment so that the formal features of the program were consistent, but that the story did not unfold sequentially; (2) each utterance by a character was edited so that it came out backwards, leaving the sequence of the segment intact but making it impossible to understand what the characters were saying; and (3) the English audio track was replaced so that all of the characters spoke in Greek. The children were shown an entire 60-minute episode of *Sesame Street* comprised of comprehensible and incomprehensible segments. The authors found that across ages, children looked more at the comprehensible segments than the incomprehensible segments, suggesting that children as young as 2-years of age rely, at least to some extent, on content comprehensibility in determining when to look at the television.

In order to see at what age the shift from perceptual salience to content comprehensibility occurs, Pempek, Kirkorian, Richards, Anderson and Lund (2010) assessed infant attention to the program *Teletubbies* using similar methods as Anderson et al., (1981), but with infants aged 6, 12, 18 and 24 months. Children were shown a normal clip of *Teletubbies*, along with a distorted clip (either randomly edited or with dubbed backwards speech). The results of this study showed that the 18- and 24-month-

old infants were sensitive to content comprehensibility (as measured by mean look length and heart rate), but that the 6- and 12-month-old infants were not, suggesting that prior to the age of 18 months, children rely primarily on the perceptual salience of formal features in guiding their attention to television.

Further evidence for this change comes from Kirkorian, Keen and Anderson (2011). In their study, the authors showed 1-year-olds, 4-year-olds, and adults comprehensible and randomly edited segments of *Sesame Street* while recording where participants looked on screen. The authors found that with age, there was increased coherence in eye movements across participants, such that adults tended to look at the same place at roughly the same time, while 1-year-olds fixations were more scattered. This finding further supports the idea that children 18-months and younger do not apply systematic, purposeful visual attention to television.

Although the random edit manipulation considerably disrupts participants' online comprehension of a program, it is theoretically possible for participants to piece together the individual shots and to achieve global comprehension of the narrative, given that all of the information necessary to understand it is presented at some point. However, neuroimaging data from Anderson, Fite, Petrovich, and Hirsch (2006) suggest that despite the potential for global comprehension of an incomprehensible narrative, processing of a comprehensible narrative is the result of a unique network of neural activity. In their study, Anderson and colleagues looked at processing of comprehensible and randomly edited narratives in adults using functional magnetic resonance imaging (fMRI). Participants were shown six 40-second segments taken from Hollywood films. Of the six segments, two were comprehensible, two were comprised of randomly edited

together shots from the same film, and two were comprised of randomly edited together shots from a handful of films. The authors found that while viewing the comprehensible narrative, participants exhibited unique brain activity in several areas, including the posterior cingulate gyrus. With these results, the authors showed that processing of televised narratives requires a great deal of coordinated neural activity that likely reflects higher order cognitive processing of the narrative. Thus, contrary to early reports of television viewing as a passive activity (e.g., Winn, 1977) the findings from Anderson and colleagues showed that television viewing requires a great deal of cognitive activity. And, in particular, that for this unique network to be activated, the narrative must be comprehensible (i.e., unfold linearly).

Narrative Comprehension

In a given narrative, a great deal of information is presented. However, only a portion of this information is necessary for understanding the narrative itself (central content) while the remaining information could be considered peripheral. Generally, central content includes things that are part of the causal chain of events in the story (e.g., a character's motivation) and is required for creating a global representation of the narrative. Peripheral content consists of information that is not necessary for comprehension of the central narrative (e.g., the color of a character's shirt). Research on narrative comprehension has shown that with increased experience with narratives and with cognitive maturation, viewers become better able to differentiate between content that is central and content that is peripheral. In doing so, viewers pay more attention during parts of a narrative where central information is presented (Collins, 1970). By assigning greater significance to central content, viewers are able to more efficiently and

thoroughly understand the narrative.

Although children with ADHD are often reported as watching large amounts of TV and enjoying TV more than their typically developing peers (e.g., Acevedo-Polakovich, Lorch, & Milich, 2007) there is reason to suspect that they may have difficulty paying selective attention to information in a given narrative. According to Brodeur and Pond (1991) one explanation for the selective attention deficits observed in ADHD children is that they apply a uniform level of attention to all stimuli and are either not able to identify what information is worthy of more processing or cannot inhibit processing of the irrelevant stimuli. Given that efficient narrative comprehension relies on making the distinction between central and peripheral content as well as preferentially processing central content, it follows that children with ADHD may have deficits in narrative comprehension. In examining attention to and comprehension of televised narratives in ADHD populations, Lorch and colleagues have shown that this is the case.

In one study (Lorch, Bellack, & Augsbach, 1987) individual subjects were shown a 15-minute segment of the television show *3-2-1 Contact* in a room with an array of attractive toys. Under these conditions (i.e., with interesting distractors present) ADHD participants' looks toward the television were about half the length of the typically developing participants' looks, suggesting that the ADHD children may not have become as cognitively engaged with the program as the typically developing children (Anderson and Richards, 2004). However, ADHD participants' performance on a subsequent cued-recall task was only marginally different from that of the typically developing children, suggesting that this lack of visual attention did not have an adverse effect on ADHD children's narrative comprehension.

Landau, Lorch, and Milich (1992) showed ADHD and typically developing children a 15-minute segment of *3-2-1 Contact* and manipulated whether or not toys were present in the room. The authors found that when toys were present, ADHD children looked at the television significantly less than control subjects. However, when toys were not present, the two groups did not differ in their visual attention to the television. With regard to story comprehension there was, again, only a marginal deficit observed for the ADHD children in the toys-present condition.

Milich & Lorch (1994) note a few methodological problems with Lorch et al. (1987) and Landau et al. (1992). First, the television viewing sessions in both studies lasted only 15 minutes, which may have been an insufficient amount of time to observe differences in attention and comprehension between the children. Second, the program used in each study was primarily educational and there was little need for participants to create a global representation of the narrative and to infer causal links between events. To address these two issues, Milich & Lorch (1994) showed ADHD and typically developing children a 75-minute video that varied program content such that a third of the programming was educational (*3-2-1 Contact*), a third was comedic (*Growing Pains*) and a third was an action/adventure (*Danger Bay*). Although data on participants' visual attention to the television was not included due to a design flaw, the authors were able to look at differences by comprehension question type between the groups. These analyses showed that the ADHD and typically developing participants did not differ in their recall for factual or causal information for the educational program. However, the two groups did differ in their ability to recall causal information for the comedy and action/adventure programs, such that ADHD children recalled significantly less causal information than

typically developing children. These findings suggest that when there is a need to make implicit causal connections and to make independent distinctions between central and peripheral content, that children with ADHD show deficits in their ability to recall parts of the narrative.

To determine if these deficits were the result of inefficient attending on the part of the ADHD children, Lorch, Milich, Astrin and Berthiaume (2006) deconstructed an episode of *Growing Pains* into segments that featured central content and segments that featured peripheral content. Next, they purposefully placed auditory probes at different points during central segments and peripheral segments, either 2, 7 or 12 seconds into the sequence. Children were told that their primary task was to watch the television program, and that their secondary task was to ‘turn-off’ any additional noise they heard throughout the program by pressing a spacebar on the keyboard in front of them.

For the typically developing children, the later into a central sequence a probe was presented, the greater the reaction time in the secondary task. For the ADHD children, response times on the secondary task did not vary as a function of time into the segment. These findings suggest that when central content was being presented, the typically developing children appropriately increased their attention to the information on screen, while the ADHD children did not show any changes in cognitive engagement. For the peripheral sequences, children with ADHD had significantly greater reaction times than the typically developing children in the secondary task, suggesting that the ADHD children were assigning greater significance to the peripheral content compared to the typically developing children. Together, these findings support the idea that children with ADHD have difficulty applying differential amounts of attention to relevant and

irrelevant information, which results in a deficit in narrative comprehension.

Summary and Conclusions

In sum, the literature reviewed here has shown that there is a fairly consistent link between ADHD and TV viewing. While the causal nature of this relationship has yet to be determined, some evidence suggests that children with ADHD are more likely to watch television than their typically developing peers. Although ADHD children may spend more time watching television than typically developing peers, they appear to have a deficit in narrative comprehension, particularly when understanding of the narrative requires that they make implicit connections between events in the story. One likely possibility for this difficulty is that children with ADHD apply a blanket level of attention to all the information presented in a narrative and do not appropriately vary their cognitive engagement based on content centrality.

The current study sought to build on the existing research on narrative comprehension in ADHD children by employing the random edit manipulation introduced by Anderson et al. (1981). Another unique aspect of the current research is that attention was examined using electrophysiological measures. Particularly, we employed a free field dichotic listening task in which selective attention was measured by event related potentials (ERPs). Thus, a brief review of this literature is necessary to understand the rationale for and discussion of the methods employed here.

Electrophysiological Indices of Spatially Selective Attention

In a now classic study, Hillyard, Hink, Schwent and Picton (1973) presented adult participants with two concurrent audio streams comprised of tone pips and asked participants to attend to only one of the streams. During the task, EEG

(electroencephalogram) was recorded from participants' scalps. The occurrence of the tone pips was time locked to the EEG recording and these events were averaged, resulting in an average 'attended' auditory evoked potential and an average 'unattended' auditory evoked potential for each participant. The morphology of these auditory evoked potentials (AEPs) was such that there was an early positive deflection followed by a negative deflection and then a later positive deflection, all of which unfolded over the 400ms following stimulus onset. Although the morphology of the AEPs did not differ as a function of stimulus location, the magnitude of the AEPs did such that, for the first negative deflection, there was a significant, negative difference between the magnitude of the AEPs to tone pips played at the attended location and the magnitude of the AEPs to tone pips played at the unattended location. This significant difference was interpreted to be the result of increased processing of information played from the attended location compared to information played from the unattended location.

The paradigm employed by Hillyard and colleagues has since been used numerous times to measure spatially selective attention in adults (e.g., Hansen et al., 1983; Hillyard, 1981). Across these studies, the positive (P1) - negative (N1) - positive (P2) oscillation of the AEPs has been observed with evidence of spatially selective attention manifested as a negative difference between the N1 to stimuli presented at the attended location and the N1 to stimuli presented at the unattended location and, in some cases, a positive difference between the P2 to stimuli presented at the attended location and the P2 to stimuli presented at the unattended location (Naatanen, 1990; Schroger & Elmer, 1997). Relative to the amount of research on ERP indices of spatially selective attention in adults, very few studies have considered this phenomenon in young children.

Coch, Sanders, and Neville (2005) examined spatially selective attention in adults and in children 6 to 8 years of age using a modified version of the Hillyard paradigm. In their study, participants were instructed to selectively attend to a recording of a narrator reading from a children's book and to ignore a recording of a different narrator reading a different children's book while EEG was recorded. Throughout the presentation of the narratives, auditory probes (e.g., a buzz sound) were played in each of the audio streams, (though not simultaneously). The continuous EEG recording was time locked to the presentation of the auditory probes these events were averaged, resulting in an average series of AEPs to probes played from the same location as the attended narrative and an average series of AEPs to probes played from the same location as the unattended narrative.

For the adults, the morphology of the AEPs followed the expected pattern, with a positive deflection occurring between 50 and 100ms after stimulus onset (P1) a negative deflection occurring between 100 and 200ms after stimulus onset (N1) and a later positive deflection occurring between 200 and 400ms after stimulus onset (P2). There was also a negative difference observed for the N1 time window, indicating greater processing of the probes played at the same location as the attended narrative compared to the probes played at the same location as the unattended narrative. Notably, the magnitude of the N1 observed by Coch et al. (2005) was attenuated, relative to previous reports in which AEPs were collected from sounds played in isolation (e.g., Hillyard et al., 1973).

For children, the morphology of the AEPs did not exhibit this typical positive-negative-positive oscillation. Rather, they showed a broad positivity that occurred

between 100 and 300ms after stimulus onset. Although morphologically distinct from the adults' AEPs, childrens' AEPs did show evidence of spatially selective attention such that the positivity elicited by probes played from the attended location was significantly larger than the positivity elicited by probes played from the unattended location.

Using a similar paradigm Sanders, Stevens, Coch, and Neville (2006) replicated the findings of Coch et al. (2005) and extended them to include 3 to 5-year-old children. Similar to their older counterparts, the younger children exhibited a broad positivity 100 to 200ms after stimulus onset that was modulated by attention, such that the positivity elicited by the probes played from the attended location was significantly greater than the positivity elicited by the probes played from the unattended location.

The findings of Coch et al. (2005) and Sanders et al. (2006) were important for several reasons. First, they provided electrophysiological evidence of spatially selective attention in children as young as three years of age. Second, they demonstrated that spatially selective attention could be indexed in adults and children by embedding auditory probes within a more engaging stimulus and without explicitly instructing participants to attend to the probes. Finally, their results showed that the morphology of AEPs was influenced by both cognitive maturity and the auditory density of the environment, which has important implications for the interpretation of AEPs as well as for understanding the development of spatially selective attention. Although in both studies adults' AEPs showed the typical P1-N1-P2 complex, the amplitude of the N1 was attenuated compared to what would be expected in a sparser auditory environment, such as that of Hillyard et al. (1973). Further, children's AEPs did not include an N1 at all, and instead were characterized by a broad positivity following stimulus onset. Previous

reports on spatially selective attention in children in this age range show that children's AEPs do exhibit the typical positive-negative-positive oscillation and a negative processing difference for the N1 to sounds played in sparse auditory environments (e.g., Bartgis, Lilly, Thomas, 2003). The fact that adults showed an attenuated N1 and children did not show one at all suggests that the density of the auditory environment in which the AEPs are being measured dictates, at least to some extent, the magnitude of the N1 to both the attended and unattended stimuli and, further, that the N1 component is more refractory in young children (Sanders et al., 2006; Sanders, Astheimer, Zobel, Breen & Demers, 2010).

Spatially Selective Attention in ADHD-like Populations

Although it is well established that children and adolescents with ADHD exhibit selective attention deficits (Brodeur and Pond, 1991) only handful of studies have examined spatially selective attention using ERPs in ADHD populations. Zambelli, Stamm, Maitinsky, and Loiselle (1977) compared the AEPs of adolescent boys who had been referred for hyperactivity during their childhood to the AEPs of a group of typically developing boys under two conditions. In one condition, participants were presented with a single auditory stream made up of a series of clicks. In the second condition, participants were presented with concurrent auditory streams comprised of tonal pips asked to selectively attend to one. Throughout both conditions, EEG was recorded. In the monaural condition (clicks only) the authors found no differences in peak waveform amplitude as a function of ADHD status. However, in the dichotic listening condition there was a significant negative processing difference for the typically developing boys during the N1 time window but not for the hyperactive boys, suggesting selective

attention deficits in the latter group.

Loiselle, Stamm, Maitinsky, and Whipple (1980) replicated the dichotic listening condition used by Zambelli et al. (1977) on a similar sample of typically developing and hyperactive adolescent boys. Again, the data suggested spatially selective attention deficits in the hyperactive boys compared to their typically developing counterparts. Taken together, the findings described above suggest the presence of spatially selective attention deficits in hyperactive boys.

In addition to these two studies, there is a wealth of literature that has examined electrophysiological differences between typically developing and ADHD populations. However, the findings from this line of research are quite varied, with some showing deficits in processing of auditory and visual stimuli in ADHD and ADHD-like populations and others showing no differences (for a review, see Barry et al., 2003). In terms of the N1, research suggests that amplitude differences between typically developing and ADHD populations are not manifested until between 7-9-years of age (Holcomb, Ackerman, & Dykman, 1986; Satterfield, Schell, & Nicholas, 1994) and that after this time, there are amplitude differences between the groups such that participants with ADHD show decreased waveform amplitude (e.g., Johnstone, Barry, & Anderson, 2001, Loiselle et al., 1980, Zambelli et al., 1977). With regard to the P2, research suggests that ADHD populations exhibit greater amplitude during this time window compared to typically developing populations (e.g., Satterfield et al., 1994). Specifically, in situations in which both attended and unattended information are presented, Satterfield et al., observed a smaller amplitude P2 to attended auditory information (compared to unattended information) in typically developing 6-year-olds, while the opposite pattern

emerged for 6-year-olds with ADHD. There were no differences in the amplitude of the P2 to unattended information across the groups. However, the authors concluded that these differences were due to different morphology of the AEPs across the groups – particularly the presence of an early negativity in only the typically developing participants – which was indicative of a deficient preferential processing in the ADHD participants.

To date, no available research has examined AEPs in preschool children with symptoms of inattention or hyperactivity. The research that is available has focused on older children and has focused almost exclusively on males due to the increased preponderance of ADHD in that group. However, given that many of the studies reviewed do show, at least, electrophysiological differences in the AEPS of typically developing and ADHD children, and in light of the findings from Sanders et al., 2006, we expected that we might see group differences, although it was unclear the exact pattern which these findings may exhibit.

Summary and Implications for the Current Research

A great deal of research from Lorch, Milich and colleagues has shown that children with ADHD suffer from high order cognitive deficits, particularly in making implicit connections between events in a narrative. Relatively less research has examined spatially selective attention in ADHD populations, though the work that has been done suggests some deficit in selective perception. Although previous research suggests that ADHD children's difficulty with narrative comprehension stems from their tendency to apply a blanket level of attention to all information presented, it is not clear if this is due to a cognitive deficit (i.e., not being capable of determining what information is central

versus what information is peripheral) or a perceptual deficit (i.e., being able to make the cognitive distinction, but being unable to inhibit processing of the irrelevant information). The primary objective of the current research was to begin to parse apart those possibilities by combining the random edit manipulation first used by Anderson et al. (1981) with the spatially selective attention paradigms employed by Coch et al. (2005) and Sanders et al. (2006).

In the current study, participants were asked to selectively attend to two 10-minute televised narratives while ignoring a competing audio track from another narrative. One of the narratives was comprehensible and one of the narratives was rendered incomprehensible via random edit. The video for the attended narrative was shown on a screen in front of participants. At the end of each narrative, participants' recollection of the events in the attended narrative was measured. Throughout both blocks of the experiment white noise probes were played from the same location as the attended narrative and from the same location as the unattended narrative, though not simultaneously. The continuous EEG recording was time locked to the presentation of the white noise probes and averaged, resulting in an average series of AEPs for the attended narrative (comprehensible and incomprehensible) and an average series of AEPs for the unattended narrative (comprehensible and incomprehensible).

Based on previous literature, we hypothesized that adults would show the typical P1-N1-P2 oscillation and that the typically developing and ADHD children would exhibit a broad positivity in place of the N1. For adults, attention modulation would be exhibited as a negative difference between the attended and unattended AEPs for the N1 and, potentially, a positive difference between the attended and unattended AEPs for the P2.

For the typically developing children, attention modulation would be exhibited as a positive difference between the attended and unattended AEPs during a broad positivity approximately 100-200ms after stimulus onset. The extent to which ADHD children's AEPs would show evidence of attention modulation was left open-ended. On one hand, previous research has shown that these children will pay equal amounts of visual attention to television in the absence of distractors, so we might not expect to see differences in their AEPs compared to typically developing children. On the other hand, the few studies that have looked at ERP indices of selective attention suggest that these children may have difficulty selectively attending and, thus, may not show attention modulation in their AEPs.

An additional line of research questions emerges when the comprehensibility manipulation is considered. By manipulating the comprehensibility of the narrative, we were able to examine how higher order cognition was associated with lower order processing. Though, how, if at all, this increase in cognitive load might be manifested in AEPs was unknown. Given that children with ADHD do not seem to make implicit causal connections between events in televised narratives, one might expect that those children's AEPs would be unaffected by the comprehensibility manipulation, whereas typically developing children and adults may show neurocognitive changes based on narrative comprehensibility.

By examining differences in AEPs across and within the groups, as well as considering participants' ability to recollect central and peripheral content from the narratives, the findings from the current study begin to address the question of whether ADHD children's difficulty in strategically applying attention comes from a lack of

exogenous attentional control or from an inability to determine content significance within a given channel. If the former, then we might expect to see no attention modulation in the children who exhibit ADHD symptoms. If the latter, then we might expect to see attention modulation, but deficient performance on the comprehension task relative to their typically developing peers.

