Summer 7-16-2021

Different Pathways To Cognition: An Erp Investigation of Enhanced Perceptual Functioning And Autistic Traits in School-aged Children

Elizabeth Anne Kaplan-kahn
Syracuse University

Abstract

Autistic[1] individuals show enhanced perceptual functioning on a range of behavioral tasks. Neurophysiological evidence, from both fMRI and event related potential (ERP) studies, also supports the conclusion that autistic individuals utilize perceptual processes to a greater extent than neurotypical comparisons to support problem solving and reasoning. Despite substantial evidence supporting differential information processing streams in autism, the relationship between these processing streams and autistic traits is not well understood. One study has investigated the relationships between autistic traits, early perceptual ERPs, and subsequent cognitive ERPs in neurotypical adults; however, these relationships have yet to be explored in autistic and neurotypical children and adolescents. The goals of the current study were to test how the relationship between early perceptual and subsequent cognitive ERPs may differ between autistic and neurotypical individuals and to investigate how autistic traits may impact these relationships. 14 autistic and 10 neurotypical children and adolescents participated in a semantic violation ERP task. Path models were compared to test undirectional relationships among an early perceptual ERP (P1 component), a subsequent cognitive ERP (N400 effect), and the Attention to Detail subscale of the Autism Spectrum Quotient. Though conclusions are limited by the smaller than expected sample size (due to the COVID-19 pandemic), preliminary results indicate that autistic individuals' level of attention to detail is related to early perceptual processing, as evidenced by the condition differences in their P1 components. Path analysis model comparisons are also preliminary but support the conclusion that the relationship between participants' levels of attention to detail and the size of their N400 effect may be mediated by the size of condition differences in their P1 components. Such results replicate and extend previous findings regarding the nature of differential information processing pathways in autism and their relationship to autistic traits.

Keywords: Autism, Perception, ERP, Path Analysis, Attention to Detail

[1] 'Identity-first' language is preferred by the majority of autistic adults (e.g., Bottema-Beutel et al., 2021; Kenny et al., 2015) and will be used throughout this document.

DIFFERENT PATHWAYS TO COGNITION: AN ERP INVESTIGATION OF ENHANCED PERCEPTUAL FUNCTIONING AND AUTISTIC TRAITS IN SCHOOL-AGED CHILDREN

by

Elizabeth A. Kaplan-Kahn

B.A., Johns Hopkins University, 2013
M.S., Syracuse University, 2018

Dissertation
Submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in School Psychology.

Syracuse University
July 2021

Acknowledgements

I am immensely grateful for the countless ways that my amazing support network has helped me reach this milestone. First, I would like to thank the many faculty members of the Syracuse University Psychology Department who have invested their time and effort in my education as both a clinician and a researcher. I am especially grateful to my faculty advisor, Dr. Natalie Russo, for continually fostering my intellectual curiosities and development. These past five years have been challenging and rewarding in so many ways because of your guidance and support, and I am ever thankful to have you as a lifelong mentor.

Elizabeth Cotter, Patricia Goodhines, Lisa LaRowe, and Lea Taylor are the epitome of strong, brilliant, and outstanding women, who I am so very honored to also call friends. Thank you all for your limitless validation and for encouraging me to always be my most authentic self. I cannot wait to see the outstanding heights you all achieve as we take these next steps into our lives and careers.

I am the woman I am today because of my family, Zack, Michael, Regina and Ken Kaplan, who have all provided lifelong support that will forever be my bedrock of strength. Mom and Dad, you both have been my constant source of encouragement, comfort, optimism, and love. There are not words to express how profoundly grateful I am to be your daughter.

Finally, to my spouse, Dan Kahn. This achievement is as much yours as it is mine. From moving with me across the country at the beginning of graduate school, to guiding me through last-minute tech crises, you have been with me on each and every step of this journey, and I could not have gotten to this point without you. Having you as my partner has been the greatest joy of my life, and you will forever have my deepest love and gratitude.

Elizabeth A. Kaplan-Kahn

Table of Contents

Different Pathways to Cognition: An ERP Investigation of Enhanced Perceptual Functioning and Autistic Traits in School-Aged Children

In March of 2020, the Centers for Disease Control and Prevention's Autism and Developmental Disabilities Monitoring Network released its most recent estimate that approximately 1 in 54 eight-year-old children have a diagnosis of autism spectrum disorder (hereafter 'autism;' Maenner et al., 2020). This updated report continues the now well-established trend of increasing rates of autism among school-age children in the United States (Blumberg et al., 2013; CDC - Centers for Disease Control and Prevention, 2018; Matson & Kozlowski, 2011; Newschaffer, 2005). As the number of autistic students continue to increase, so too does the need to more fully understand the characteristic information processing patterns of these students in order to provide instructional environments which are maximally compatible with their learning and cognitive styles. One promising approach to this challenge is to focus on investigating *how* autistic children and adolescents process information rather than enumerating the ways these individuals *fail* to show neurotypical patterns of processing.

One framework that focuses on understanding the characteristic processing patterns of autistic individuals, particularly focusing on their strengths, is the Enhanced Perceptual Functioning model (Mottron & Burack, 2001). The focus of the Enhanced Perceptual Functioning model of autism is on the well-documented perceptual processing abilities of autistic individuals that are superior to those of age- and IQ-matched peers (e.g., Bonnel et al., 2003; Chamberlain et al., 2013; Järvinen-Pasley et al., 2008; Mottron et al., 2006). Here, perceptual processing includes mechanisms dedicated to the detection (e.g., Thomas et al., 2019), discrimination (e.g., Maye et al., 2002), and categorization (e.g., Ashby et al., 2007) of stimuli.

The current study builds upon the Enhanced Perceptual Functioning framework by examining the ways in which early differences in perceptual processing impact subsequent cognitive mechanisms. I first review the primary claims of the Enhanced Perceptual Functioning theory before providing a summary of literature highlighting the ways in which perceptual processing in autism differs from neurotypical processing based on behavioral paradigms. Next, I review literature regarding the neurophysiological underpinnings of cognitive profiles of autistic individuals and provide a summary of electrophysiological methods. Finally, I summarize previous studies connecting electrophysiological indicators of processing to autistic traits, followed by the specific aims of the current study.

Enhanced Perceptual Functioning Model

The primary claim of the Enhanced Perceptual Functioning model posits that processing mechanisms dedicated to the detection, discrimination, and categorization of perceptual stimuli are enhanced among autistic persons as compared to their neurotypical peers (Mottron et al., 2006; Mottron & Burack, 2001). The authors of the model emphasize that, because perception is an early and primary component of nearly all information processing, small changes in lower-level perceptual processing can lead to substantial impacts on higher-order cognitive mechanisms (Mottron & Burack, 2001). The transactional nature between different levels of mental processes (i.e., sensory, perceptual, and cognitive) features prominently in the Enhanced Perceptual Functioning model. Assuming that autistic perceptual processing is enhanced, it follows that autistic individuals capitalize on these strengths and use such perceptual processes as their "default setting" in the information processing stream (Mottron et al., 2006). As these processing streams are repeated over the course of a lifetime, particular patterns of information flow are reinforced and strengthened, increasing the likelihood that the processing stream will be

used again, perpetuating the pattern of information processing (Smith & Thelen, 2003). Small and early diversions in such processing streams therefore have the ability to result in substantial cognitive and behavioral differences over the course of development (Spencer et al., 2011).

The Enhanced Perceptual Functioning model conceptualizes many autistic traits as a consequence of the atypical weighting of perceptual processes over cognitive ones in everyday reasoning and problem solving. This is not to say that higher-order cognitive mechanisms are deficient in autistic individuals but, rather, that such mechanisms are optional in autistic individuals, whereas they are mandatory among neurotypical individuals (Mottron et al., 2006). Over the course of development, the increased weighting of perceptual processes over cognitive processes in autism leads to a superior performance on a variety of perceptual tasks, and such perceptual expertise may underlie savant abilities exhibited by some individuals on the autism spectrum (Mottron et al., 2009, 2013). In essence, the model proposes that autistic persons utilize information processing streams that are different from neurotypical persons and holds that these different information flows are adaptive in that they exploit strengths in their unique neurobiological and psychological processing systems.

The Enhanced Perceptual Functioning framework of autism is supported by an impressive body of empirical evidence detailing superior perceptual skills in autism as compared to neurotypical individuals. Enhanced perceptual functioning in autism is demonstrated across nearly all sensory modalities, including olfaction (Ashwin et al., 2014), haptic/tactile perception (Hadad & Schwartz, 2019; Nakano et al., 2012), and audition (Bonnel et al., 2003, 2010; Heaton et al., 1998; Mottron et al., 1999; O'Riordan & Passetti, 2006; Pring et al., 2008; Stanutz et al., 2014); however, the domain of vision is the most thoroughly investigated (Dakin & Frith, 2005; Kaldy et al., 2016; Simmons et al., 2009). The following literature review first discusses

behavioral paradigms supporting the Enhanced Perceptual Functioning model of autism and then summarizes relevant neurophysiological studies that provide further compelling evidence in support of the framework.