To start, we report on findings from a group of healthy adults. The purpose of these adult data was twofold: first, to ensure that the setting and stimuli were effective at eliciting standard AEPs; and second, to provide a set of fully mature comparison AEPs with which to compare the children's AEPs.

CHAPTER II

EXPERIMENT 1

Method

Participants

The data described here came from 16 adults, with a mean age of 25.9 years (SD = 4.8). Approximately half of the sample ($n = 7$) was female. All participants reported being right-handed native English speakers with normal hearing and vision and with no known neurological disorders. No participant reported taking psychoactive medication. A majority of the sample was Caucasian (81.3%) while 18.7% of participants described themselves as multiracial. Additionally, 6.3% of the sample described their ethnicity as Hispanic. All participants were undergraduate or graduate students at UMass-Amherst. Each participant provided written consent and received research credits or payment in exchange for their participation. Data from five additional participants were excluded from the final analyses because of recording errors ($n = 3$) or because of high frequency noise in the data ($n = 2$).

Stimuli

The stimuli used here were taken from two children's television shows, *Clifford* and *Curious George*. Two 11-minute segments were taken from each show (four segments total: *Clifford Cleans* and *Jetta's Project* from *Clifford* and *George's Sand Castle* and *George the Sea Monkey* from *Curious George*).

During data collection, two audio tracks were presented from two speakers simultaneously, therefore it was of the utmost importance that the two tracks were equivalent as possible in terms of volume and auditory formal features. Thus, substantial

effort was used to select the four segments from which these stimuli were created. Twelve episodes from each series (24 narratives total) were coded for their auditory formal features, paying specific attention to the number of adult male voices, the number of adult female voices, the number of peculiar or child voices, and the number of sound effects. The segments from *Clifford* that most closely matched the segments from *Curious George* were paired throughout the study as the attended and unattended audio tracks. As it happened, whenever a participant heard *Clifford Cleans* from one speaker, *George the Sea Monkey* played from the other speaker and whenever a participant heard *Jetta's Project* from one speaker, *George's Sand Castle* played from the other speaker.

From each of the four segments, two sequences were created. In the first, the comprehensible sequence, the narrative unfolded linearly, as it normally would on television. In the second, the incomprehensible sequence, the narrative unfolded out-of-order. This was achieved using a method from Anderson et al. (1981) in which the raw video file was cut each time there was an edit in the video segment. After each shot had been isolated, they were randomly re-ordered, thus maintaining local comprehensibility and disrupting global comprehensibility. The segments ranged in length from 10 minutes and 46 seconds to 11 minutes and 3 seconds and had an average length of 10 minutes and 54 seconds.

Upon creation of the four incomprehensible sequences, each of the 8 video tracks (*Clifford Cleans*, comprehensible and incomprehensible; *Jetta's Project*, comprehensible and incomprehensible; *George's Sand Castle*, comprehensible and incomprehensible; and *George the Sea Monkey*, comprehensible and incomprehensible) was exported to a QuickTime video file. Then, each of the video tracks was scaled down to 36.1% so that

when played on the monitor, the entire video would be within 5 degrees of visual angle.

The 8 audio tracks were exported at 16-bit/48 kHz using Pro Tools audio editing software. A digital peak limiter was applied with identical settings to each sound track in order to achieve a more uniform dynamic range within and between the tracks. In addition to equating the audio tracks on volume and dynamicity, 200-sample cross fades, lasting approximately two frames, were placed at every cut for the incomprehensible sequences only. This was done to prevent the audio tracks for the incomprehensible sequences from sounding as though they had been artificially manipulated. The final video tracks were merged with their respective audio tracks and with the audio track from another one of the segments in Final Cut Pro.

As an additional check for consistency among the paired audio tracks, the finished files were normalized on a group of adult participants ($n = 10$) to ensure that the sound levels were perceptually matched between all 8 audio tracks and across all conditions. Each volunteer was asked whether one audio track sounded louder than the competing audio track, whether one was easier to follow (i.e., selectively attend to) than another, and if one seemed more distracting than another. Participants' responses indicated no disparity among the audio tracks.

In addition to the video and audio tracks taken from the raw video files, the stimuli also included bursts of white noise to which the EEG recording was time-locked. The probes were identical 50ms bursts of white noise with 4-sample onset and offset ramps. The ramps were applied to the sound files to prevent noise artifacts (e.g., clicks) that might have occurred from starting the white noise without any fade-in. An additional 10ms of silence was inserted at the beginning and end of the sound file. The silence was

added to the beginning and the end of the probe to ensure that the probe played in its entirety. Probes were presented 10 dB louder than the audio tracks that accompanied the video segments. A total of 780 probes were played during each session: 360 during the comprehensible narrative condition and 360 during the incomprehensible narrative condition. Within each condition, 180 of the probes were presented from the same location as the attended audio track, and 180 were presented from the same location as the unattended track.

Procedure

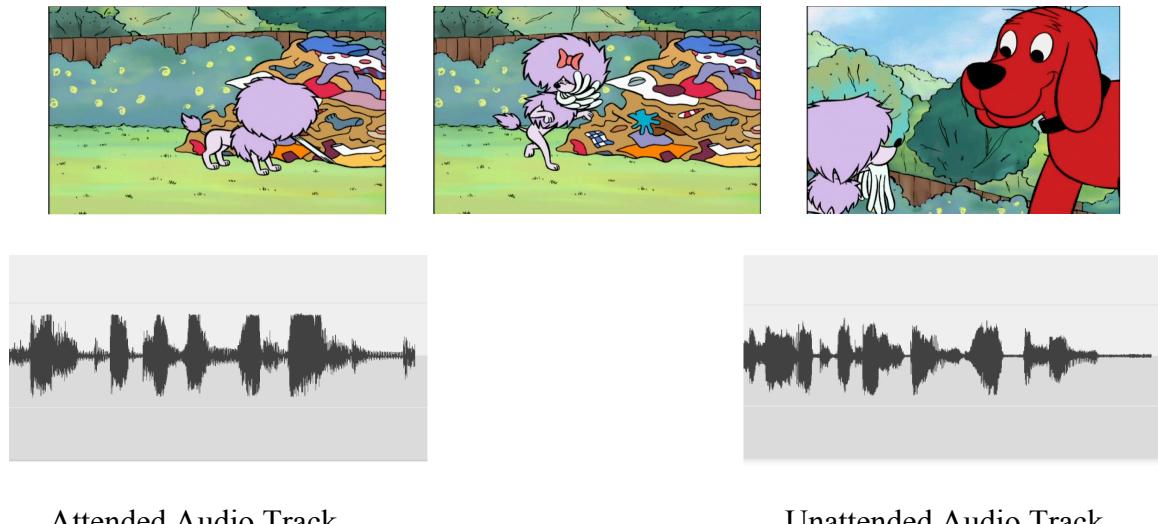
Upon arrival to the session, participants completed an informed consent and were given the opportunity to ask questions about the procedure. Next, each participant completed the Disruptive Behavior Rating Scale (DBRS) for adults (Barkley & Murphy, 1998) (See Appendix B). This scale is comprised of 18 items, each of which measures inattentiveness or hyperactivity and impulsivity on a scale from 0 (Never) to 3 (Very Often). Point values were summed across items and treated as a continuous variable to get a rough measure of each participant's level of inattentiveness and hyperactivity relative to the rest of the members of this non-clinical sample. In doing this, possible scores on this measure range from 0 to 54. In the current sample, the average score on the DBRS was 10.63 ($SD = 6.31$); scores ranged from 0 to 22.

Participants were also asked about the amount of time they spend watching television on an average weekday and weekend day. The value provided for an average weekday was multiplied by five and the value provided for the average weekend day was multiplied by two before being summed to estimate participants' average amount of TV viewing per week. The mean hours of weekly TV viewing was 11.9 ($SD = 7.50$) and

ranged from 0 to 21.

During the experiment, participants were seated in a chair approximately 1.5m from the video monitor and 1.4m from each of the speakers. Participants were told which location the attended audio track would be played from and that the audio track they were to attend to matched the video track.

Figure 1. Screenshots from *Clifford Cleans* with Accompanying Audio.



Throughout presentation of the audio-visual stimuli, 50ms white noise probes, were played pseudo-randomly from the same location as the attended audio track and from the same location as the unattended audio track with inter-stimulus intervals (ISIs) of 1000 - 2500ms. Time between probes was defined across location of presentation so probes were never simultaneously from the two locations. To ensure consistency across participants, prior to data collection, stimulus sound levels were measured at the approximate location where participant's heads would be during the experiment.

Because each participant watched two 11-minute segments (one comprehensible and one incomprehensible), each participant heard the audio from all four segments in either the attended or unattended auditory streams over the course of the session. In all

conditions, the video that matched the attended audio track was shown on screen. Taking into account the counterbalancing of attended and unattended side, as well as the counterbalancing of the comprehensible and incomprehensible narrative there were 16 possible orders (see Table 1).

Subsequent to viewing each narrative participants were asked to recall parts of the attended narrative only. Participants were not asked to recall anything about the narrative in the unattended audio track to discourage attempts to attend to both audio tracks (this is especially important for the child participants in Experiment 2). The adult participants were asked 6 questions about each of the attended narratives: 3 that required recollection of central content and 3 that required recollection of peripheral content.

Continuous EEG was sampled at a rate of 250 Hz and a bandwidth of .01-100 Hz from a 128-channel HydroCel Geodesic Sensor Nets (Electrical Geodesics Inc., Eugene, OR). Impedance was measured below 50 k Ω at every electrode at the beginning of the experiment and maintained below 100 k Ω for the duration of the study. A 60 Hz offline filter was applied to the EEG data. The EEG was divided into 600 ms time epochs using 100ms before to 500ms after the presentation of the white noise probes. Trials with differential amplitude larger than 100 μ V around the eyes or 150 μ V anywhere on the scalp were excluded from the final averages. Remaining trials that appeared to include artifacts from eye blinks, eye movements, or head motion were excluded based on visual inspection of the raw data. Data from the remaining trials were averaged by subject and condition, re-referenced to the average of the two mastoid electrodes, and corrected to the 100 ms pre-target baseline. For the incomprehensible narrative condition this included 115.38 trials (SD = 39.10) for attended, 115.63 trials (SD = 38.39) for unattended. For the

comprehensible narrative condition this included 110.38 trials ($SD = 38.53$) for the attended and 107.32 trials ($SD = 40.52$) for the unattended.

Measures

Data from 24 of the 128 electrodes were divided into a 4 (Anterior to Posterior – Levels A, B, C, and D) by 3 (Medial to Lateral – Levels 1, 2, and 3) by 2 (Left and Right Hemisphere) array (see Figure 2). These anterior and medial electrodes were selected for analysis based on previous literature showing evidence of auditory spatially selective attention over these regions (Coch et al., 2005; Sanders et al., 2006). Mean amplitude was measured at these electrodes across four time windows: 50-90ms after stimulus onset during the first positive peak (P1); 100 -150ms after stimulus onset during the first negative peak (N1); 150-250ms after stimulus onset during the second positive peak (P2); and 250-400ms after stimulus onset during a sustained negativity.

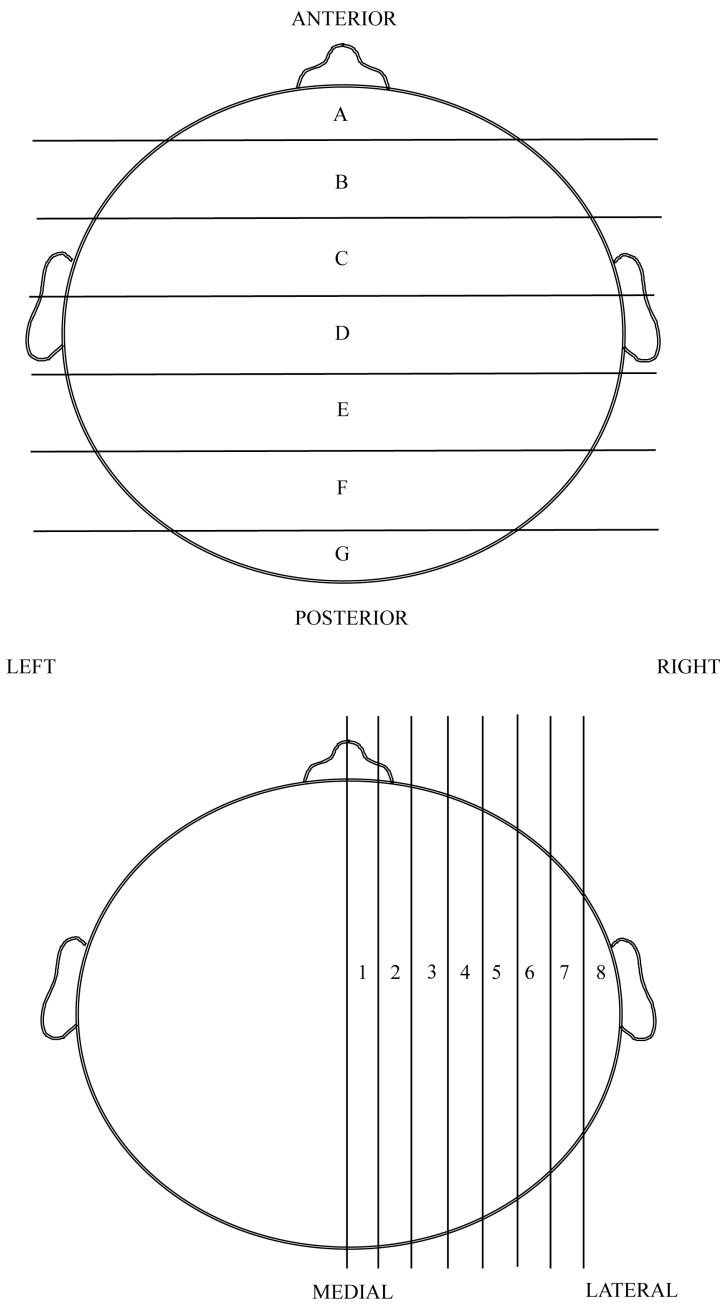
These data were included in a 2 (Attention: Attended and Unattended) x 4 (Anterior/Posterior) x 2 (Hemisphere) x 3 (Laterality) x 2 (Order: Incomprehensible First, Comprehensible Second or Comprehensible First, Incomprehensible second) mixed-model ANOVA. Visual inspection of the morphology of the waveforms for the comprehensible and incomprehensible narratives suggested that probes presented under these two conditions elicited distinct auditory evoked potentials. Further, preliminary analyses that included both the comprehensible and incomprehensible data consistently produced interactions between narrative comprehensibility, attention, and electrode location. Therefore, the data from the comprehensible and incomprehensible narratives were analyzed separately, resulting in a total of 8-mixed model ANOVAs (4 time epochs x 2 levels of comprehensibility).

Preliminary exploratory analyses examined whether adults' DBRS scores or their TV viewing in the home predicted the magnitude of attention modulation, however there were no significant relationships and these variables were not included in subsequent analyses. In order to maximize statistical power and reduce the probability of making a Type 1 error, only the main effect of and interactions with the Attention factor were tested. The Greenhouse-Geisser correction was applied to all *F* tests that included a factor with more than 2 levels

Table 1. Counterbalancing of Videos and Attended Side

	Narrative Segment #1		Narrative Segment #2	
	Attended (Right)	Unattended (Left)	Attended (Right)	Unattended (Left)
Order 1	Clifford Cleans (Incomprehensible)	George the Sea Monkey (Incomprehensible)	George's Sand Castle (Comprehensible)	Jetta's Project (Comprehensible)
Order 2	Clifford Cleans (Comprehensible)	George the Sea Monkey (Comprehensible)	George's Sand Castle (Incomprehensible)	Jetta's Project (Incomprehensible)
Order 3	Jetta's Project (Incomprehensible)	George's Sand Castle (Incomprehensible)	George the Sea Monkey (Comprehensible)	Clifford Cleans (Comprehensible)
Order 4	Jetta's Project (Comprehensible)	George's Sand Castle (Comprehensible)	George the Sea Monkey (Incomprehensible)	Clifford Cleans (Incomprehensible)
Order 5	George the Sea Monkey (Incomprehensible)	Clifford Cleans (Incomprehensible)	Jetta's Project (Comprehensible)	George's Sand Castle (Comprehensible)
Order 6	George the Sea Monkey (Comprehensible)	Clifford Cleans (Comprehensible)	Jetta's Project (Incomprehensible)	George's Sand Castle (Incomprehensible)
Order 7	George's Sand Castle (Incomprehensible)	Jetta's Project (Incomprehensible)	Clifford Cleans (Comprehensible)	George the Sea Monkey (Comprehensible)
Order 8	George's Sand Castle (Comprehensible)	Jetta's Project (Comprehensible)	Clifford Cleans (Incomprehensible)	George the Sea Monkey (Incomprehensible)
	Attended (Left)	Unattended (Right)	Attended (Left)	Unattended (Right)
Order 1	Clifford Cleans (Incomprehensible)	George the Sea Monkey (Incomprehensible)	George's Sand Castle (Comprehensible)	Jetta's Project (Comprehensible)
Order 2	Clifford Cleans (Comprehensible)	George the Sea Monkey (Comprehensible)	George's Sand Castle (Incomprehensible)	Jetta's Project (Incomprehensible)
Order 3	Jetta's Project (Incomprehensible)	George's Sand Castle (Incomprehensible)	George the Sea Monkey (Comprehensible)	Clifford Cleans (Comprehensible)
Order 4	Jetta's Project (Comprehensible)	George's Sand Castle (Comprehensible)	George the Sea Monkey (Incomprehensible)	Clifford Cleans (Incomprehensible)
Order 5	George the Sea Monkey (Incomprehensible)	Clifford Cleans (Incomprehensible)	Jetta's Project (Comprehensible)	George's Sand Castle (Comprehensible)
Order 6	George the Sea Monkey (Comprehensible)	Clifford Cleans (Comprehensible)	Jetta's Project (Incomprehensible)	George's Sand Castle (Incomprehensible)
Order 7	George's Sand Castle (Incomprehensible)	Jetta's Project (Incomprehensible)	Clifford Cleans (Comprehensible)	George the Sea Monkey (Comprehensible)
Order 8	George's Sand Castle (Comprehensible)	Jetta's Project (Comprehensible)	Clifford Cleans (Incomprehensible)	George the Sea Monkey (Incomprehensible)

Figure 2. Electrode Array



Results

Behavioral Results

All participants were at ceiling for the 6 comprehension questions concerning the comprehensible narrative. Two participants missed a central content question for the incomprehensible narrative. However, those two participants were not outliers in any other regard and were included in all analyses. Although data from clinical populations suggests a correlation between ADHD symptoms and TV viewing, such a relationship was not present in these data.

ERPs: Comprehensible Narrative

For the probes played during the comprehensible narrative, adult participants' auditory evoked potentials (AEPs) exhibited the P1-N1-P2 oscillation typically found in research on auditory processing (e.g., Hillyard 1973, Coch et al., 2005, Sanders et al., 2006). See Figures 3 and 4. However, of the four time epochs of interest, only the N1 showed evidence of attention modulation. Specifically, there was some evidence of negative attention modulation at the central electrode sites (Anterior/Posterior levels C and D) in participants who viewed the comprehensible narrative first (mean difference: -.618, $SE = .285$, $F(1, 7)=4.708$, $p = .067$) contrasted with positive, left lateralized attention modulation at the anterior electrode sites (Anterior/Posterior levels A and B) in participants who viewed the comprehensible narrative second (mean difference: 1.086, $SE = .459$, $F(1, 7)= 5.588$, $p = .05$). These simple effects of attention were qualified by a nearly significant Attention x Anterior/Posterior x Laterality x Order interaction in the overall mixed ANOVA: $F(6, 84)=2.985$, $p = .056$, $\eta^2 = .174$.