Enhanced Perceptual Processing in Autism

Behavioral Tasks

The most well-studied behavioral paradigms documenting enhanced performance of autistic individuals are visual search tasks (Treisman & Gelade, 1980) and embedded figure tasks (Witkin et al., 1971). Visual search tasks vary in nature, but all measure participants' reaction times as they identify a target visual stimulus amongst an array of distractors. Autistic individuals show superior performance (i.e., faster reaction times to identify targets) on visual search tasks throughout the lifespan, including toddlers (Kaldy et al., 2011), children (Plaisted et al., 1998), adolescents (Joseph et al., 2009), and adults (Kemner et al., 2008; O'Riordan, 2004) on the autism spectrum. These processing advantages at visual search tasks have been demonstrated to arise at the early, bottom-up level of processing perceptual features, rather than later attentional processes (Shirama et al., 2017). Furthermore, superior performance on visual search tasks at 15-months (Gliga et al., 2015) and 3-years of age (Cheung et al., 2018) specifically predicts later autistic traits and neither Attention Deficit/Hyperactivity Disorder (ADHD) nor anxiety symptoms. These data all support the Enhanced Perceptual Functioning model of autism in that they find that autistic individuals demonstrate enhanced perceptual discrimination and detection for low-level features of visual stimuli.

Findings of perceptual advantages in autism have also been noted for embedded figure tasks, in which participants are asked to identify a common shape (e.g. a triangle) which is embedded within a larger image (e.g., a line drawing of a stroller; Witkin et al., 1971). Similar to

the enhanced performance demonstrated on visual search tasks, autistic children and adults show superior performance to neurotypical individuals in terms of both accuracy (Brosnan et al., 2012; Morgan et al., 2003; Mottron et al., 2003; Pellicano et al., 2005, 2006; Ropar & Mitchell, 2001; Shah & Frith, 1983) and speed (Brosnan et al., 2012; Falter et al., 2008; Jolliffe & Baron-Cohen, 1997) on embedded figure tasks. Despite some contrary findings (Brian & Bryson, 1996; Kaland et al., 2007), a meta-analysis on autistic performance on this task revealed that the overall effect of the autistic advantage on embedded figure tasks is significant (Muth et al., 2014). The autistic advantage on embedded figure tasks may arise from the use of differential processing tendencies: while neurotypical individuals likely engage in higher-order cognitive operations to detect the embedded figure, autistic individuals appear to rely on earlier perceptual processes (Jarrold et al., 2005).

In sum, there is a substantial evidence base demonstrating the enhanced performance of autistic individuals across the lifespan on behavioral tasks, including a range of visual search tasks and embedded figure tasks. These processing differences appear to arise very early in development (Cheung et al., 2018; Gliga et al., 2015), before other behaviors that are considered for a diagnosis of autism (e.g., social reciprocity differences or focused interests) typically develop, suggesting that such advantages are not secondary to other autistic traits. Further, enhanced behavioral performance has been associated with bottom-up perceptual processes (detection and discrimination) rather than advantages with memory (Joseph et al., 2009) or attentional mechanisms (Shirama et al., 2017); however, although such behavioral studies are interesting, they do not provide evidence regarding how these processing differences are represented in the brain. For example, it would be a reasonable critique of the evidence presented thus far to argue that the data do not provide support for *differential* processing, but the *same*

type of processing happening at a *faster* rate. Neuropsychological evidence can help elucidate the neurocognitive mechanisms underlying these behavioral differences.

Neurophysiological Evidence of Cognitive Profiles in Autism

Neurophysiological evidence is a crucial complement to behavioral paradigms because it allows for the study of how psychological mechanisms are instantiated at a neuronal level in the brain (Aue et al., 2009). Just as different street directions can get a driver to their destination at approximately the same time, so too might different neurophysiological mechanisms allow individuals to exhibit similar behavioral performances. Thus, neurophysiological studies can not only help elucidate relationships between brain regions and behavioral outcomes but also reveal how differential neurological mechanisms may represent comparable solutions in the complex development of information processing streams.

Research employing functional magnetic resonance imaging (fMRI) has yielded strikingly consistent patterns of brain activation in autistic individuals across a variety of perceptual reasoning tasks, including visual search and embedded figure tasks. When completing feature visual search tasks, autistic children and adolescents display increased activation in occipital regions as compared to age- and IQ-matched neurotypical participants (Keehn et al., 2008). Such patterns of activation suggest that the autistic advantage on these tasks may stem from increased recruitment of areas of the brain dedicated to early perceptual processing. Increased recruitment of visual cortex is also found in autistic children (Lee et al., 2007), adolescents (Damarla et al., 2010; Manjaly et al., 2007), and adults (Ring et al., 1999) performing more complex visual searches in embedded figure tasks. Again, these neurophysiological data suggest that autistic individuals recruit regions of the brain dedicated to low-level feature processing when completing these visual tasks. In addition to the increased

occipital cortex activation, autistic participants in these studies also demonstrate decreased recruitment of prefrontal cortical areas as compared to neurotypical participants (Damarla et al., 2010; Lee et al., 2007; Ring et al., 1999). Critically, although autistic and neurotypical participants demonstrate brain-based differences on these tasks, the groups do not exhibit differences in their behavioral performances, suggesting again that these brain-based differences are alternative neural approaches to comparable behavioral performance (Damarla et al., 2010; Lee et al., 2007; Ring et al., 1999).