Figure 3. Adults' Auditory Evoked Potentials During the Comprehensible Narrative (Comprehensible First)

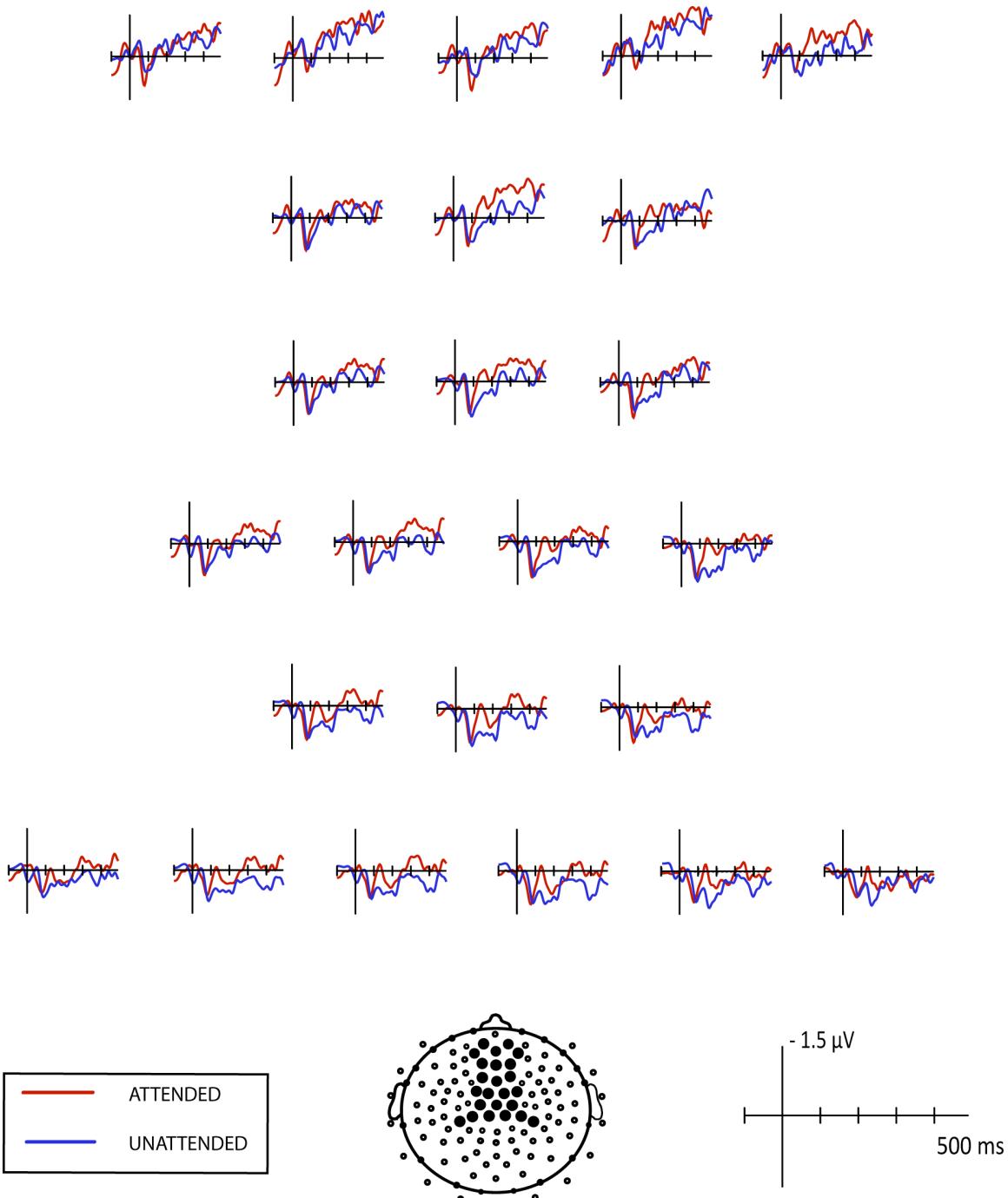
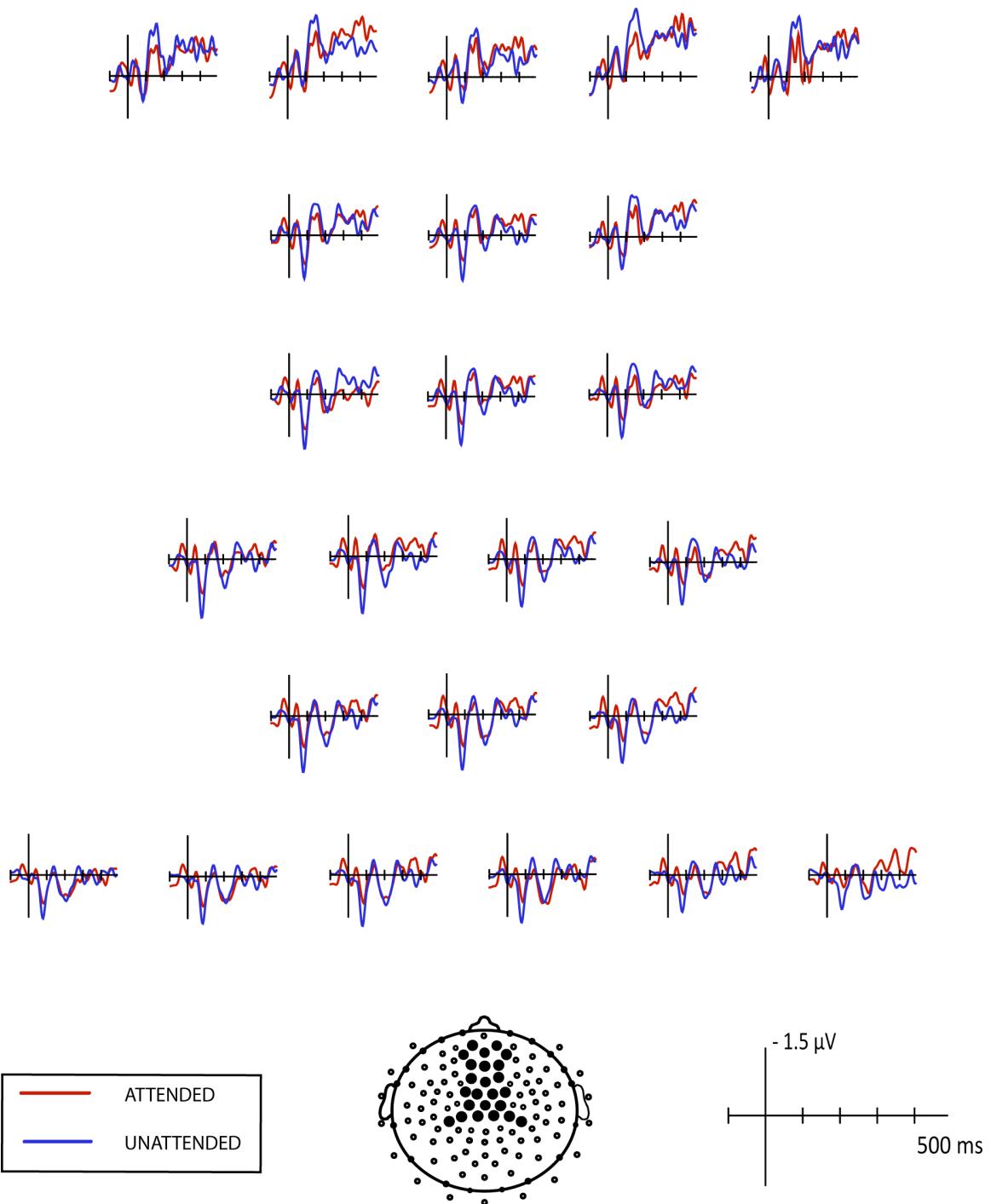


Figure 4. Adults' Auditory Evoked Potentials During the Comprehensible Narrative (Comprehensible Second)



ERPs: Incomprehensible Narrative

As was observed during the comprehensible narrative, participants' waveforms exhibited the typical P1-N1-P2 waveform oscillation. However, the magnitude of the P2 to the probes played from the same location as the attended audio track during the incomprehensible narrative was noticeably larger than the P2 to the probes played from the same location as the attended stream during the comprehensible narrative. See Figures 5 and 6. In addition to exhibiting somewhat different morphology, the auditory evoked potentials elicited during the incomprehensible narrative also showed more evidence of attention modulation than the auditory evoked potentials elicited during the comprehensible narrative, particularly during the later time windows.

For the P1 the overall mixed-ANOVA yielded no main effect of or interactions with attention. For the N1, there was significant, positive attention modulation over the left hemisphere at the medial electrode sites (Laterality level 1) for participants who viewed the incomprehensible narrative during the first block of the experiment (mean difference: .904, $SE = .304$, $F(1, 7)=8.870, p = .021$) contrasted with no attention modulation in participants who viewed the incomprehensible narrative during the second block of the experiment (mean difference: .025, $p>.90$). These simple effects of attention were qualified by an Attention x Anterior/Posterior x Hemisphere x Order interaction $F(3, 42)=4.677, p = .011, \eta^2 = .250$ and an Attention x Laterality interaction $F(2, 28)=4.504, p = .020. \eta^2 = .243$ in the overall mixed-ANOVA.

During the P2 time window, participants exhibited positive attention modulation at the central electrode sites (Anterior/Posterior levels C and D) regardless of narrative order (mean difference: .801, $SE = .331$, $F(1, 14)=5.862, p = .030$). Analysis at the

central electrode sites was motivated by an Attention x Anterior/Posterior x Hemisphere/Laterality $F(6, 84)=3.052, p = .028, \eta^2 = .179$) and an Attention x Hemisphere x Laterality interaction $F(2, 28)=5.689, p = .009, \eta^2 = .289$ in the overall mixed ANOVA.

Finally, for the late negativity participants exhibited positive, though nonsignificant, attention modulation over the right hemisphere at the medial anterior electrodes (Anterior/Posterior levels A and B; Laterality level1) (mean difference: .579, $p>.330$). Analysis at the anterior electrodes was motivated by interactions among Attention x Anterior/Posterior x Hemisphere x Laterality $F(6, 84)= 2.570, p = .044, \eta^2 = .155$ and Attention x Hemisphere x Laterality $F(2, 28)=3.765, p = .041, \eta^2 = .212$ in the overall mixed ANOVA.

Figure 5. Adults' Auditory Evoked Potentials During the Incomprehensible Narrative (Incomprehensible First)

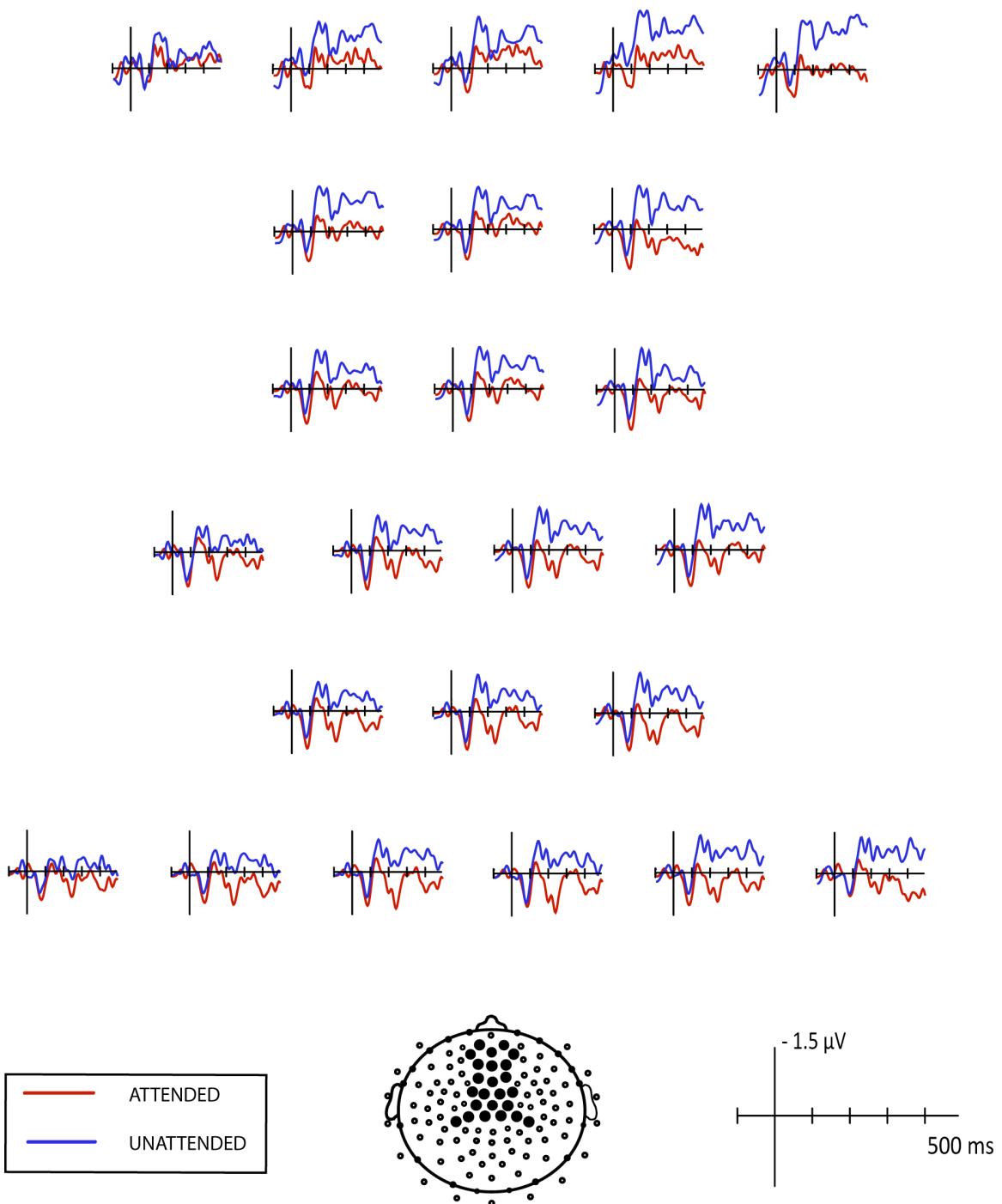
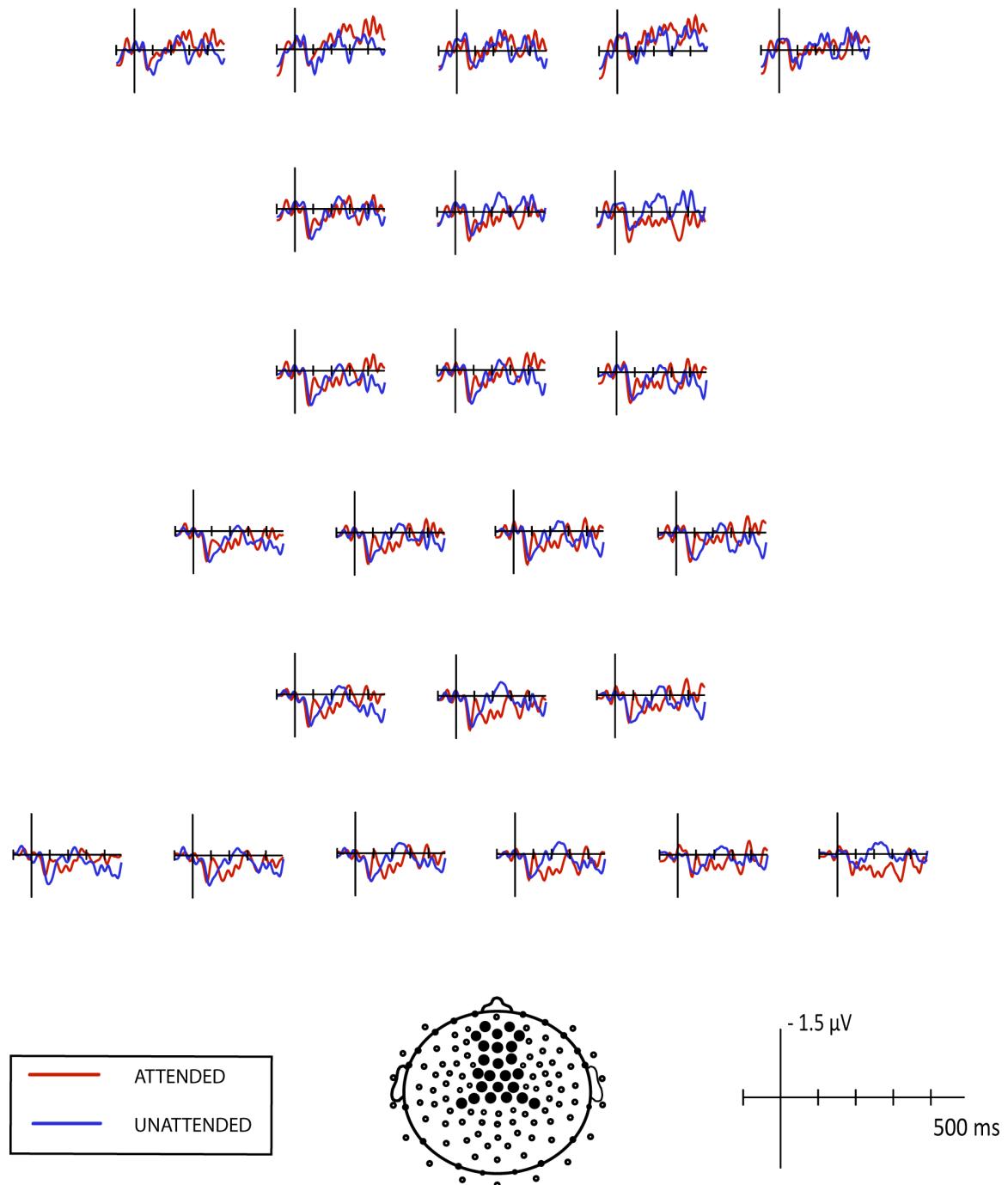


Figure 6. Adults' Auditory Evoked Potentials During the Incomprehensible Narrative (Incomprehensible Second)



Interim Discussion

Several studies have shown that adults' auditory evoked potentials (AEPs) exhibit a positive-negative-positive oscillation. With changes in the density of the auditory environment (meaning more numerous and more complex sounds) the amplitude of the N1 becomes attenuated (Coch et al., 2005; Sanders et al, 2006). Thus, in a relatively sparse auditory environment, when participants are asked to selectively attend to a series of beeps, the difference between the peak amplitudes of the N1 and the P2 is much greater than in a more complex environment, such as the one used by Sanders et al. (2006), where the N1 was present, but noticeably reduced in magnitude. In the current study, adults' AEPs showed this P1-N1-P2 oscillation, and as was observed by Sanders and colleagues, the magnitude of the N1 was attenuated. Given that the auditory environment of the current study was denser than that of Sanders et al. (2006) but the attenuation of the N1 is comparable, there may be a floor effect whereby the N1 is attenuated to a point, but will not become increasingly so despite additional perceptual load.

Also noteworthy is that the polarity, and to some extent, the morphology of the AEPs differed based on the comprehensibility of the narrative as well as the order in which the narratives were presented. In terms of morphology, in the comprehensible narrative, participants' AEPs to the probes at the same location as the attended stream had a distinct positive-negative-positive pattern, whereas in the incomprehensible narrative, participants' AEPs to the probes at the same location as the attended stream elicited a larger P2 as compared to the P2 elicited by the probes at the same location as the attended stream in the comprehensible narrative. One possible cause for this

difference is the cross fades that were imposed on the audio in the incomprehensible narrative condition. Although these cross fades were necessary to make the audio tracks for the incomprehensible narratives sound more ‘natural’, it could be that this manipulation of the stimuli resulted in participants hearing more probes in isolation or in times of relative quiet in the incomprehensible narrative condition compared to the comprehensible narrative condition, where no cross fades were applied. Because the probes were played at a pseudo-random rate, there is no recourse for investigating this explanation given the data that we have. To verify or discount this explanation, additional research where the playing of the probes is controlled would be required.

In terms of the polarity of the attention modulation for the N1 the direction of this difference depended on whether or not participants were in the first or second block of the experiment. Although the data from the comprehensible and incomprehensible narrative were analyzed separately, if we consider the data as a whole, the pattern of findings that emerged was such that participants who viewed the comprehensible narrative during the first block and the incomprehensible narrative during the second block showed marginally significant, negative attention modulation during the comprehensible narrative and virtually no attention modulation during the incomprehensible narrative. Participants who viewed the incomprehensible narrative during the first block and the comprehensible narrative during the second block exhibited significant, positive attention modulation throughout both blocks. Although there are numerous possibilities for this pattern of findings, before considering the theoretical or methodological reasons for it, it is important to consider the remainder of the data, which came from a group of typically developing and ADHD-like preschool children.

CHAPTER III

EXPERIMENT 2

Method

Participants

The data described here came from 37 children (19 female) with a mean age of 5.27 years ($SD = .680$). This age range was of particular interest to this research given previous work using this paradigm (i.e., Sanders et al., 2006) and also because these children would be unlikely to be on psychoactive medication. Child participants were recruited from two sources. The first source was the UMass Child Study Center's birth record database. These families were sent a letter describing the study and contacted via telephone or email a few days later. At that time, appointments were scheduled for the interested families. The second source of recruitment was the UMass Psychological Services Center where parents of children who were deemed at risk for ADHD were participating in a parenting intervention program. These parents were given a letter describing the study during a meeting and were asked to provide consent to be contacted about the study if they were interested. Parents who were interested were contacted via telephone or email to schedule an appointment.

All participants were reported as being native English speakers, and as having no hearing or vision difficulties or neurological disorders. One child was reported as taking psychoactive medication and those data were excluded from analyses. A majority of the children were right handed ($n = 34$); two were reported as left-handed and 1 was reported as 'Unsure'. A majority of the sample was Caucasian (90%) while 10% of children were reported as being multiracial. Data from three additional participants were excluded from

the final analyses because of recording errors ($n = 2$), noise in the data ($n = 1$), and because the child was unwilling to participate ($n = 1$). For two participants, only data from the first block of the experiment were included in analyses because of a recording error during the second block of trials ($n = 1$) and because the child did not wish to complete the experiment ($n = 1$). All parents/guardians provided written consent for their child's participation. In exchange for participation, children received a \$10 gift card and a small toy.

Although efforts were made to recruit children who were clinically identified as at high-risk for ADHD, at the time of data collection, only one child had been diagnosed with ADHD. For the remaining children, categorization as typically developing or ADHD-like (hereafter, ADHD) was based on the Disruptive Behavior Rating Scale (DBRS) (Barkley & Murphy, 1998) which was completed by each parent (Appendix C). This scale is comprised of 18 items, each of which measures inattentiveness or hyperactivity and impulsivity on a scale from 0 (Never) to 3 (Very Often) and is summed over to create an index of ADHD symptoms (with possible scores ranging from 0 to 54). Overall, parents' reported an average of 11.76 symptoms ($SD = 7.783$) with an average of 6.46 ($SD = 4.32$) for symptoms of hyperactivity/impulsivity and an average of 5.19 ($SD = 3.86$) for symptoms of inattention.

When possible, scores on the DBRS were kept in their continuous form for analysis. However, for many of the analyses the DBRS scores were divided based on a mean split and ADHD status was treated as a categorical variable. The mean was selected as the division for the two groups (rather than the median) based on examination of the distribution of the scores. The primary reason for treating this variable categorically was

that the data reduction software used to process the ERP data cannot plot adjusted means, as would be necessary if the variable had been kept continuous for the analyses. Using this criterion, there were 22 children in the typically developing group and 15 in the ADHD group. Average score on the DBRS was 6.27 ($SD = 2.585$) for the typically developing group and 19.80 ($SD = 5.40$) for the ADHD group. Although doing the mean split resulted in the design being somewhat unbalanced (meaning that there was not exactly one typically developing and ADHD child for each of the 8 orders and each of the 2 attended sides) examination of contingency tables showed no difference in number for the groups based on attended side or narrative order (incomprehensible or comprehensible first) ($p > .46$) nor did the two groups differ by age ($p > .40$).

Stimuli

The stimuli used here are identical to those used in Experiment 1.

Procedure

Upon arrival, parents completed an informed consent on behalf of their child and were given the opportunity to ask questions about the procedure. Next, each parent completed the DBRS as well as a short survey. In the survey, parents were asked to report about how much television their child watched home on a typical weekday and a typical weekend day. The value provided for an average weekday was multiplied by 5 and the value provided for the average weekend day was multiplied by two before being summed in order to estimate average hours of TV viewing per week. The mean hours of weekly TV viewing were 10.80 ($SD = 8.80$) and ranged from 0 to 28.5. Parents also were asked to rate their child's familiarity with the *Clifford* and *Curious George* animated series on a scale from 1 (Never seen the show before) to 5 (Watches the show regularly). The two

groups did not differ significantly in TV viewing or familiarity with each of the two programs ($p > .20$). See Table 2.

Table 2. Children's Familiarity with the *Clifford* and *Curious George* Series

	<i>Clifford</i>	<i>Curious George</i>
Typically Developing	2.636 (.726)	2.909 (.750)
ADHD	2.466 (.743)	2.533 (.743)

Note. Standard Deviations are in parentheses.

The procedure for the child participants was identical to Experiment 1 with the exception of the comprehension questions. Children were given the opportunity to freely recall aspects of the story and were only asked specific comprehension questions if they were unwilling or unable to recollect on their own. Comprehension question data were collected from 33 of the 37 child participants. One child's data were lost due to a recording error and three children were unresponsive when asked the comprehension questions and no data could be collected.

Continuous EEG was sampled at a rate of 250 Hz and a bandwidth of .01-100 Hz from a 128-channel HydroCel Geodesic Sensor Nets (Electrical Geodesics Inc., Eugene, OR). Impedance was measured below 50 kΩ at every electrode at the beginning of the experiment and maintained below 100 kΩ for the duration of the study. A 60 Hz offline filter was applied to the EEG data. The EEG was divided into 600ms time epochs using 100ms before to 500ms after the presentation of the white noise probe. Trials with differential amplitude larger than 400μV anywhere on the scalp were excluded from the final averages. Remaining trials that appeared to include artifacts from eye blinks, eye movements, or head motion were excluded based on visual inspection of the raw data.

Data from the remaining trials were averaged by participant and condition, re-referenced to the average of the two mastoid electrodes, and corrected to the 100 ms pre-target baseline. The average number of trials per condition is provided in Table 3. These numbers did not significantly differ by ADHD status.

Table 3. Usable Trials by Condition and ADHD Status.

	Typically Developing	ADHD
Incomprehensible Attended	92.11 (30.172)	92.62 (31.487)
Incomprehensible Unattended	94.47 (29.115)	91.08 (35.316)
Comprehensible Attended	88.89 (34.612)	105.23 (42.478)
Comprehensible Unattended	86.00 (32.852)	103.23 (40.719)

Note. Standard Deviations are in parentheses

Measures

Data from 24 of the 128 electrodes were divided into a 4 (Anterior to Posterior – Levels A, B, C, and D) by 3 (Medial to Lateral – Levels 1, 2, and 3) by 2 (Left and Right Hemisphere) array (see Figure 2). These electrodes were selected for analysis based on previous literature showing evidence of spatially selective attention in children over these regions (Coch et al., 2005; Sanders et al., 2006). Mean amplitude was measured from these electrodes across five time epochs: 0-50ms, 50-100ms, 100-150ms; 150-250ms; and 250-400ms. This segmentation was done based on visual inspection of the morphology of the auditory evoked potentials (AEPs) for each group and condition and also to allow for more detailed analysis of the waveforms in this relatively understudied population.

First, these data were included in a 2 (Attention: Attended and Unattended) x 4 (Anterior/Posterior) x 2 (Hemisphere) x 3 (Laterality) x 2 (Order: Incomprehensible First,

Comprehensible Second or Comprehensible First, Incomprehensible Second) mixed model ANOVA. As in Experiment 1, the data from the comprehensible and incomprehensible condition were analyzed separately.

The goal of these ANOVA-based analyses was to examine qualitative differences between the typically developing and ADHD children. Therefore, their data were considered in separate analyses. In total, 20 mixed ANOVAs were run (5 time epochs x 2 levels of comprehensibility x 2 levels of ADHD status). In order to maximize statistical power and reduce the probability of making a Type 1 error, only the main effect of and interactions with the Attention factor were tested. The Greenhouse-Geisser correction was applied to all F tests that included a factor with more than 2 levels.

After qualitatively examining group differences, the relationship between DBRS score and spatially selective attention was investigated quantitatively using a series of regression analyses. Also of interest here, was the extent to which children's age was associated with the magnitude of attention modulation.

Results

Behavioral Results

The typically developing and ADHD children did not differ in the amount of central and peripheral content they recollect (see Table 4). Across narrative type and ADHD status, children recalled more peripheral content than central content: for the comprehensible narrative, children recalled an average of 2.67 ($SD = .957$) pieces of peripheral information and 1.3 ($SD = 1.015$) pieces of central information $t(32)=5.555$, $p<.001$. For the incomprehensible narrative, children recalled an average of 3.03 ($SD = 1.159$) pieces of peripheral information and 1.24 ($SD = 1.30$) pieces of central

information $t(32)=6.211$, $p<.001$.

The data were also examined to see if there was a correlation between parent-reported TV viewing and scores on the DBRS. In this dataset, there was a positive, but nonsignificant relationship between the two variables ($r = .260$, $p = .110$).

Table 4. Number of Accurate Recollections by Narrative Type and ADHD Status

	Typically Developing	ADHD
Comprehensible		
Peripheral	2.74 (1.046)	2.54 (.877)
Central	1.26 (.933)	1.38 (1.193)
Incomprehensible		
Peripheral	3.11 (1.410)	3.00 (.707)
Central	1.26 (1.147)	1.31 (1.548)

Note. Standard Deviations are in parentheses.

ERPs

Overall, children's auditory evoked potentials exhibited the broad positivity previously reported by Coch et al. (2005) and Sanders et al. (2006). This positivity occurred between 100 and 200ms and peaked at about 150ms, though this varied somewhat by narrative order and ADHD status (see Figures 7 through 12).

Comprehensible Narrative

Typically Developing Children

During the earliest time epoch (0-50ms) attention modulation was greatest over the right hemisphere at the medial central electrodes: Attention x Anterior/Posterior x Hemisphere x Order $F(3, 57)=3.165$, $p = .047$ $\eta^2 = .170$. However, follow-up analyses

revealed no simple effects of attention (overall mean difference: -.090, $p > .79$). For the remaining four time epochs, there were no main effects of or interactions with attention in any of the mixed ANOVAs.

ADHD Children

During the earliest time epoch (0-50ms) attention modulation was greatest over the left hemisphere at the anterior electrode sites (Anterior/Posterior Levels A and B): Attention x Hemisphere x Laterality $F(2, 26) = 4.776$, $p = .041$, $\eta^2 = .257$. However, this modulation was not statistically significant (mean difference: .450, $p > .340$).

During the 50-100ms time window, there was positive, but nonsignificant attention modulation in children who viewed the comprehensible narrative during the first block (mean difference: .819, $p > .20$) and positive, significant attention modulation in children who viewed the comprehensible narrative during the second block (mean difference: 2.151, $SE = .577$, $F(1, 13) = 13.876$, $p = .003$). This simple effect was qualified by an Attention x Order interaction $F(1, 13) = 12.345$, $p = .004$, $\eta^2 = .487$ in the overall mixed ANOVA.

During the 100-150 time window there was nonsignificant, negative attention modulation in children who viewed the comprehensible narrative during the first block of the experiment (mean difference: -.630, $p > .28$) contrasted with positive attention modulation for children who viewed the comprehensible narrative during the second block of the experiment (mean difference: 1.773, $SE = .529$, $F(1, 13) = 11.248$, $p = .005$). This simple effect of attention was qualified by interactions among Attention x Laterality x Order $F(2, 26) = 4.140$, $p = .035$, $\eta^2 = .242$ and Attention x Order interaction $F(1, 13) = 9.639$, $p = .008$, $\eta^2 = .426$ in the overall mixed ANOVA.

During the 150-250ms time window, there was nonsignificant, negative attention modulation in children who viewed the comprehensible narrative first (mean difference: -1.00, $p > .10$) contrasted with significant, positive attention modulation in children who viewed the comprehensible narrative during the second block of the experiment (mean difference: 1.640, $SE = .528$, $F(1, 13) = 9.645$, $p = .008$. This simple effect was qualified by interactions of Attention x Order $F(1, 13) = 11.660$, $p = .005$, $\eta^2 = .473$, Attention x Anterior/Posterior x Order $F(3, 39) = 4.960$, $p = .023$, $\eta^2 = .276$; attention x laterality x order $F(2, 26) = 4.691$, $p = .019$, $\eta^2 = .265$, and Attention x Anterior/Posterior x Hemisphere x Order $F(3, 39) = 3.186$, $p = .047$, $\eta^2 = .197$ in the overall mixed ANOVA.

During the latest time window of interest (250-400ms) there was no main effect or interactions with attention.

In sum, for the comprehensible narrative, there was little evidence of attention modulation in the typically developing children. The ADHD children exhibited some evidence of attention modulation, however the magnitude of the modulation depended largely on the order of the narratives, such that children who viewed the comprehensible narrative during the first block showed no statistically significant attention modulation but children who viewed the comprehensible narrative during the second block showed positive, significant attention modulation.

Figure 7. Typically Developing Children's Auditory Evoked Potentials During the Comprehensible Narrative.

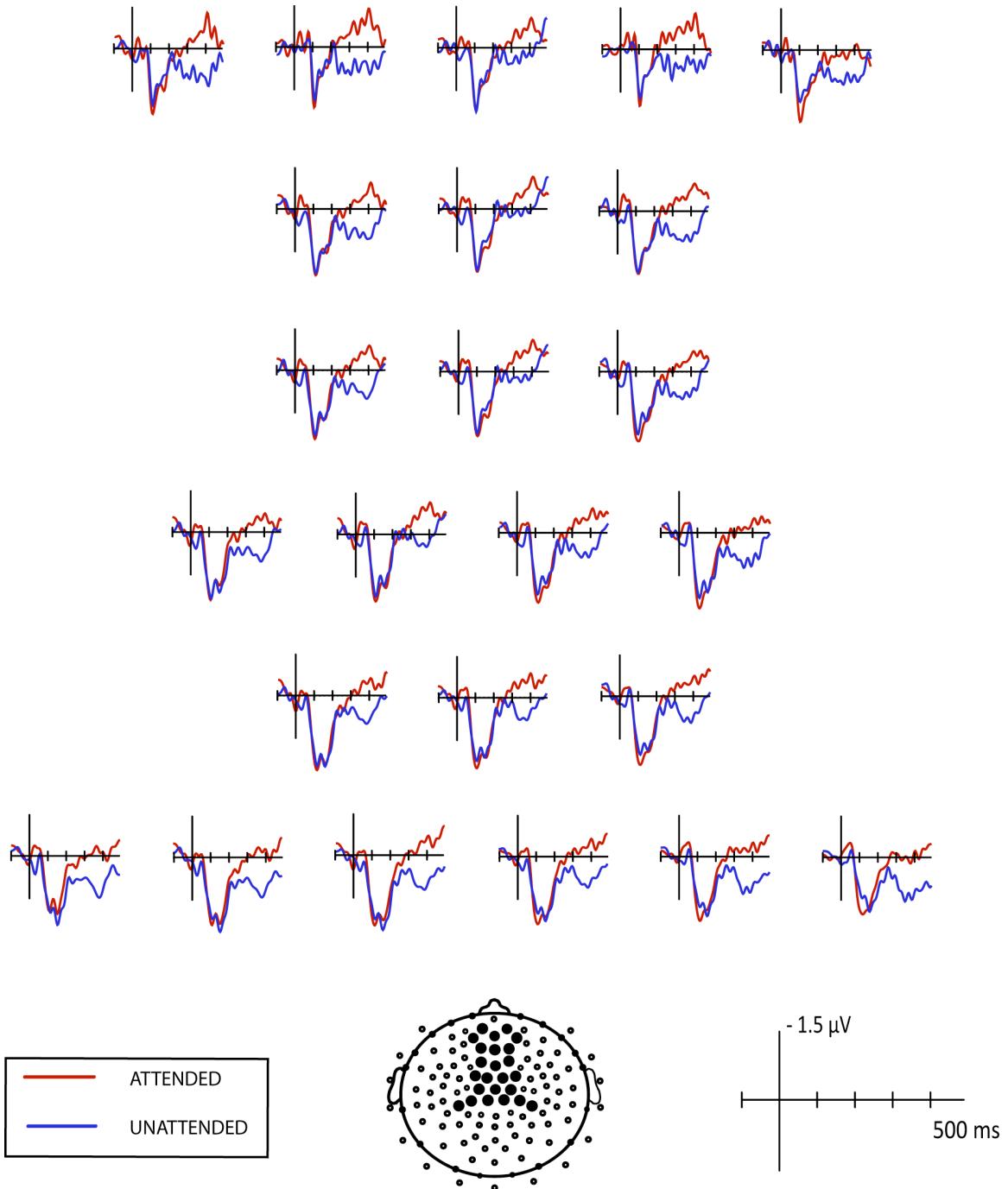


Figure 8. ADHD Children's Auditory Evoked Potentials During the Comprehensible Narrative (Comprehensible First)