Similar neurophysiological results are also evidenced in tasks aimed to assess cognitive processing styles and reasoning. For instance, autistic individuals demonstrate superior visuospatial abilities on the Block Design subtest of the Wechsler Intelligence Scales (Caron et al., 2006; Ishida et al., 2009; Morgan et al., 2003; Muth et al., 2014; Pellicano et al., 2006; Shah & Frith, 1993; Van Lang et al., 2006). In a modified version of the Wechsler Block Design task, autistic participants demonstrate increased activity in occipital brain regions specialized for perceptual functions as compared to age-matched neurotypical participants (Hubl et al., 2003). Autistic participants also exhibit this same pattern of neural activation while completing the matrix reasoning task of the Raven's Standard Progressive Matrices (Sahyoun et al., 2010; Soulières et al., 2009). Prefrontal activity while completing the matrix reasoning task was, in contrast, decreased in autistic participants, which replicate findings of similar fMRI studies. These differences in neural activation are found even when autistic and neurotypical participants were matched on accuracy and reaction times while completing the matrix reasoning task (Soulières et al., 2009). Such findings underscore the importance of conducting neurophysiological investigations of autistic cognition, as they reveal potentially important differences in the neural underpinnings of information processing among autistic individuals.

Finally, recent Activation Likelihood Estimation meta-analyses of fMRI studies (Jassim et al., 2020; Samson et al., 2012), provide persuasive evidence confirming the reliability of differential patterns of activation when autistic participants engage in reasoning and problem solving tasks. Taken together, these results provide strong neurophysiological evidence that autistic persons utilize brain regions dedicated to perceptual processes to a greater degree than neurotypical individuals when reasoning and problem solving and do so without a loss in accuracy or reaction time.

In sum, there is robust behavioral and neurophysiological evidence for enhanced perceptual functioning among autistic individuals. What is less clear, however, are how such early perceptual processing differences unfold in time and impact cognitive functions. Put differently, what are the later cognitive consequences of such early perceptual processing differences? Although fMRI studies indicate that autistic individuals recruit different brain regions than neurotypical peers in problem solving, they provide less evidence regarding the time course of *when* information processing differences occur. The temporal resolution of fMRI is on the order of multiple seconds, much slower than our brains process information. Testing the relationships between perceptual and cognitive processes is therefore not possible using fMRI, because the processes progress in rapid succession. As an alternative and complementary method to fMRI, electrophysiology allows researchers to break into the moment-to-moment processing of stimuli and test specific hypotheses about the ways in which these processes unfold over time.

Electrophysiology

Electrophysiology is the study of electrical activity associated with the nervous system, usually recorded by electrodes placed on the scalp. The electrical recording, also known as the electroencephalogram (EEG), reflects the coordinated firing of postsynaptic potentials of

pyramidal cells (Luck, 2014). Although the spatial resolution of EEG is not as exact as other brain imaging techniques, such as fMRI, EEGs have extremely precise temporal resolution, which allows for the study of how perceptual and cognitive processes progress over time. A clear advantage of using electrophysiology in addition to behavioral measures (e.g., reaction time and accuracy), is that examining EEG-related changes in the brain can reveal differences in the timing of information processing that may not be reflected in behavioral differences (Banaschewski & Brandeis, 2007). In order to isolate and make sense of specific neural responses relating to specific perceptual and cognitive mechanisms, EEG signals can be time-locked to the presentation of a stimulus, resulting in a measure of the change in electrical voltage over time, or event-related potential (ERP).

ERPs reflect meaningful changes in electrical voltage in the brain; however, this electrical signal is small in comparison to other electrical activity in the brain that is unrelated to experimental manipulations (Luck, 2014). In other words, within a single trial, the ratio between the ERP signal to other electrical noise in the brain, or 'signal-to-noise' ratio, is very small. As a result, repeated trials of stimulus presentation are necessary in order to average out unrelated voltage changes and isolate the ERP signal. The logic of the averaging technique is that electrical potentials that are indicative of neurocognitive processes occur in a tightly linked temporal fashion every time the neurocognitive mechanism is deployed, while electrical potentials unrelated to the neurocognitive process do not show a similar time-locked relationship to the stimulus. Combining ERP responses to repeated trials increases the signal-to-noise ratio of the ERP signal (Coles & Rugg, 1995) because electrical changes that are unrelated to the presentation of a stimulus are averaged out, whereas changes in electrical potential that are time-locked to the stimulus and reflect meaningful variation remain.