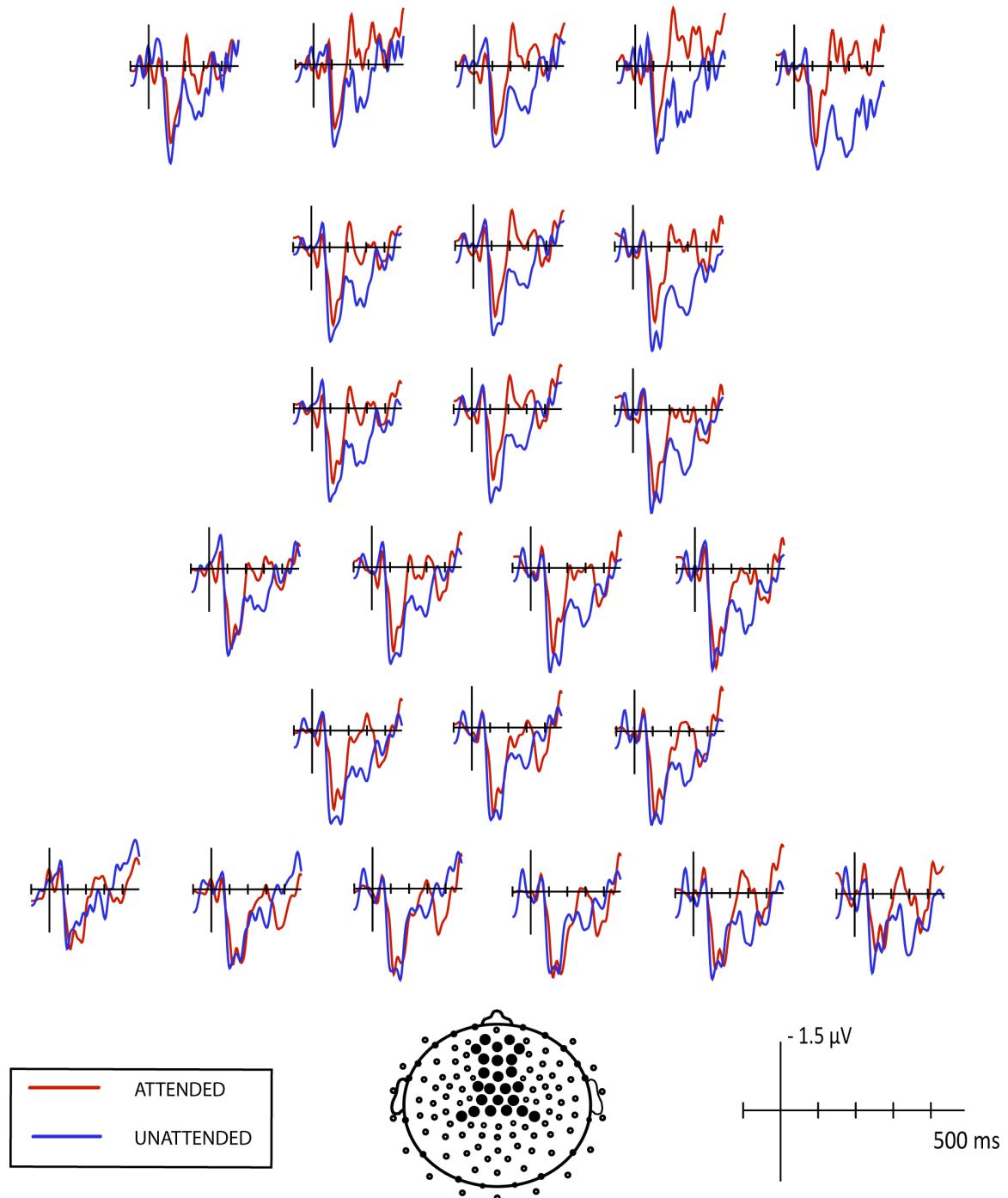
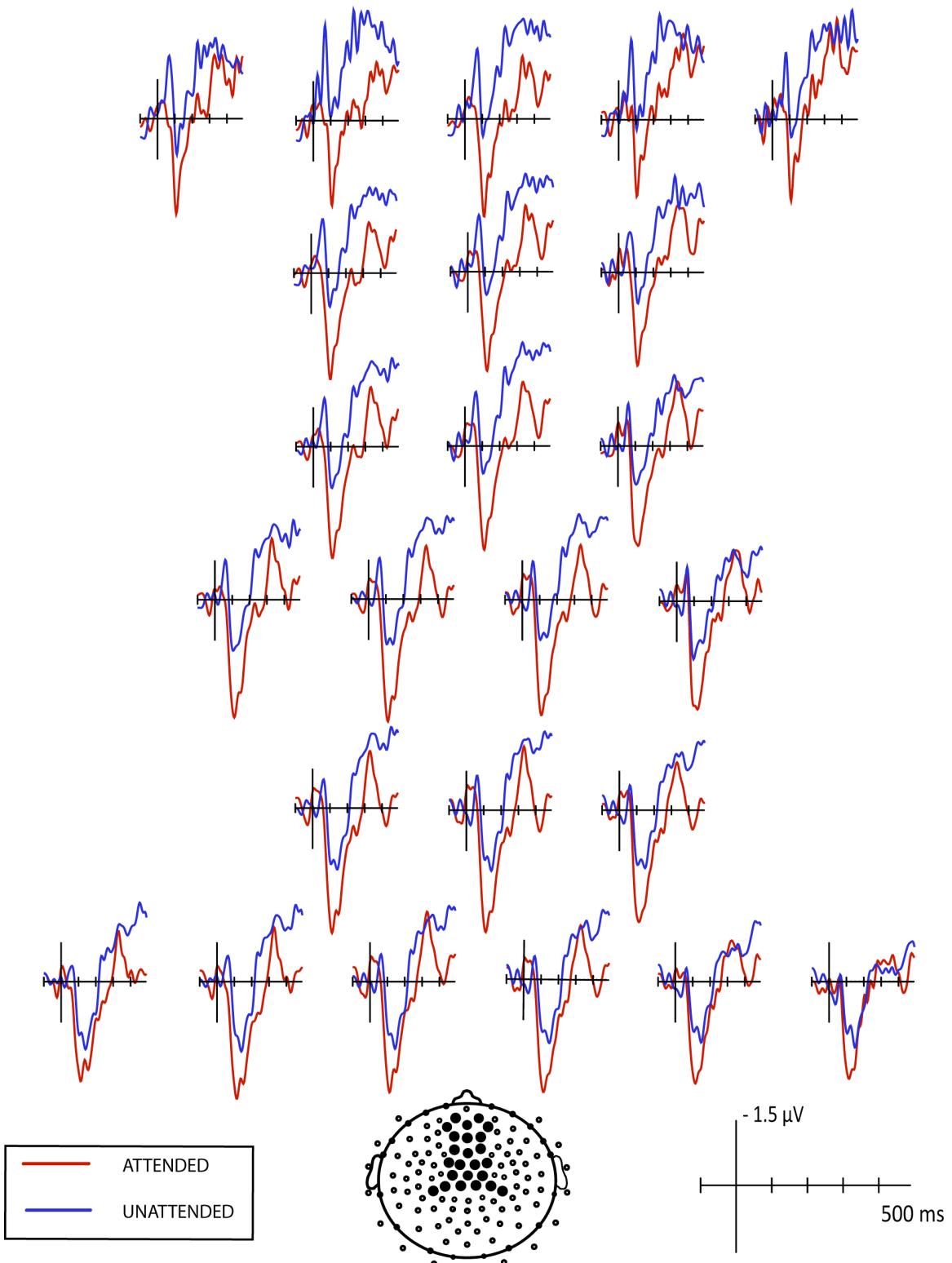


Figure 9. ADHD Children's Auditory Evoked Potentials During the Comprehensible Narrative (Comprehensible Second)



Incomprehensible Narrative

Typically-developing Children

During the earliest time window (0-50ms) the typically developing children exhibited negative attention modulation over the central electrode sites (Anterior/Posterior levels C and D) (mean difference: $-.833, SE = .398, F(1, 20)=4.374, p = .049$. This simple effect of attention was qualified by interactions between Attention x Anterior/Posterior $F(3, 60)=12.166, p<.001, \eta^2 = .426$ and Attention x Anterior/Posterior x Laterality $F(6, 120)=2.699, p = .047, \eta^2 = .113$ in the overall mixed ANOVA.

For the 50-100ms time window, there was negative, nonsignificant attention modulation over the central electrode sites (Anterior/Posterior levels C and D) (mean difference $-.834, p = .085$). Analysis of the central electrodes was motivated by an Attention x Anterior/Posterior interaction $F(1, 20)=3.669, p = .053 \eta^2 = .155$ in the overall mixed ANOVA.

For the 100-150ms time window, there was no main effect of or interactions with attention in the overall mixed ANOVA.

During the 150-250ms time window, there was negative, nonsignificant attention modulation over the right hemisphere at the most lateral electrodes (Laterality level 3) (mean difference $-.521, p>.320$). Analysis of these electrodes was motivated by an Attention x Hemisphere x Laterality interaction $F(2, 40)=4.901, p = .026, \eta^2 = .197$ in the overall mixed ANOVA.

For the 250-400ms time window there was no main effect of or interactions with attention.

ADHD Children

For the earliest time window (0-50ms) there was nonsignificant evidence of attention modulation across children, however for children who viewed the incomprehensible narrative during the first block, modulation was greatest at the central electrodes (mean difference: $-.702, p > .40$) and for children who viewed the incomprehensible narrative during the second block, modulation was greatest at the anterior electrodes (mean difference: $-.867, p > .40$). This pattern of findings was qualified by an Attention x Anterior/Posterior x Order interaction $F(3, 36)=3.738, p = .035, \eta^2 = .229$ in the overall mixed ANOVA.

For the 50-100ms time window, there was no main effect of or interactions with attention.

For the 100-150ms time window, there was marginal evidence of positive attention modulation across children at the anterior electrode sites (mean difference: $1.108, SE = .544, F(1, 12)=4.143, p = .065$). This simple effect of attention was qualified by an Attention x Anterior/Posterior interaction $F(3, 36)=5.022, p = .032, \eta^2 = .295$ in the overall mixed ANOVA.

During the 150-250ms time window, attention modulation was greatest at the central electrode sites, however, the polarity of the modulation depended on narrative order such that children who viewed the incomprehensible narrative first showed nonsignificant, negative attention modulation (mean difference: $-1.025, p > .28$) while children who viewed the incomprehensible narrative second show significant, positive attention modulation (mean difference: $2.291, SE = 1.048, F(1, 12)=4.774, p = .049$). This simple effect of attention was qualified by interactions among Attention x

Hemisphere x Laterality x Order $F(2, 24) = 7.422, p = .011, \eta^2 = .382$; Attention x Anterior/Posterior x Laterality x Order $F(2, 24) = 3.809, p = .042, \eta^2 = .241$; Attention x Anterior/Posterior x Hemisphere x Order $F(1, 12) = 6.574, p = .025, \eta^2 = .354$; and Attention x Order $F(1, 12) = 5.716, p = .034, \eta^2 = .323$ at the central electrode sites.

Further analysis at the central electrodes was motivated by interactions of Attention x Anterior/Posterior x Order $F(3, 36) = 4.025, p = .045, \eta^2 = .251$ and Attention x Hemisphere x Laterality x Order $F(2, 24) = 6.159, p = .024, \eta^2 = .339$ in the overall mixed ANOVA.

For the final time window (250-400ms) there was negative, nonsignificant attention modulation for children who viewed the incomprehensible narrative during the first block (mean difference: $-.383, p > .60$) and positive attention modulation in children who viewed the incomprehensible narrative during the second block (mean difference: $2.518, SE = .872, F(1, 12) = 8.335, p = .014$). This simple effect of attention was qualified by interactions among Attention x Hemisphere x Laterality x Order $F(2, 24) = 4.759, p = .042, \eta^2 = .284$; Attention x Anterior/Posterior x Order $F(3, 36) = 8.472, p = .002, \eta^2 = .414$; and Attention x Order $F(1, 12) = 6.323, p = .027, \eta^2 = .345$ in the overall mixed ANOVA.

In sum, for the incomprehensible narrative, typically developing children only showed statistically significant attention modulation during the earliest time window. This attention modulation was negative in polarity and was not affected by narrative order. The ADHD children exhibited some evidence of positive attention modulation during the 100-150ms time window, irrespective of order, at the anterior electrode sites.

During the final two time windows ADHD children who viewed the incomprehensible narrative during the second block showed positive, significant attention modulation while children who viewed the incomprehensible narrative during the first block exhibited nonsignificant, negative attention modulation.

Taken together, the findings from the comprehensible and incomprehensible narrative conditions provide very little evidence of attention modulation in typically developing children, with the exception of an early effect for the incomprehensible narrative. The ADHD children showed more evidence of attention modulation across the two conditions, however, this was dependent on whether the data were collected during the first or second block of the experiment.

Figure 10. Typically Developing Children's Auditory Evoked Potentials During the Incomprehensible Narrative.

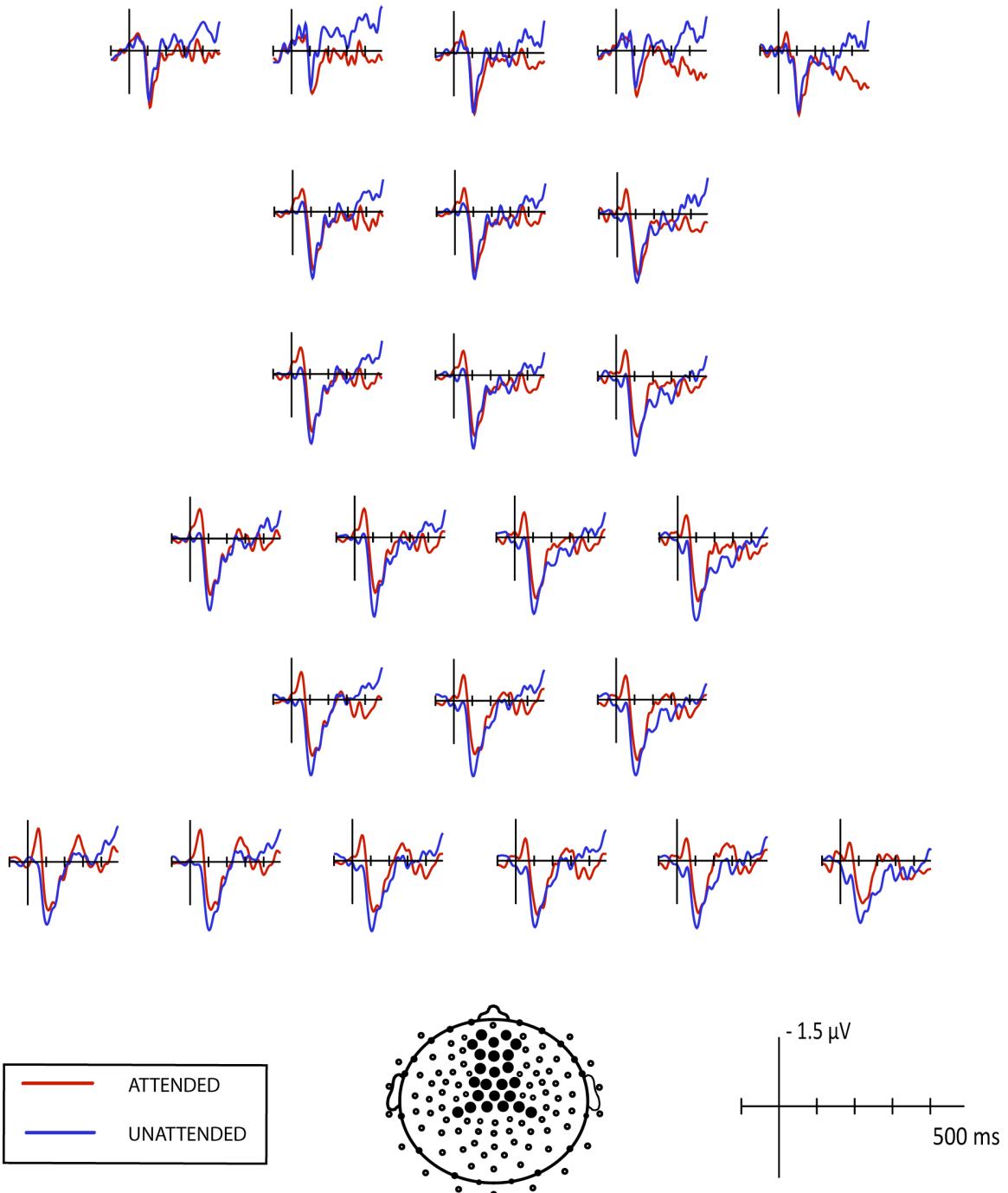


Figure 11. ADHD Children's Auditory Evoked Potentials During the Incomprehensible Narrative (Incomprehensible First)

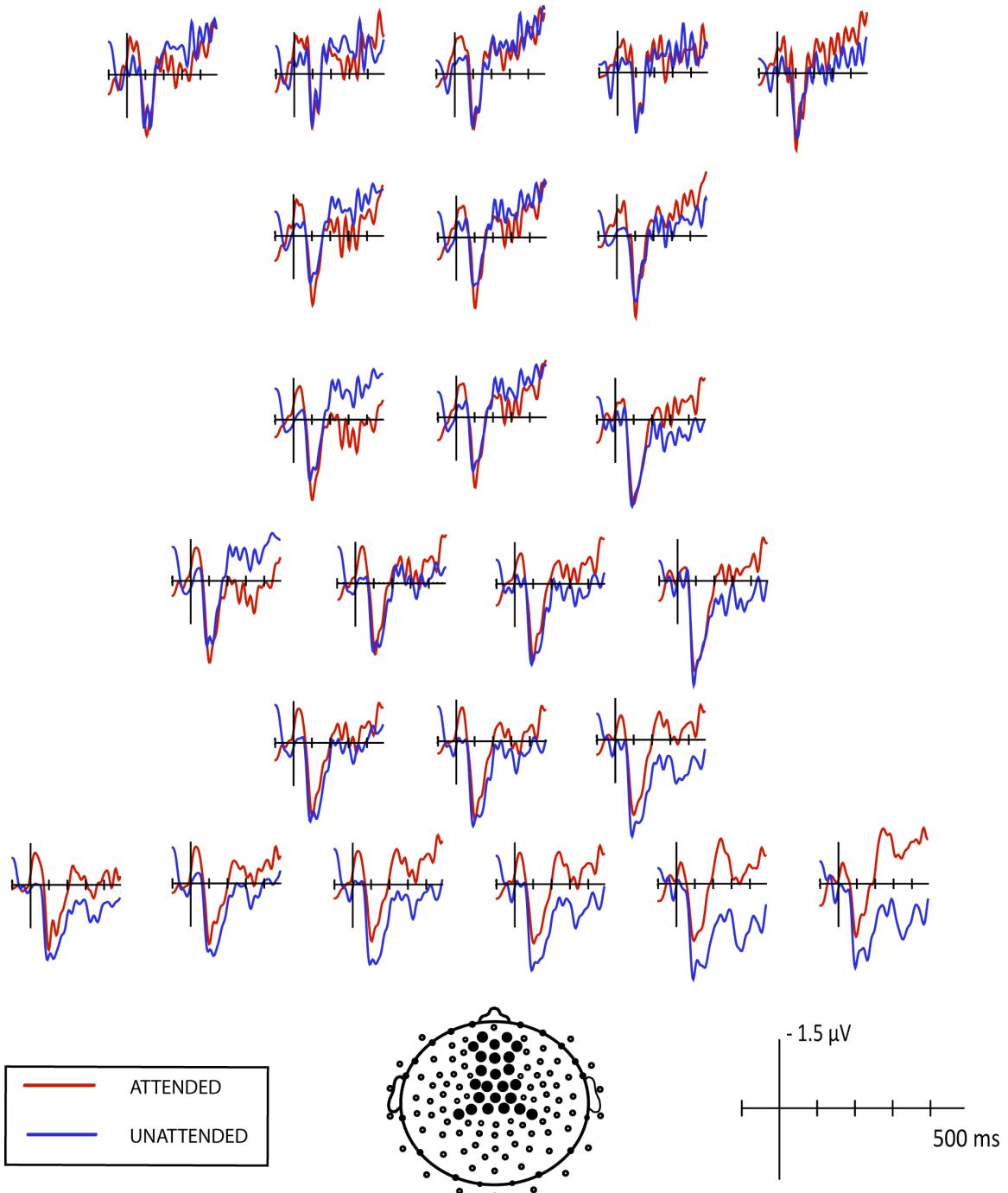
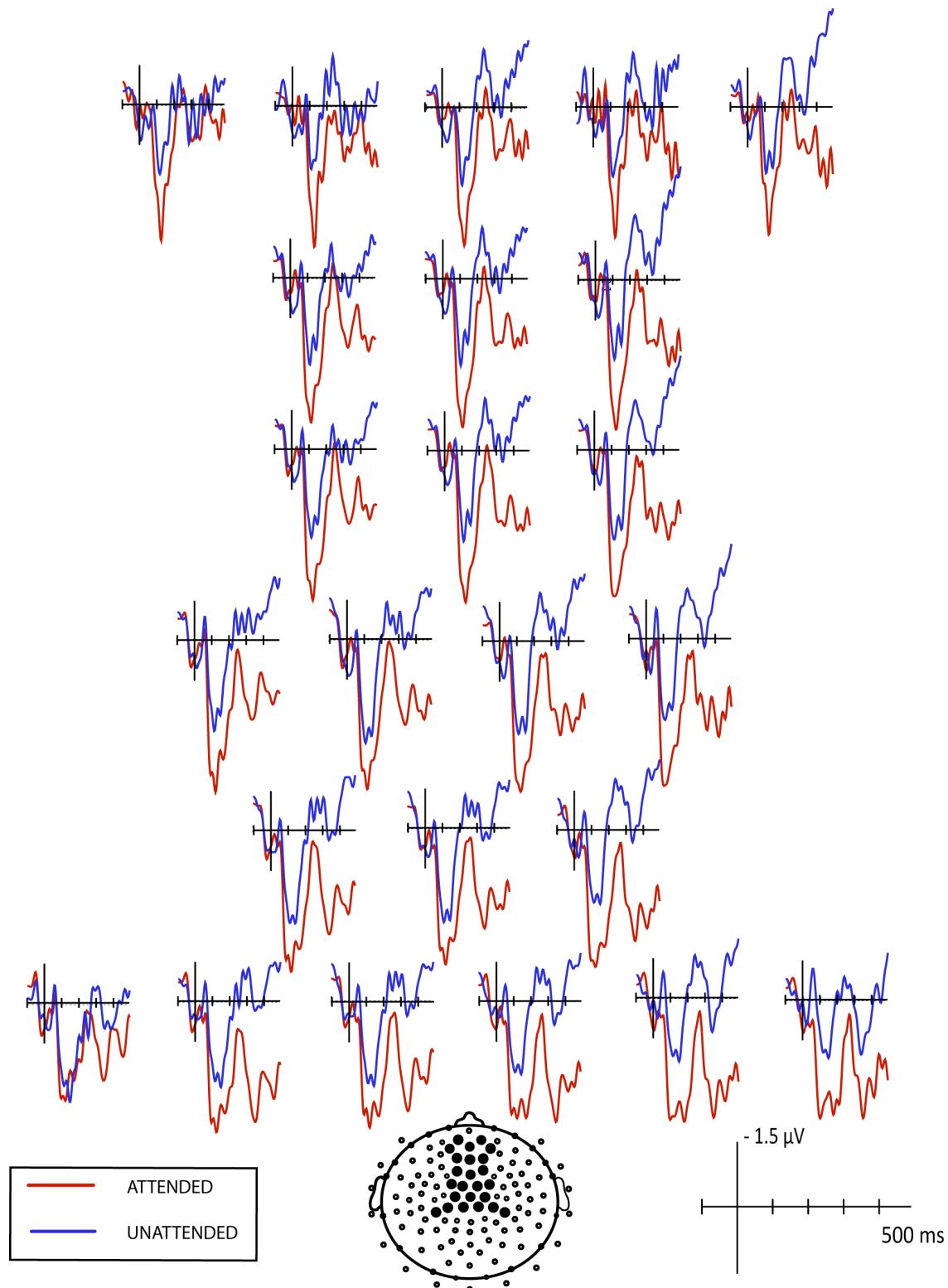


Figure 12. ADHD Children's Auditory Evoked Potentials During the Incomprehensible Narrative (Incomprehensible Second)



Regression Analyses

Despite showing differences in spatially selective attention, the two groups did not differ based on their recollection of central or peripheral content. This suggests that the typically developing children were selectively attending to the appropriate audio track, but that a relevant control variable (e.g., child's age) may have been left out of these analyses. Thus, the next set of analyses considered the data set as a whole and included children's DBRS score, narrative order, and children's age as predictors.