ERP waveforms that have characteristic latencies and amplitudes are called components. In ERP research, latency is operationalized as the time in milliseconds (ms) after the presentation of the stimulus, and amplitude is operationalized as microvolts (μV). Many of the early components, first discovered when ERP research was in its infancy, were defined primarily by the polarity (positive or negative amplitude), latency of the waveforms, and general scalp distribution (Luck, 2014). For example, the visual P1 component is the first positive-going peak in the ERP waveform that occurs when a visual stimulus is presented; it is followed by the visual N1 component, the first negative-going peak in the waveform, and then the visual P2 component, the second positive-going peak. However, these definitions fall short of capturing the function of the underlying cognitive processes because they simply describe aspects of the resulting waveform. Put another way by Donchin and colleagues, "the idea that these waveforms have 'components' reflects the assumption that ERP represents the activity of distinctly functioning [neural] aggregates" (Donchin et al., 1978, p. 353). If ERP studies are to make claims about perceptual and cognitive processes, components need to be defined by factors intrinsic to the component (Luck, 2014). Conceptually, an ERP component is a measure of the electrical activity in the brain that results from the deployment of a specific processing operation.

Because of their precise temporal resolution, ERPs are useful tools to test how differences in early perceptual mechanisms may effect later cognitive processes and how such relationships may differ in autistic and neurotypical individuals. For this study, ERP modulations occurring prior to 200-250 ms are assumed to reflect perceptual processes, while cognitive processes are reflected in modulations after this time period (Doniger et al., 2000). In particular, the current study examined differences in the early perceptual P1 component and the relatively later cognitive N400 effect.

P1 Component

The P1 wave is an obligatory ERP response to exogenous stimuli. The P1 is the conventional name for the first positive-going peak in the ERP wave. The P1 component is largest at occipital electrode sites and begins approximately 60-90 ms after the onset of the stimulus, peaking between 100-130 ms (Luck, 2014). The P1 component exhibits developmental sensitivity in that its amplitude (Itier & Taylor, 2004a, 2004b) and latency (Hileman et al., 2011; Itier & Taylor, 2004a) both decrease with age, both of which are hypothesized to be the result of synaptic pruning and myelinization over the course of development (Itier & Taylor, 2004b). These developmental changes in the P1 component are evidenced in both autistic and neurotypical children (Hileman et al., 2011).

The P1 component was selected as the perceptual waveform of interest for the current study because previous research has indicated that autistic participants may exhibit early differences in their P1 waves in response to semantically congruent versus semantically incongruent stimuli (Russo et al., 2012). In neurotypical individuals, differences between semantically congruent and incongruent conditions are typically seen in later ERP time windows that are more reflective of cognitive processing (see below). Such an early condition difference in the ERP waveforms of autistic participants suggests that they may utilize different processes, ones that are perceptual rather than cognitive in nature, when completing the same task that neurotypical participants employ cognitive mechanisms to complete.

N400 Effect

The N400 is a relatively later ERP component which is elicited when a stimulus is incongruent with the preceding context. The N400 effect is characterized by a frontal negativity that peaks approximately 400 ms after the onset of an incongruous stimulus (Luck, 2014).

Though initially studied within the context of linguistic processing (Kutas & Hillyard, 1980), the N400 effect has been broadly linked to the processing of semantic information more generally (Kutas & Federmeier, 2011), including the congruousness of picture sequences (Ganis et al., 1996), motor actions (Amoruso et al., 2013; Shibata et al., 2009) and mathematical equations (Niedeggen et al., 1999). These studies support the conclusion that the N400 effect is not an indicator of language processing, specifically, but instead reflects the cognitive processing of semantic meaning in a more general sense.

Though there are some contrary findings in the literature, particularly for non-linguistic tasks (Coderre et al., 2017; Manfredi et al., 2020; McCleery et al., 2010; O'Rourke & Coderre, 2021), there is substantial evidence that autistic individuals show decreased N400 effects to semantically incongruous stimuli as compared to neurotypical individuals in both linguistic (Braeutigam et al., 2008; Dunn et al., 1999; Dunn & Bates, 2005; Fishman et al., 2011; Manfredi et al., 2020; McCleery et al., 2010; Pijnacker et al., 2010; Strandburg et al., 1993) and non-linguistic (Coderre et al., 2018; Verbaten et al., 1991) tasks. Many have interpreted decreased N400 effects in autism to be indicative of a deficit in semantic processing, despite behavioral accuracy on these tasks being comparable across autistic and neurotypical groups (e.g., Coderre et al., 2018; Dunn & Bates, 2005), leaving open the question of *how* autistic individuals are solving such tasks.

In their non-linguistic semantic violation paradigm, Russo and colleagues also found decreased N400 effects in the group of autistic adolescents (Russo et al., 2012). The simplicity of the task used in their experiment is notable in the context of other studies using more complex tasks, such as reading written sentences (e.g., Pijnacker et al., 2010) or identifying idioms (Laurent et al., 2006), which require many additional cognitive abilities (e.g., reading fluency,

figurative language, etc.) above and beyond semantic reasoning. The semantic violation in Russo et al. (2012) involved identifying whether a picture of an animal (e.g., a dog or a frog) matched with an animal sound (e.g., a bark or a ribbit). The authors found that although the autistic participants did not exhibit a classic N400 effect to incongruent trials, they showed an *earlier* effect of congruency in their P1 waveforms (Russo et al., 2012). Further, behavioral performance in terms of accuracy and reaction time, did not differ between the groups of autistic and neurotypical participants. The ERP results of Russo et al. (2012) compliment extant fMRI evidence that persons on the autism spectrum recruit different areas of cortex, specifically regions dedicated to early perceptual processing, when engaging in tasks for which neurotypical participants typically utilize prefrontal regions dedicated to later cognitive processes. To reiterate, it appears that even when behavioral performance is the same across groups, autistic participants tend to rely on early perceptual processes to arrive at the same outcomes as neurotypical participants using later cognitive strategies.