For each model DBRS score, narrative Order, and an Order x DBRS score interaction term were entered before any other predictors or interaction terms. This was done because the qualitative comparison of the typically developing and ADHD children suggested different patterns of attention modulation based on ADHD status and narrative order. Next, the child's age along with a DBRS x Age and an Order x Age interaction were included in the model. No three-way interactions were tested due to the limited sample size. Preliminary analyses showed no relationships between television viewing and attention modulation so TV viewing was not included in the reported analyses.

Subsequent to fitting the full model, all models were trimmed based on the overall significance of the *F*-test, by examining each predictor's contribution to r^2 , and also by considering the significance of individual coefficients. Factors that did not contribute to the model were removed, starting with the interaction terms. Only the best fitting models were retained for interpretation. Prior to the calculation of the interaction terms, all the covariates were mean centered to reduce collinearity among the predictors (Aiken & West, 1991).

In total, 10 regression models are reported here (2 narrative types x 5 time

windows). The first set of models considered attention modulation during the comprehensible narrative and the second set considered attention modulation during the incomprehensible narrative. The outcome measures were aggregate difference scores calculated by subtracting the mean amplitude of the AEPs to the unattended probes from the mean amplitude of the AEPs to the attended probes and averaging the differences across the 24 electrodes.

Comprehensible Narrative

For the earliest time window (0-50ms), the best fitting model included DBRS score, Order, Age, DBRS x Age and Order x Age as predictors $F(5, 30)=2.161, p = .085$, overall $r^2 = .265$. There were significant interactions of DBRS x Age $\beta = -.140, SE = .066, t = 2.110, p = .043$, contribution to $r^2 = .09$ and Order x Age $\beta = 2.525, SE = 1.054, t = 2.396, p = .023$, contribution to $r^2 = .14$. See Figures 13 and 14. The DBRS x Age interaction was the result of children with lower DBRS scores not showing much change in the magnitude or direction in their attention effect with age, but children with higher DBRS scores showing a decrease in the magnitude of the difference score with age. The Age x Order interaction was a crossover relationship, such that children who viewed the comprehensible narrative during the first block of the experiment had slight, positive change in the magnitude of the attention effect with age, compared to children who viewed the comprehensible narrative during the second block, where there was a negative slope associated with increases in age.

Figure 13. Age by DBRS Interaction for the Comprehensible Narrative (0 to 50ms)

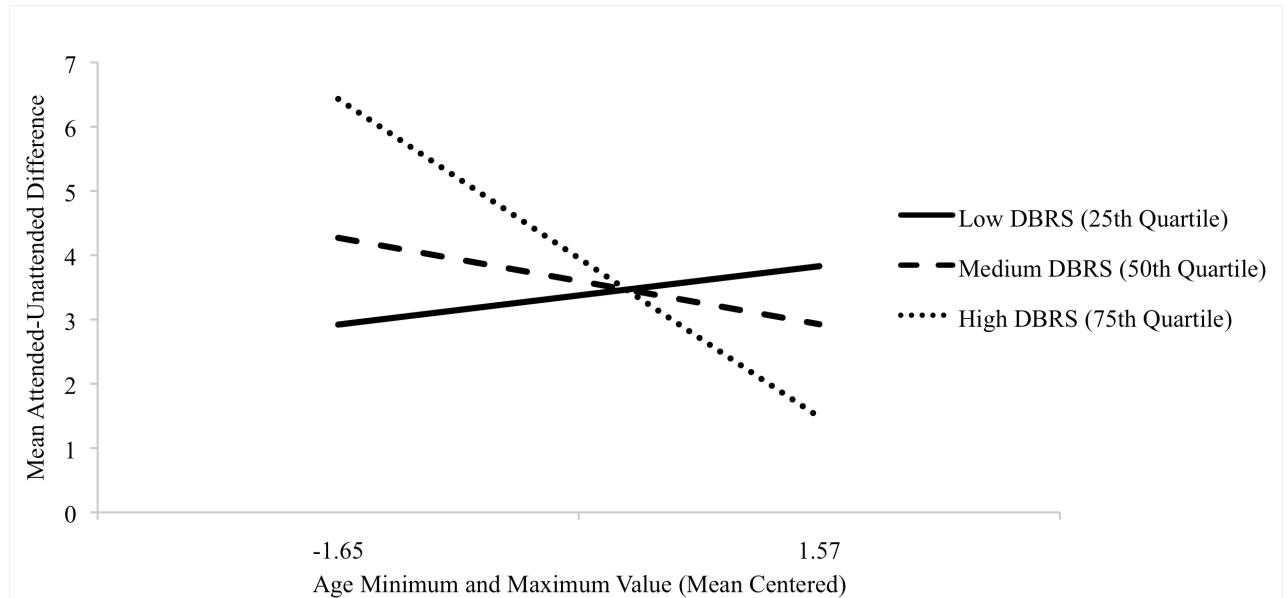
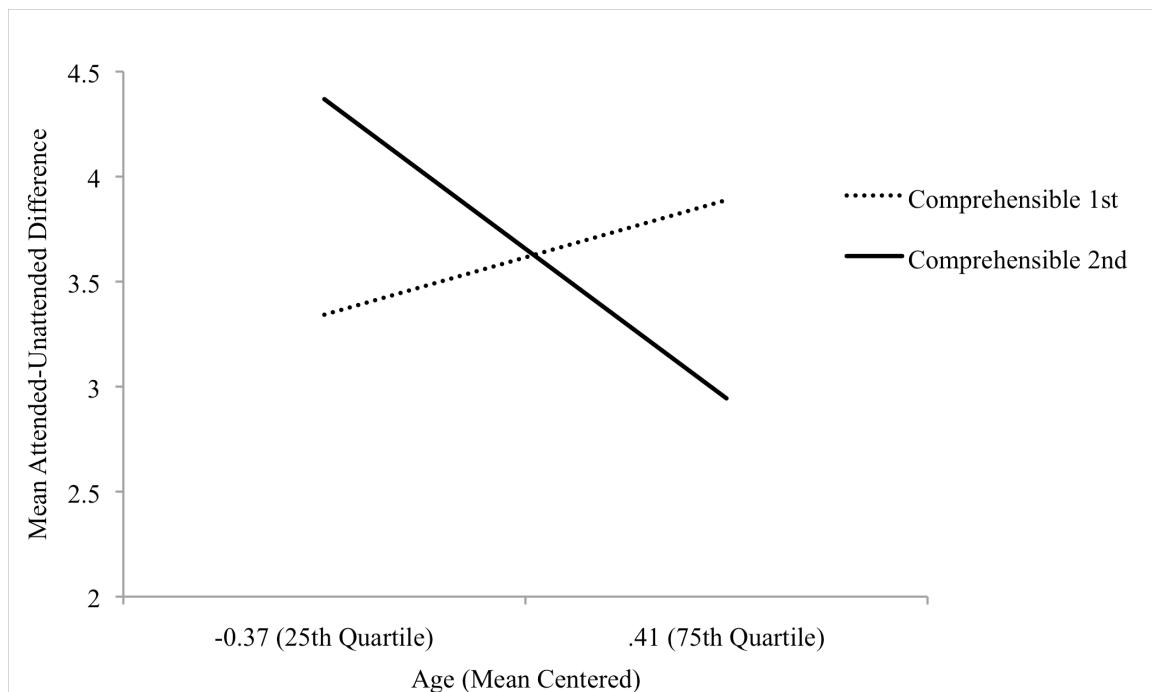


Figure 14. Age by Order Interaction for the Comprehensible Narrative (0 to 50ms)



For the 50-100ms time window, the best fitting model included DBRS score, Order, DBRS x Order, DBRS x Age, and Age x Order as predictors $F(6, 29)=2.820, p =$

.028, overall $r^2 = .368$. There were significant interactions of DBRS x Order $\beta = -.258$, $SE = .113$, $t = 2.286$, $p = .030$, contribution to $r^2 = .102$, Order x Age $\beta = .114$, $SE = 1.209$, $t = 2.577$, $p = .015$, contribution to $r^2 = .150$ and a marginally significant DBRS x Age interaction $\beta = -.165$, $SE = .088$, $t = 1.879$, $p = .070$, contribution to $r^2 = .077$. The Age x Order interaction was the result of there being a difference in the magnitude and polarity of the attention effect in younger children, depending on the order in which they saw the comprehensible narrative, compared to older children whose attention effects did not differ by order. The DBRS x Order interaction was the result of an increase in the magnitude of attention modulation with an increase in DBRS score, however, the direction of this change depending on narrative order, such that children who viewed the comprehensible narrative first showed a more negative attention effect as DBRS score increased while children who viewed the comprehensible narrative second showed a more positive attention effect as DBRS score increased. The marginal DBRS x Age effect followed the same pattern as for the 0-50ms time window. See Figures 15 through 17.

Figure 15. Age by Order Interaction for the Comprehensible Narrative (50 to 100ms)

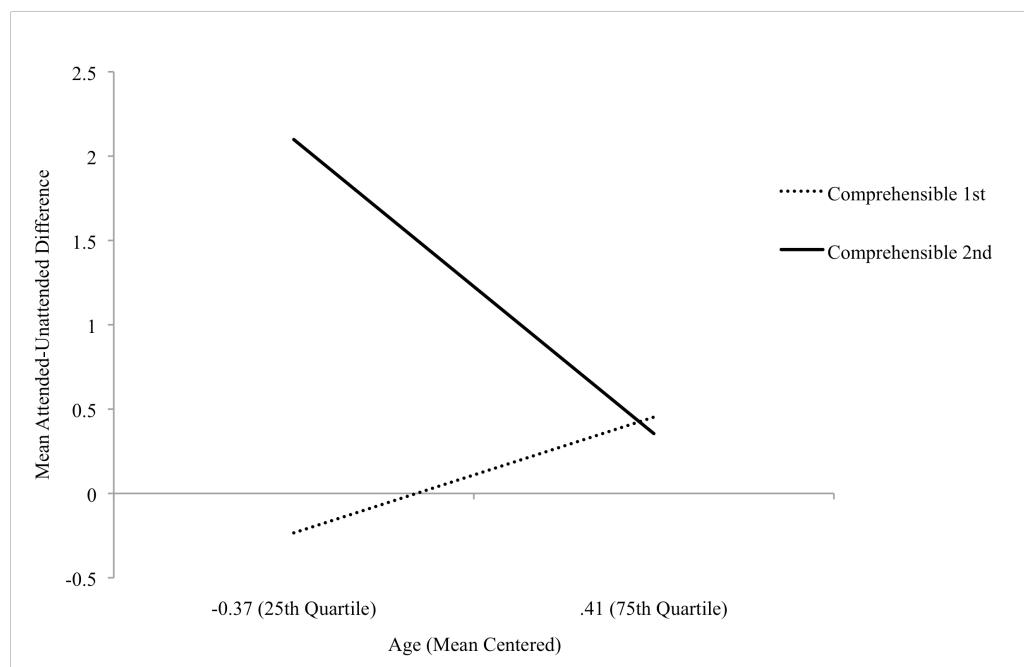


Figure 16. DBRS by Order Interaction for the Comprehensible Narrative (50 to 100ms)

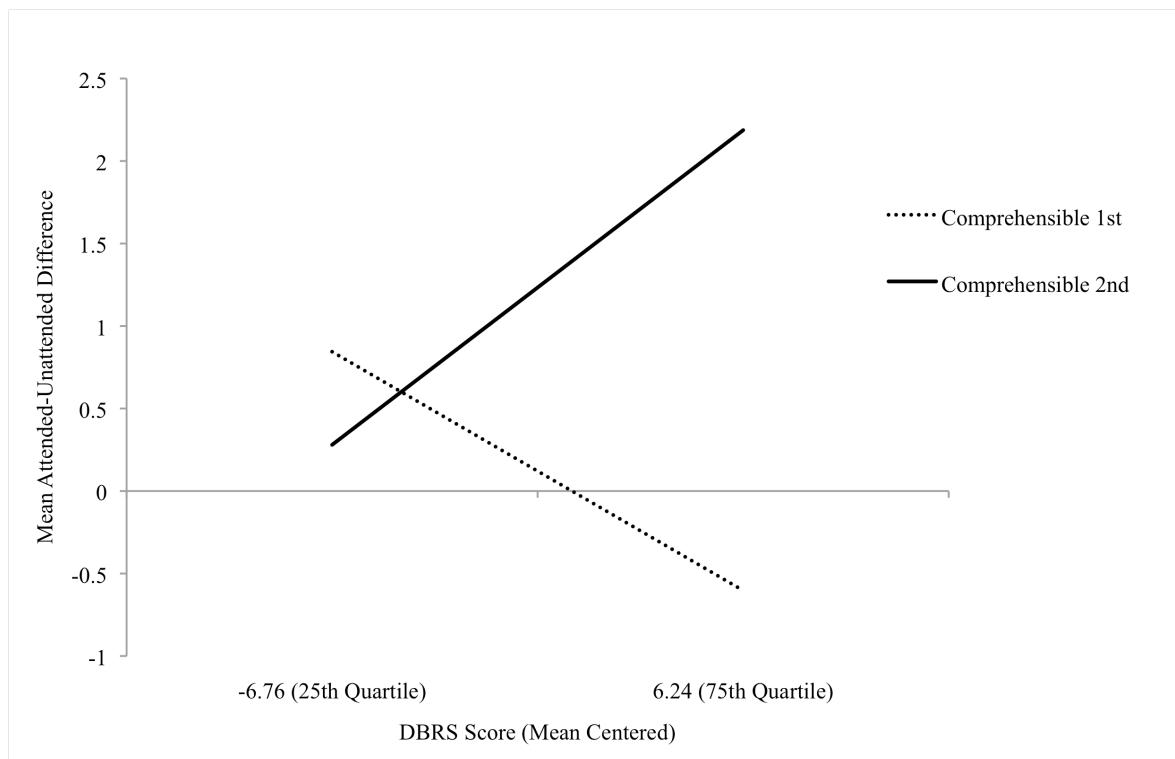
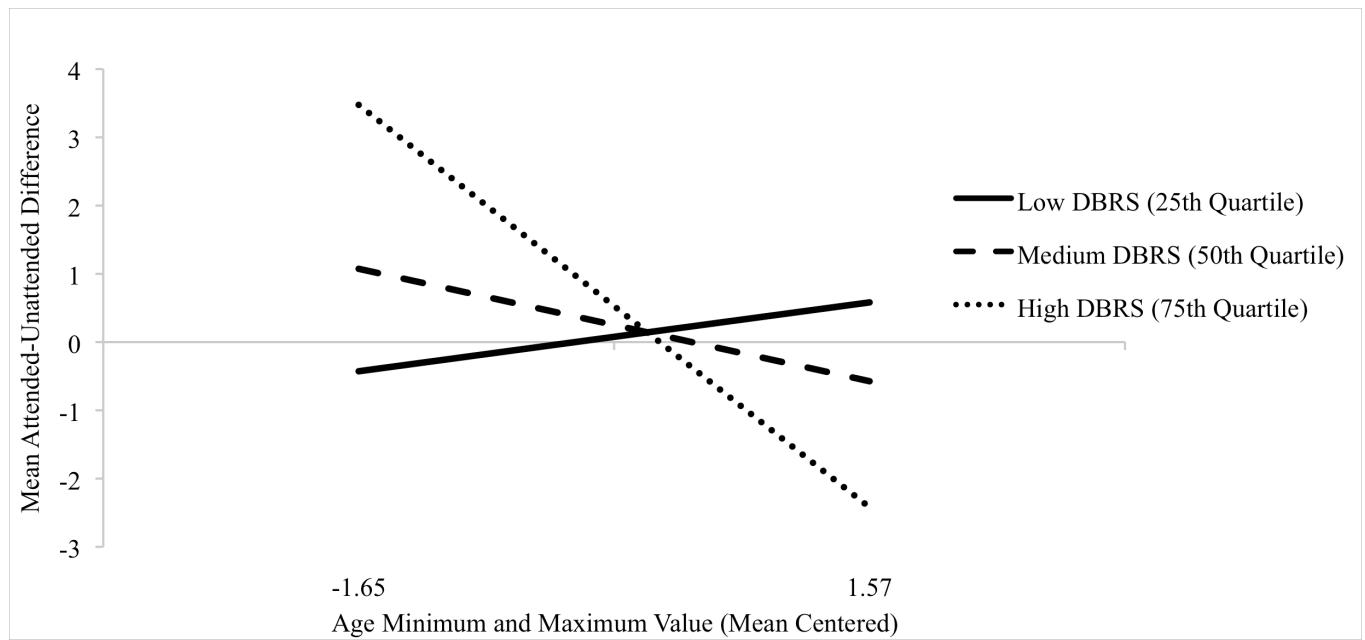


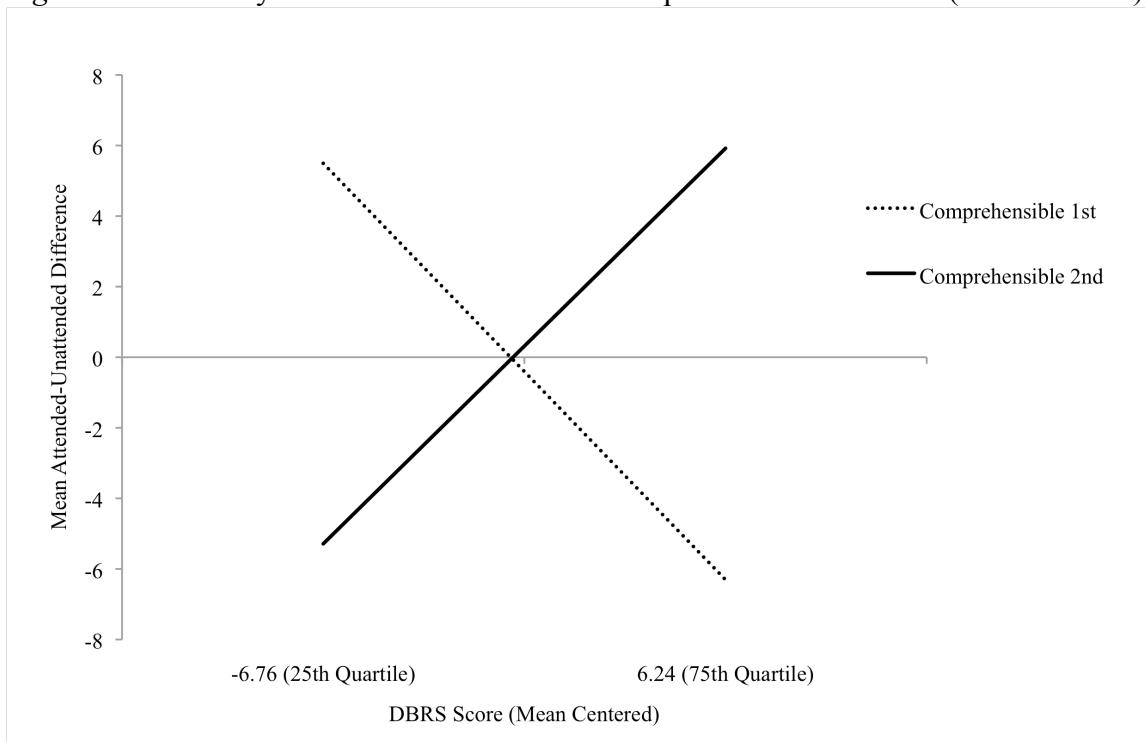
Figure 17. Age by DBRS Interaction for the Comprehensible Narrative (50 to 100ms)



For the 100-150ms time window, there were no significant predictors.