Linking Brain and Behavior

While the results of Russo et al. (2012) provide compelling evidence suggesting differential information processing streams between autistic and neurotypical adolescents, the relationship between participants' early perceptual ERP (the P1 component) and their later cognitive ERP (the N400 effect) were not explored. Put differently, while there were group differences as to where in the ERP waveforms participants distinguished between congruent and incongruent trials, the authors did not test how the relationship between the ERP components may have differed between the groups. Further, the data could not speak to how these processing differences may relate to autistic traits. To investigate these outstanding questions, our lab conducted an ERP experiment with neurotypical adults that was closely modeled from the

paradigm in Russo et al. (2012), wherein participants watched and listened to trials of animal pictures and sounds that either matched (congruent condition) or mismatched (incongruent condition) while their EEG activity was recorded. ERP results confirmed the hypotheses that the neurotypical adults did not demonstrate significant condition differences in their P1 waves and showed the expected N400 effect; however, despite the overall non-significant P1 condition differences, the relationship between participants' P1 condition differences was positively correlated with their N400 condition differences (Kaplan-Kahn et al., 2021). In other words, for neurotypical adults, larger early perceptual condition differences were related to larger cognitive condition differences.

We also explored how participants' ERP components were related to their levels of self-reported autistic traits, as measured by the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). Specifically, we examined the Attention to Detail subscale of the AQ. Attention to detail is a trait commonly described in autism (e.g., Baron-Cohen et al., 2009; Ruthsatz & Urbach, 2012; Smith & Milne, 2009), and this AQ subscale had been previously linked to aspects of perception (Stevenson et al., 2017). We found that participants' self-reported levels of attention to detail were significantly correlated with the size of their early perceptual (P1 component) condition differences but not the size of their later cognitive ERP (N400 component). In order to test for unidirectional relationships between these variables (perceptual ERP, cognitive ERP, and attention to detail), we compared two path analysis models. The path analysis model that demonstrated the best fit to the data revealed a significant mediation effect of the size P1 component for the relationship between participants' self-reported level of attention to detail and the size of their N400 component. Neurotypical adults with higher levels of attention to detail

showed larger P1 differences, which, in turn, corresponded to larger N400 effects (Kaplan-Kahn et al., 2021).

To summarize, the data reviewed thus far demonstrate that autistic individuals demonstrate faster accuracy and reaction times across a range of tasks that rely on perceptual processes, specifically the detection and discrimination of stimuli. These perceptual advantages are seen behaviorally across the lifespan, from infancy and childhood through adulthood. fMRI studies suggest that autistic individuals are not only faster at perceptual tasks, but they also recruit different areas of the brain when solving such tasks. More specifically, autistic individuals show increased activation in their occipital cortex when reasoning and problem solving whereas neurotypical individuals show increased activation in their frontal cortex when completing the same tasks. As a compelling complement to fMRI evidence, which demonstrates *where in the brain* information processing occurs, ERP evidence has further substantiated many of the claims of the Enhanced Perceptual Functioning framework of autism by providing evidence as to *when in the information processing stream* differences arise. Our ERP data from a large group of neurotypical adults suggest that these processing stream differences may be related to levels of autistic traits. In particular, the relationship between an individual's self-reported levels of attention to detail and their cognitive processes (as evidenced by the size of the N400 effect) is mediated by their perceptual processes (as evidenced by the size of their P1 component).

Current Study

The current study sought to advance the extant literature supporting the Enhanced Perceptual Functioning model of autism by addressing three specific aims. The first aim was to replicate the ERP results of Russo et al. (2012) in a younger age group of participants.

Replication has been described as the “most important approach” for ensuring true effects, particularly in ERP research wherein the researcher makes many decisions that may lead to increases in Type 1 error rates (Baldwin, 2017; Luck & Gaspelin, 2017, p. 150). This first aim was achieved through an ERP experiment closely modeled from the methods used in Russo et al. (2012). It was hypothesized that there would not be group differences with regards to participants’ accuracy or reaction time on the behavioral task and that significant interactions between condition and group would be found for both the P1 and N400 component analyses. These predictions were motivated by the expectation that autistic participants, but not neurotypical participants, would show P1 differences as a function of condition, whereas neurotypical participants, but not autistic participants, would show N400 differences as a function of condition.

The second aim was to investigate whether there are relationships between early perceptual ERPs (the P1 component) and later cognitive ERPs (the N400 component) in autistic and neurotypical children and adolescents. Although Russo et al. (2012) demonstrated differential information processing between autistic and neurotypical groups, the relationships between the early perceptual and later cognitive ERPs were not examined. Kaplan-Kahn et al. (2021) demonstrated initial evidence supporting a significant relationship between the size of participants’ P1 condition differences and the size of their N400 effects; however, this relationship was exhibited by a group of neurotypical adults. The current study extended these findings to children and adolescents and tests whether these relationships differ between autistic and neurotypical individuals.

The third aim of the current study was to test for unidirectional relationships between autistic and neurotypical youths’ ERPs and their level of autistic traits, specifically attention to

detail. Again, although our lab has provided preliminary evidence that individuals' perceptual processing significantly mediated the relationship between reported levels of attention to detail and their cognitive processing, these relationships were tested among neurotypical adults, and it is unknown whether the same unidirectional relationships are seen among autistic and neurotypical children and adolescents. To address this third aim, the two path analysis models that were tested in adults in our previous study will be run and directly compared among autistic and neurotypical youth. It was hypothesized that the child and adolescent data would support the same mediation model as the adults, in that the relationship between attention to detail and the size of the N400 effect would be mediated by the size of the P1 effect. Data supporting the same mediation model as found in adults would provide compelling evidence pointing towards the stability of these relationships between autistic traits, perceptual processing, and cognitive mechanisms.

The current study has the potential to make a novel contribution to the literature by directly relating autistic traits to differential patterns of information processing among autistic youth. In addition, the expected findings would advance the neuropsychological evidence base of the Enhanced Perceptual Functioning model, demonstrating *different*, not *deficient,* processing mechanisms in autistic individuals. Relating these differential processing streams to autistic traits establishes an important link between brain functioning and behavioral traits that are characteristic of autism. The purpose of emphasizing differential information processing pathways among autistic individuals is not to inform, create, or develop interventions that would encourage more neurotypical functioning. On the contrary, it is to reiterate that these information processing differences are adaptive for autistic persons in that they utilize their unique neuropsychological strengths. Rather than justification for intervention, a deeper understanding

of different pathways to cognition provides evidence that there is no singular "right" way of processing the richness of our world and encourages the opportunity for professionals of all kinds (researchers, clinicians, educators, etc.) to embrace and celebrate neurodiversity.

Method

Participants

Autistic Participants

14 autistic participants (11 males) between the ages of 6 and 17 years participated in the study. Exclusion criteria included abnormal or non-corrected-to-normal vision, a history of a hearing disorder, seizures, or any other neurological disorders. Participants were also excluded if their Full-Scale IQ (FSIQ) was less than 75 on the basis of the Wechsler Abbreviated Scales of Intelligence, Second Edition (WASI-II; Wechsler, 2011). Autism diagnoses were confirmed using the Autism Diagnostic Observation Schedule, Second Edition (Lord et al., 2012), the Autism Diagnostic Interview, Revised (Rutter et al., 2003), and clinical judgment. The combination of these instruments represents the 'gold standard' in both clinical and research autism diagnostic settings.

Neurotypical Participants

A total of 11 neurotypical participants (6 males) between the ages of 6 and 17 years participated in the study. Similar to the autistic group, any neurotypical participants with a FSIQ of less than 75, abnormal or non-corrected-to-normal vision, a history of a hearing disorder, seizures, or any other neurological disorders were excluded. Additionally, neurotypical participants did not have any history of psychological diagnoses, such as ADHD, anxiety, or depression. One neurotypical participant who completed the experiment was excluded from all analyses due to below-chance accuracy (47%) on the behavioral task, indicating that they were

not sufficiently attending to the experiment and their results are unlikely to reflect meaningful variation in the data. This resulted in a neurotypical sample size of $n = 10$.

Participant Note

Although the initial recruitment goals of the study were to include 17 autistic participants and 43 neurotypical participants between the ages of 6 and 16 years, participant recruitment was stopped in March 2020 due to the COVID-19 pandemic. A total of 20 participants (10 autistic and 10 neurotypical) between the ages of 6 and 16 years were run in the experiment before in-person data collection was discontinued. Four additional 17-year-old participants were run on the same experimental task as pilot participants prior to the study's proposal. Although 17-year-old participants were initially going to be excluded from all analyses due to differences in reporters (self-report versus parent-report) on the Autism Quotient (described below), they were included in the behavioral analyses and ERP analyses described below. The purpose of including the 17-year-old autistic participants in these analyses was to increase statistical power in analyses that do not include the Autism Quotient as a variable of interest. The 17-year-old participants were not included in the path analyses due to the Autism Quotient being a relevant variable for these analyses.