For the 150 to 250ms time window, the best fitting model included DBRS score, Order, and a DBRS score x Order interaction $F(3, 32)=3.256$, $p = .034$, overall $r^2 = .234$. The DBRS x Order interaction was significant: $\beta = -.177$, $SE = .080$, $t = 2.204$, $p = .035$, contribution to $r^2 = .116$ and was the result of a crossover interaction between Order and DBRS Score. See Figure 18.

Figure 18. DBRS by Order Interaction for the Comprehensible Narrative (150 to 250ms)



For the 250-400ms time window, the best fitting model included DBRS score as the sole predictor $\beta = .132$, $SE = .057$, $t = 2.301$, $p = .028$, $F(1, 34)=5.294$, $p = .028$, overall $r^2 = .134$. This relationship was such that an increase on the DBRS was associated with a positive change in the attention effect.

Incomprehensible Narrative

For the 0-50ms time window, there were no significant predictors

For the 50-100ms time window, the best fitting model included DBRS score, Order, DBRS x Order, Age, and Order x Age as predictors $F(5, 30)=3.263, p = .018$, overall $r^2 = .352$. Both of the interaction terms were significant DBRS x Order $\beta = .274, SE = .096, t = 2.856, p = .008$, contribution to $r^2 = .139$; Order x Age $\beta = 2.917, SE = 1.182, t = 2.468, p = .019$, contribution to $r^2 = .132$. The DBRS x Order interaction was such that with an increase in DBRS score, children who viewed the incomprehensible narrative during the second block of the experiment had a steeper, positive slope compared to children who viewed the incomprehensible during the first block of the experiment. The Age x Order interaction was such that overall, children who viewed the incomprehensible narrative first showed negative attention modulation while children who viewed the incomprehensible narrative second showed positive attention modulation. However, with increases in age, this difference became more pronounced.

See Figures 19 and 20.

Figure 19. DBRS by Order Interaction for the Incomprehensible Narrative (50 to 100ms)

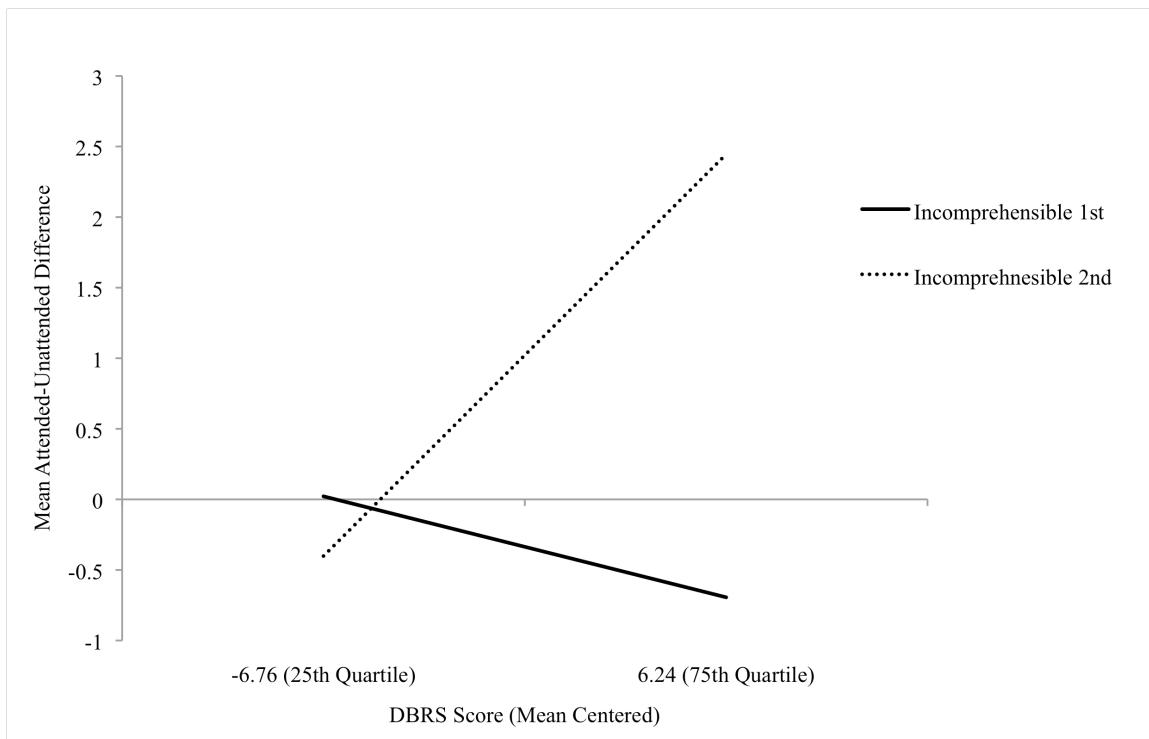
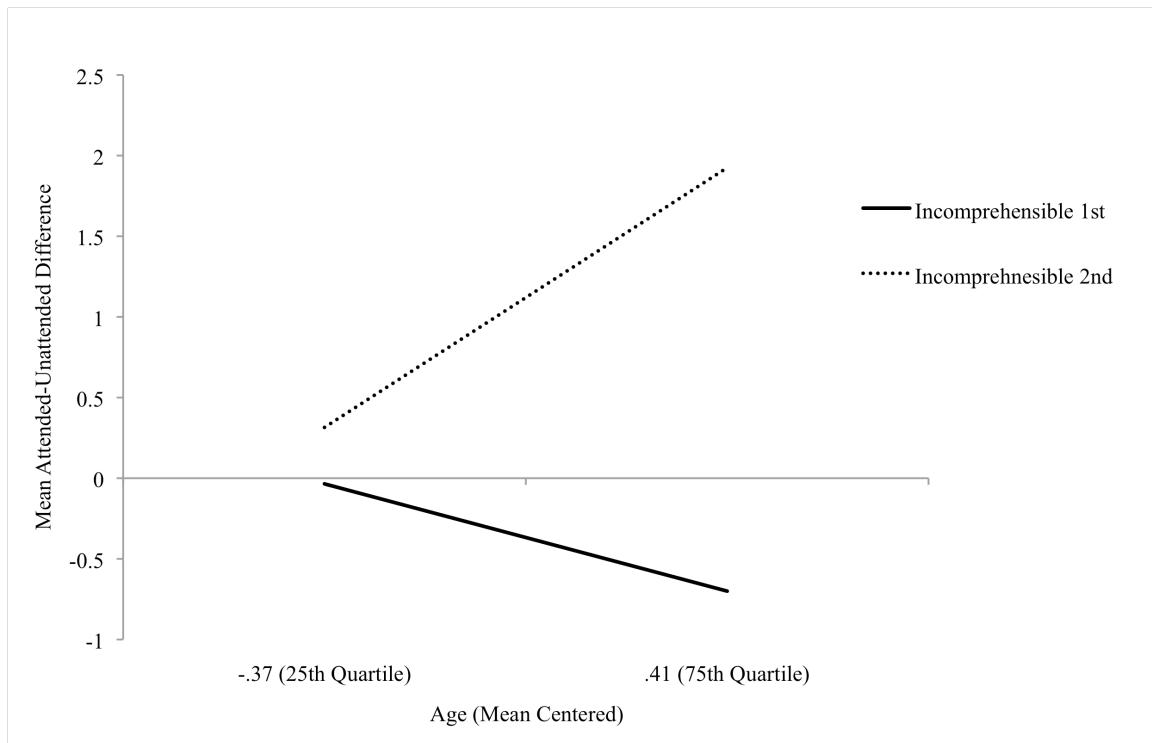


Figure 20. Age by Order Interaction for the Incomprehensible Narrative (50 to 100ms)



For the 100-150ms time window, the best fitting model included DBRS score, Order, DBRS x Order, Age, and Order x Age as predictors $F(5, 30)=2.200, p = .081$, overall $r^2 = .268$. Both of the interaction terms were significant DBRS x Order $\beta = .240$, $SE = .092, t = 2.61, p = .014$, contribution to $r^2 = .130$; Order x Age $\beta = 2.661, SE = 1.133, t = 2.349, p = .026$, contribution to $r^2 = .135$, and were due to crossover relationships between the two predictors. See Figures 21 and 22.

Figure 21. DBRS by Order Interaction for the Incomprehensible Narrative (100-150ms)

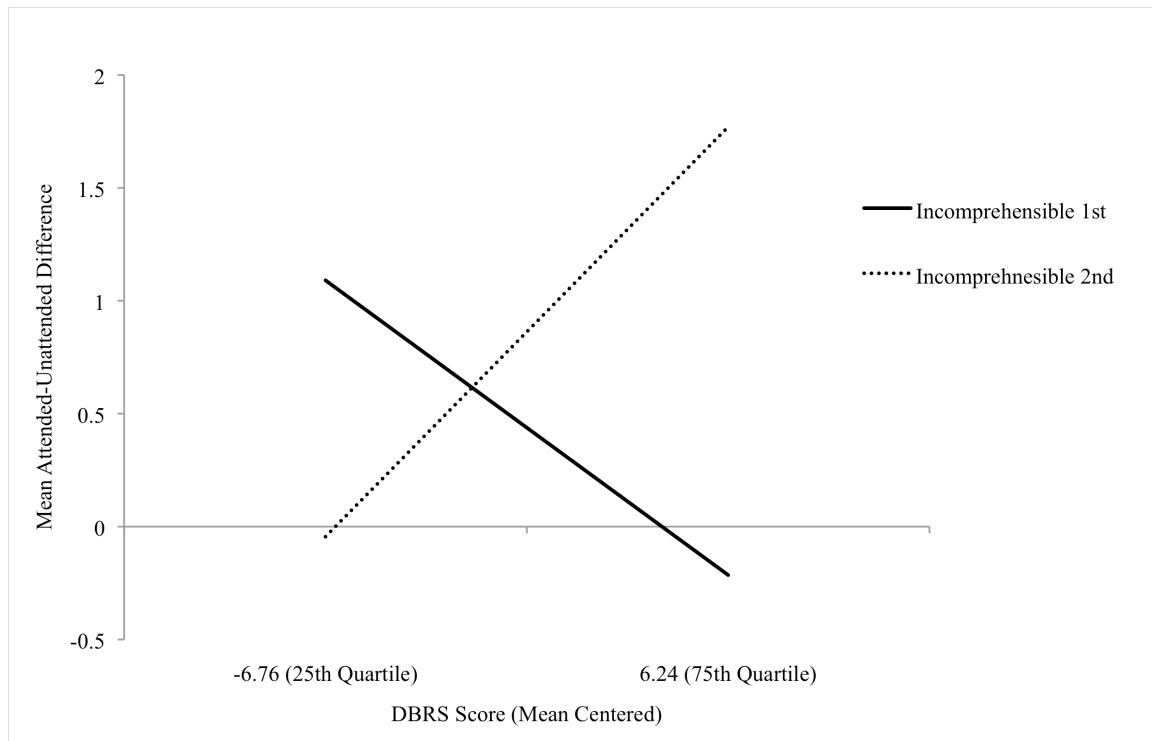
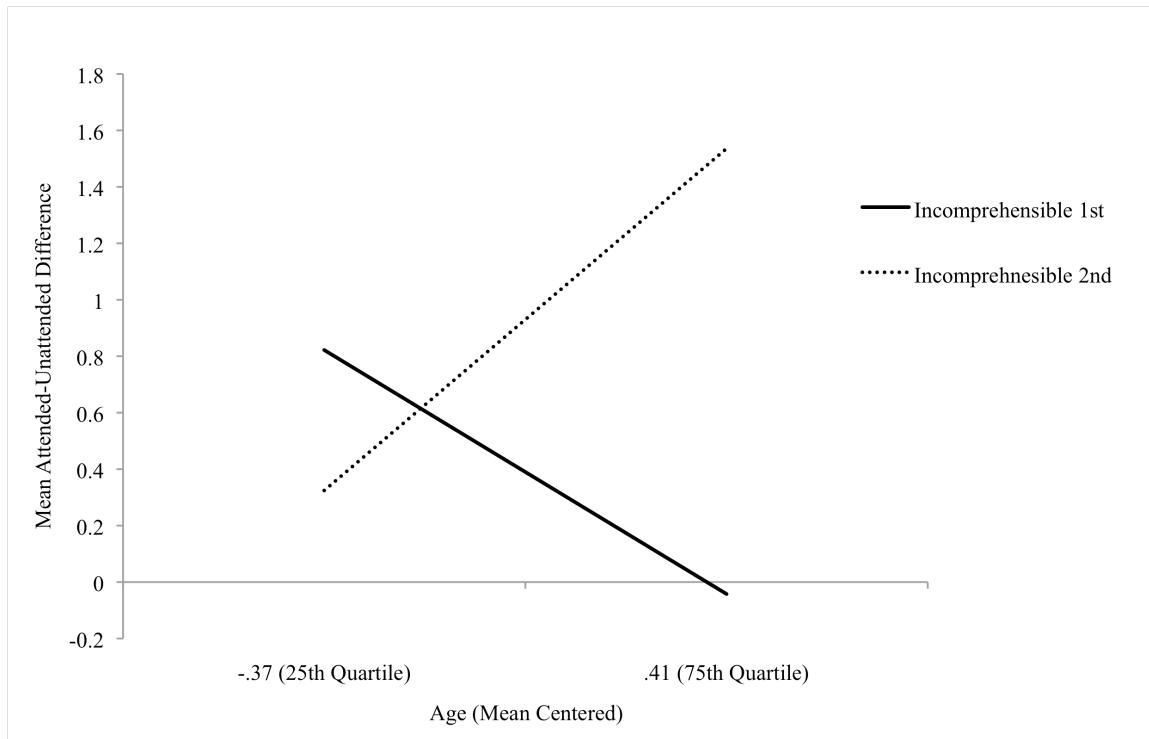
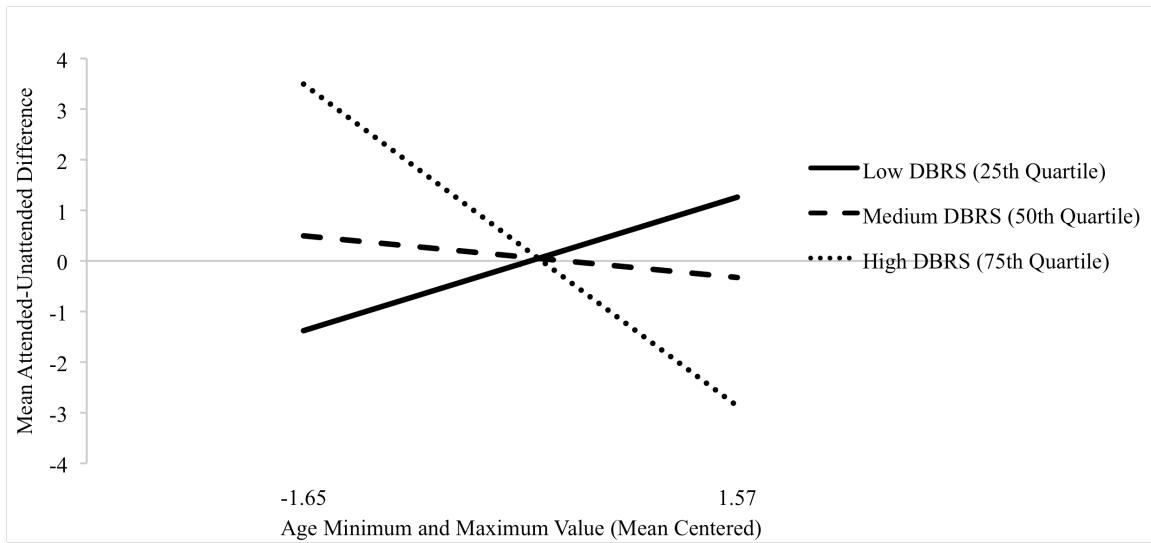


Figure 22. Age by Order Interaction for the Incomprehensible Narrative (100 to 150ms)



For the 150-250 the best fitting model included DBRS score, Age and a DBRS x Age interaction $F(3, 32)=2.177, p = .110$, overall $r^2 = .169$. The DBRS x Age interaction was significant: $\beta = -.215, SE = .085, t = 2.526, p = .017$, contribution to $r^2 = .166$. This interaction was the result of children with higher DBRS scores having steep, negative slopes, and with decreases in DBRS score, less steep, positive slopes See Figure 23.

Figure 23. Age by DBRS Interaction for the Incomprehensible Narrative (150 to 250ms)



For the final time window (250-400ms) there were no significant predictors.

In sum, for the comprehensible narrative, processing during the earliest two time windows (0-50 and 50-100ms) was affected by Age, DBRS score, and Order. In particular, children with higher scores on the DBRS showed the greatest attention modulation, though the direction of this modulation depending on the age of the child. The order of the narratives also predicted the magnitude and direction of attention modulation such that younger children and children with higher DBRS scores had the greatest differences in their attention modulation based on whether they were viewing the comprehensible narrative during the first or second block. For the penultimate epoch,

there was a crossover interaction between DBRS score and narrative order such that there was attention modulation across children with low and high DBRS scores, but the polarity of the attention modulation depended on the narrative order. The latest time window (250-400ms) DBRS score was the sole predictor of attention modulation, and was such that increases in DBRS score were associated with positive increases in the polarity and magnitude of attention modulation.

For the incomprehensible narrative, there were no significant predictors for either the earliest or the latest time windows of interest. For the 50-100ms and 100-150ms time windows, there were interactions of Order x Age and Order x DBRS. The pattern of these interactions was such that during the 50-100ms time window, the magnitude and polarity of attention modulation for older children and for children with higher DBRS scores depended more on the order of the narratives than for the younger children and for children with lower DBRS scores, whereas for the 100-150ms time window, these interactions were closer to orthogonal and were the result of narrative order affecting children across ages and DBRS scores differentially. In the 150-250ms time window, there was a DBRS x Age interaction, which was the result of children with higher DBRS scores showing the greatest attention modulation, though the polarity of the modulation depended on the age of the child.

Interim Discussion

In the current data, children's AEPs exhibited the broad positivity following stimulus onset as observed by Coch et al. (2005) and Sanders et al. (2006). Although it is difficult to draw direct parallels given that those two studies did not collect information about ADHD symptoms and that the stimuli were different, the data from the current

study do add to the growing literature suggesting that the N1 auditory evoked component is more refractory in children.

As a whole, the analyses showed that children with higher scores on the DBRS showed more evidence of attention modulation in their auditory-evoked potentials. The ANOVA-based analyses, which were used to make qualitative comparisons across the two groups, showed more evidence of attention modulation in children who scored above the group mean on the DBRS. However, the magnitude and polarity of the attention modulation in this group depended largely on which block of the experiment the data were collected during. Despite showing qualitative differences in attention modulation, the two groups did not differ in the amount of information they recalled from either of the narratives.

To better understand the relationship between DBRS score and attention modulation, a series of regression analyses were run that also included narrative order and the child's age as predictors. Taken together, these regression analyses revealed a fairly complex set of relationships between spatially selective attention to television and the covariates. Of particular note, was that for the comprehensible narrative, children's age was a significant moderator only for the earliest time windows, whereas for the incomprehensible narrative, children's age moderated attention modulation during the three middle time windows. This pattern of findings suggests age related differences in spatially selective attention based on the complexity of the stimuli in which the task is embedded.

CHAPTER IV

GENERAL DISCUSSION

The current paper reports on two experiments that examined spatially selective attention to television in adults, typically developing preschoolers, and preschoolers who exhibited ADHD symptoms. In terms of behavioral findings, not surprisingly, adults showed no deficit in their comprehension of the stories as a function of narrative comprehensibility. However, contrary to our hypotheses, the two groups of children did not differ in the amount or type of information they recollect about each of the narratives. Based on previous literature, we expected that the typically developing children would outperform the ADHD children on recollection of central content, at least in the comprehensible narrative condition.

The fact that we failed to replicate the findings reported by Lorch and colleagues in numerous studies could be due to the fact that the narratives selected for this study were too simple to produce differences between the groups. Although both *Curious George* and *Clifford* require that viewers make implicit connections between events, these programs are intended for a preschool audience and it could be that these connections are so easy to make that the ADHD children did not show a deficit relative to their typically developing peers. This explanation seems especially likely given that neither of the groups differed on their recollection as a function of narrative comprehensibility, where we would expect some deficit across groups for the incomprehensible narrative. Further, the simplicity of these narratives afforded only a modest amount of comprehension questions about both central and peripheral content. It could be that more data points are required per participant in order to detect the effect.

Another difference between this study and previous research is that these children are younger than the children from which data were collected by Lorch and colleagues.

Bailey et al. (2010) showed that with age, differences in successful story comprehension between typically developing and ADHD children become more pronounced. It could be that at this young age the differences between the groups were not pronounced enough to be detected.

In terms of the electrophysiological measures, the morphology of the auditory evoked potentials for the adults and the morphology of the auditory evoked potentials for the children were both consistent with the morphologies reported by Coch et al. (2005), Sanders et al. (2006) in that adults' AEPs included the typical P1-N1-P2 complex with an attenuated N1, while the children exhibited a broad positivity between 100 and 200ms following stimulus onset. This pattern of findings adds to a growing literature suggesting that the presence and prominence of the N1 auditory evoked potential is dependent on an interaction between the density of the auditory environment as well as the maturity of participants' auditory evoked potentials.

With regard to the larger literature that has examined electrophysiological differences in auditory processing between typically developing and ADHD populations, the current findings are somewhat hard to place. Recall that generally, differences by ADHD status in the N1 are not identifiable until 7-to-9-years of age. In the current data, the children's AEPs did not exhibit this N1. As was mentioned earlier, we believe that this difference in morphology is likely due to the density of the auditory environment in the current study. However, during the time window in which the N1 would typically be observed, we did see group differences by ADHD status, such that the ADHD-like

children showed a greater waveform amplitude compared to the typically developing children. Previous research showing differences by ADHD status in the P2 (e.g., Satterfield et al., 1994) attribute these differences to the presence of an early negativity in typically developing but not ADHD participants. In the current study, we observed such an early negativity that was modulated by attention in the typically developing but not the ADHD-like participants. Thus, in this regard, our findings are somewhat in line with the existing literature on AEPs in ADHD populations. However, it is important to keep in mind that the existing literature is widely varied in the paradigms used, the diagnostic criteria to determine ADHD status, and substantial variability in the age group of interest. Together, these differences make it challenging to firmly place the current data within the larger framework, given that all available evidence suggests that these three factors interact to produce differences in AEPs that are not necessarily due to global selective attention abilities but that are artifacts of methodological decisions (see Barry et al., 2003).

In terms of attention modulation, as a whole, the ADHD preschoolers showed the most electrophysiological evidence of spatially selective attention, followed by adults and then the typically developing children. This pattern is contrary to our hypotheses which were, generally, that we would see the greatest attention modulation in adults, followed by typically developing children, and ADHD children having the least attention modulation. However, it is important to keep in mind that the auditory evoked potentials were measuring selective processing of the white noise probes that were played from the same location as the attended audio track compared to processing of the probes that were played from the same location as the unattended audio track, not attention to the audio

tracks themselves. This distinction is crucial in that it provides some information regarding our primary question, which was, whether ADHD children's inability to strategically apply attention is due to a perceptual or cognitive deficit.

Although speculative, one argument for the findings attained here is that the adults and the typically developing children were able to inhibit processing of the auditory probes in the attended location and focus solely on the audio stream that matched the video in the comprehensible narrative condition. Thus, these participants were engaging in spatially selective attention, however within the attended location, they were applying an additional filter which allowed them to efficiently comprehend the narrative without having to process the probes from that location. Given that all participants had at least some experience with TV or film, and, more than likely, had experience selectively attending to screen media, it makes sense that when presented with a comprehensible narrative, these participants were able to ignore all irrelevant information, regardless of location, which resulted in them having adequate comprehension of the narrative, though not exhibiting attention modulation in the AEPs. Further, in the comprehensible narrative, participants' were better able to make predictions about what they would hear next based on previous shots and on what was shown on the screen which might have allowed them to discount the probes as "noise" earlier during the block. For the incomprehensible narrative, participants could not readily predict what was going to happen next, and they may have applied a less stringent filter to the attended location, which resulted in additional processing of the auditory probes in the attended location and was manifested as more attention modulation in the AEPs, relative to the comprehensible condition.

Recall that for adults, the pattern of findings was such that participants who viewed the comprehensible narrative during the first block and the incomprehensible narrative during the second block showed negative, but only marginally significant attention modulation during the comprehensible narrative and virtually no attention modulation during the incomprehensible narrative. Participants who viewed the incomprehensible narrative during the first block and the comprehensible narrative during the second block exhibited significant, positive attention modulation throughout the both blocks. Although somewhat convoluted, it could be argued that the adult participants who started with the comprehensible narrative more quickly discounted the auditory probes as meaningful and became more adept at ignoring them. During the second block, this strategy was maintained and thus they showed a hint of attention modulation during the first block, and no attention modulation during the second block which was the incomprehensible narrative. Conversely, adult participants who started with the incomprehensible narrative were not as quick to apply an additional filter to the probes played from the attended location, because they were allowing additional information to be processed given the relative unpredictability of the stimulus. Why this effect may have carried over into the second block (the comprehensible narrative), though, is also a matter of speculation. It could be that, by attending to the incomprehensible (and therefore, less predictable) narrative first, the adult participants were somehow primed to continue processing some irrelevant information (the probes). Or, perhaps, that it was most parsimonious to continue with the same strategy throughout the experiment then to change strategy halfway through.

Although for typically developing children attention modulation during the

incomprehensible narrative showed up during an early negativity (as opposed to during the broad positivity as hypothesized), the fact that these participants showed more attention modulation in the incomprehensible condition supports the theory outlined above. The fact that typically developing kids' AEPs were not affected by order suggests that whatever mechanism induced these order effects in adults was not present in the typically developing children.

The ADHD children's data present a somewhat different story. If, in fact, the adults and typically developing children were attending around the probes played from the attended location, then the fact that the ADHD children show the most attention modulation in their AEPs suggests that these children were processing more of the irrelevant information, but within the appropriate location. That is, these children were able to engage in spatially selective attention but could not engage in more fine tuned selective attention within that location.

During the earliest time window in which attention modulation was detected in these children (100-150ms) the difference between the AEPs to the probes in the attended location and the AEPs to the probes in the unattended location was positive and unaffected by order. During the latest two time epochs, children who viewed the incomprehensible narrative during the second block showed positive, significant attention modulation while children who viewed the incomprehensible narrative during the first block exhibited nonsignificant, negative attention modulation.

Together, these findings suggest that regardless of narrative order, the ADHD children were engaging in early processing of the probes within the attended location. One likely possibility why we observed increased, later processing of the probes in the

attended stream for the second block is that the children's task vigilance was waning, and what filter they had applied between the attended probes and the attended narrative was weakening, and more irrelevant stimuli within the attended location were being processed. Previous research on attentional deficits in ADHD (e.g., Tsal, Lilach, & Mevorach, 2005) has shown that these children do show deficits in sustained attention, which may explain why we see this additional modulation in the ADHD children toward the end of the study.

Overall, the explanation for our findings is in concordance with existing research on the attentional capabilities of children with ADHD. Friedman-Hills, Wagman, Gex, Pine, et al. (2010) examined the extent to which top down attentional control impacted distractibility in ADHD children (8-13 years of age). In their study, children partook in a facial discrimination task (target face or deviant face). In addition to the faces on screen, distractor images were also presented along the periphery. In order to assess the contributions of exogenous and endogenous attention, the authors manipulated both the task difficulty by presenting faces that would be perceived as ambiguous by subjects as well as distractor salience by graying out the pictures on the periphery to varying degrees so that in some trials the images were bright and in others they were subdued. The authors found that both task difficulty and distractor salience affected the extent to which ADHD children successfully filtered out the distractors: when the task was at its most difficult, ADHD children performed as well as typically developing children and adults at filtering out the distractors. However when the task was easiest, children with ADHD underperformed compared to the typically developing children and the adults. The authors interpret these findings as tentative evidence that ADHD children have a deficit

in deploying top down selective attention, opposed to a deficit in bottom up sensory inhibition.

Although the paradigm used by Friedman-Hills et al. (2010) is very different from the one used in the current study, the idea that children with ADHD do not have a deficit in inhibiting the processing of irrelevant information but instead have a top down deficit is in line with the findings of the current study – specifically that children with ADHD were able to selectively attend to a given channel, but that within that channel they had difficulty identifying the auditory probes as irrelevant and ignoring them.

Although seemingly less adept at selectively attending within a given location, in the current task, this deficit was not manifested as an underperformance on narrative comprehension by ADHD compared to the typically developing children for either central or peripheral content. However, it is likely that ADHD children's seeming inability to engage in more fine-tuned selective attention would cause deficits in performance under other conditions (e.g., a classroom). Or, as mentioned previously, it could simply be that the measure of narrative comprehension used in the current study was insufficient to detect group differences.

The regression analyses revealed a complex relationship between the child's age, their DBRS score, and narrative order. Although additional research and replication of these findings is necessary before any firm conclusions can be drawn, it seems that regardless of age, children with higher DBRS scores processed the irrelevant information from the attended location, but that this processing was manifested as a positive difference between AEPs for the younger children and a negative difference between AEPs for the older children. Previous research on the AEPs suggests that the

morphology of AEPs is highly dependent on context – namely, the paradigm used and the age of the children. What this change in polarity between the difference scores indicates is a matter for future research, however the fact that these children had the greatest differences between the AEPs to the probes in the attended location and the AEPs to the probes in the unattended suggests that regardless of age, children with higher scores on the DBRS processed more irrelevant information than other participants.

Limitations

Although novel in many ways, the current research had a handful of methodological limitations. Foremost of these limitations was the fairly narrow criterion used to determine group membership among the child participants. While the children included in the sample were a few years shy of the age of average ADHD diagnosis of 6 or 7 (Achenbach, Edelbrock, & Howell, 1987) and therefore would be unlikely to have an official diagnosis yet, the fact that information about ADHD symptoms was gathered just one parent means that there may have been biased or inaccurate reporting, which could have affected the results.

Another potential limitation was the stimuli used. Although great care was taken to ensure that the televised narratives matched on basic auditory formal features and in volume, because the stimuli were not created artificially, we could not possibly control every feature of the audio, which may have introduced additional noise into the data. However, this limitation was necessary given that the research questions all dealt selective attention to television. While it is theoretically possible to create an animated stimulus with an embedded narrative, it is likely that the quality of such a stimulus would not be as good as a commercially produced program, thereby reducing the external

validity of the study.

A final limitation that was touched on earlier was the measure of narrative comprehension and recollection employed. Previous research by Lorch and colleagues included a minimum of 10 cued recall questions for each narrative and the narratives themselves typically lasted upwards of 20 minutes. Here, children were allowed to freely recall information and were then asked follow up questions as needed and the narratives were only about 10 minutes long. Although it is not clear that the same methods used by Lorch and colleagues could have been applied here given that the children in the current study were several years younger than those typically studied by Lorch and colleagues and that the narratives used here were relatively simplistic, it is possible that using a more structured and/or in depth approach to examine narrative comprehension may have yielded different findings.

Summary and Future Directions

In the current paper we argued that children with ADHD symptoms were able to engage in spatially selective attention, however, within a given channel, they had difficulty selectively attending to information. Adults and typically developing children were able to selectively attend to a specific location as well as to particular information within that location, such that they were able to perceive and comprehend all aspects of the narratives, but did not show evidence of spatially selective attention. However, it is important to note that this study represents the first of its kind, and replication of these findings is necessary before any firm conclusions can be drawn.

In terms of future research, a straightforward replication seems like an appropriate first step, with consideration of the limitations noted above. If the phenomena observed

here should prove to be robust, then a next logical step would be to conduct this study while incorporating the strategy of Lorch et al. (2006) whereby program content was categorized into central and peripheral sequences and then the auditory probes were played purposefully at different times throughout each sequence. If there is any truth to the argument made here, then in such a study we would expect typically developing children to show the greatest attention modulation in their AEPs during sequences that featured peripheral content and the least amount of attention modulation during sequences that featured central content, while we not expect to see any difference based on content relevance in the ADHD children.

Another area worthy of exploration is whether these phenomena extend to the different subtypes of ADHD. Here, scores for items on the DBRS that measured inattention were highly correlated with those that measured hyperactivity/impulsivity ($r = .724$). Moreover, the pattern of findings did not change based on whether symptoms of inattention or hyperactivity/impulsivity were considered. Together, these results suggest that the children in this study were most like children with ADHD-CT. However, future research should also be focused on including children who meet the diagnostic criteria for the primarily inattentive and primarily hyperactive/impulsive subtypes to see if the findings obtained here also extend to those populations.

Finally, additional research is needed to better understand the complex relationships observed between age and ADHD symptoms. Because age differences were not central to the current research questions, little care was applied to purposefully include children of different age ranges in the two groups. However, it is clear from the exploratory regression analyses that a child's age, even within the restricted range of the

present study, is an important factor in fully understanding the relationship between ADHD symptoms and selective attention.

APPENDIX A

ADHD DIAGNOSTIC CRITERIA

I. Either A or B:

- A. **Six or more of the following symptoms of inattention have been present for at least 6 months to a point that is disruptive and inappropriate for developmental level:**

Inattention

1. Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities.
2. Often has trouble keeping attention on tasks or play activities.
3. Often does not seem to listen when spoken to directly.
4. Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions).
5. Often has trouble organizing activities.
6. Often avoids, dislikes, or doesn't want to do things that take a lot of mental effort for a long period of time (such as schoolwork or homework).
7. Often loses things needed for tasks and activities (e.g. toys, school assignments, pencils, books, or tools).
8. Is often easily distracted.
9. Is often forgetful in daily activities.

- B. **Six or more of the following symptoms of hyperactivity-impulsivity have been present for at least 6 months to an extent that is disruptive and inappropriate for developmental level:**

Hyperactivity

1. Often fidgets with hands or feet or squirms in seat.
2. Often gets up from seat when remaining in seat is expected.
3. Often runs about or climbs when and where it is not appropriate (adolescents or adults may feel very restless).
4. Often has trouble playing or enjoying leisure activities quietly.
5. Is often "on the go" or often acts as if "driven by a motor".
6. Often talks excessively.

Impulsivity

1. Often blurts out answers before questions have been finished.
 2. Often has trouble waiting one's turn.
 3. Often interrupts or intrudes on others (e.g., butts into conversations or games).
- II. Some symptoms that cause impairment were present before age 7 years.
- III. Some impairment from the symptoms is present in two or more settings (e.g. at school/work and at home).
- IV. There must be clear evidence of significant impairment in social, school, or work functioning.
- V. The symptoms do not happen only during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder. The symptoms are not better accounted for by another mental disorder (e.g. Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

APPENDIX B
DBRS FOR ADULTS

Please circle the number next to each item that best describes your behavior ***during the past 6 months.***

Item	Never or Rarely	Sometimes	Often	Very Often
1. Fail to give close attention to details or make careless mistakes in my work	0	1	2	3
2. Fidget with hands or feet or squirm in seat	0	1	2	3
3. Have difficulty sustaining my attention in tasks or fun activities	0	1	2	3
4. Leave my seat in situations in which seating is expected	0	1	2	3
5. Don't listen when spoken to directly	0	1	2	3
6. Feel restless	0	1	2	3
7. Don't follow through on instructions and fail to finish work	0	1	2	3
8. Have difficulty engaging in leisure activities or doing fun things quietly	0	1	2	3
9. Have difficulty organizing tasks and activities	0	1	2	3
10. Feel "on the go" or "driven by a motor"	0	1	2	3
11. Avoid, dislike, or am reluctant to engage in work that requires sustained mental effort	0	1	2	3
12. Talk excessively	0	1	2	3
13. Lose things necessary for tasks or activities	0	1	2	3
14. Blurt out answers before questions have been completed	0	1	2	3
15. Am easily distracted	0	1	2	3
16. Have difficulty awaiting turn	0	1	2	3
17. Am forgetful in daily activities	0	1	2	3
18. Interrupt or intrude on others	0	1	2	3

APPENDIX C
DBRS FOR CHILDREN

Please circle the number next to each item that best describes the behavior of this child
during the past 6 months.

Item	Never or Rarely	Sometimes	Often	Very Often
1. Fail to give close attention to details or make careless mistakes in his/her work	0	1	2	3
2. Fidgets with hands or feet or squirms in seat	0	1	2	3
3. Has difficulty sustaining his/her attention in tasks or fun activities	0	1	2	3
4. Leaves his/her seat in situations in classroom or in other situations in which seating is expected	0	1	2	3
5. Doesn't listen when spoken to directly	0	1	2	3
6. Seems restless	0	1	2	3
7. Doesn't follow through on instructions and fails to finish work	0	1	2	3
8. Has difficulty engaging in leisure activities or doing fun things quietly	0	1	2	3
9. Has difficulty organizing tasks and activities	0	1	2	3
10. Seems "on the go" or "driven by a motor"	0	1	2	3
11. Avoids, dislikes, or is reluctant to engage in work that requires sustained mental effort	0	1	2	3
12. Talks excessively	0	1	2	3
13. Loses things necessary for tasks or activities	0	1	2	3
14. Blurs out answers before questions have been completed	0	1	2	3
15. Is easily distracted	0	1	2	3
16. Has difficulty awaiting turn	0	1	2	3
17. Is forgetful in daily activities	0	1	2	3
18. Interrupts or intrudes on others	0	1	2	3

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