Additional Participant Characteristics

In addition to autism diagnostic status, clinical characterizations of the study participants were collected. Given the common comorbid diagnoses of ADHD (Antshel et al., 2016; Antshel & Russo, 2019) and anxiety (Muris et al., 1998; Simonoff et al., 2008) in autistic populations, data from the Behavior Assessment System for Children, Second Edition subscales of Attention Problems, Hyperactivity, and Anxiety were used to characterize the sample of participants. Although autism, ADHD, and anxiety are hypothesized to arise through distinct developmental

pathways (Shephard et al., 2018), the impact of these characteristics in empirical investigations is still important to consider.

Participant descriptive analyses were conducted with *R* Version 3.6.0 (R Development Core Team, 2019). Due to the small and uneven group numbers, group differences were examined in order to determine which variables needed to be controlled for in subsequent analyses. Welch's *t*-tests were used to test for group differences because this analysis does not assume or require equal variances among groups, and the test exhibits increased power (de Winter, 2013) and decreased rates of Type 1 errors (Delacre et al., 2017) over standard *t*-tests when analysis groups are small and unequal in size and when groups have unequal variances (Ruxton, 2006). Autistic and neurotypical groups differed significantly from one another with regards to age (M_A = 14.27, SD_A = 3.13, M_{NT} = 11.24, SD_{NT} = 3.04; $t(19.92) = 2.38$, $p = .028$), FSIQ (M_A = 104.14, SD_A = 9.37, M_{NT} = 119.50, SD_{NT} = 10.64; $t(17.88) = -3.65$, $p = .002$), AQ Total Scores (M_A = 136.71, SD_A = 13.57, M_{NT} = 103.50, SD_{NT} = 17.06; $t(16.62) = 5.26$, $p < .001$), and *t*-scores on the BASC-2 Hyperactivity (M_A = 61.62, SD_A = 14.79, M_{NT} = 47.80, SD_{NT} = 10.85 $t(20.98) = 2.58$, $p = .017$) and Attention Problems (M_A = 62.38, SD_A = 9.14, M_{NT} = 45.6, SD_{NT} = 5.62; $t(20.91) = 5.42$, $p < .001$) subscales (see Table 1). Groups did not differ with regards to their perceptual reasoning index (PRI) on the WASI-II, AQ Attention to Detail raw score, nor BASC-2 Anxiety subscale scores (all *p*'s > .05). All participant descriptive variables were continuous and normally distributed (skewness = -0.30 to 0.36; kurtosis = -1.27 to 0.21).

Measure of Autistic Traits - The Autism Spectrum Quotient (AQ)

The Autism Spectrum Quotient (AQ) is a brief screening measure of autistic traits, originally developed as a self-report for adults over the age of 16 years (Baron-Cohen et al., 2001). Subsequent extensions of the AQ included parent-report versions for adolescents between

the ages of 12 and 16 years, as well as children between the ages of 4 and 11 years (Auyeung et al., 2008; Baron-Cohen et al., 2006). Given that the age range for this study spaned 6 to 17 years of age, all 3 versions of the AQ were used (though see Participant Note above regarding which analyses included the AQ as a variable). All versions of the AQ demonstrate sufficient test-retest reliability and internal consistency (Auyeung et al., 2008; Baron-Cohen et al., 2001, 2006). Individuals over the age of 16.9 years completed the AQ-Adult, while the AQ-Child and AQ-Adolescent versions were used for children between 6 and 16.9 years. All of the AQ scales consist of 50 items scored on a four-point Likert scale, ranging from *definitely agree, slightly agree, slightly disagree,* to *definitely disagree*. In addition to a total score, the AQ also includes five subscales – Social Skills, Attention Switching, Attention to Detail, Communication, and Imagination. The current study specifically examined participants' score on the Attention to Detail subscale of the AQ.

There are slight differences in item wording for select items between the different versions of the AQ (e.g., AQ-Adult Item 26: "I frequently find that I don't know how to keep a conversation going;" AQ-Adolescent Item 26: "S/he frequently finds that s/he doesn't know how to keep a conversation going;" AQ-Child Item 26: "S/he is good at taking care not to hurt other people's feelings"). In the original AQ-Adult, scale items were scored dichotomously and reported in terms of raw scores that range from 0 to 50, with higher scores indicating a greater degree of autistic traits. Although some subsequent research has employed the same dichotomous scoring system, collapsing between *definitely/slightly agree* and *definitely/slightly disagree* responses (Baron-Cohen et al., 2006; Woodbury-Smith et al., 2005), other studies have scored the response scale on a four-point Likert scale (Auyeung et al., 2008; Hoekstra et al., 2007), arguing that the degree of endorsement reflects meaningful information regarding

variability of autistic traits. The current study used a Likert scale scoring system ranging from 1 (lowest autistic traits) to 4 (highest autistic traits), with total scores ranging from 50 to 200.

Procedure

Testing took place in the Center for Autism Research and Electrophysiology (CARE) lab, part of the psychology laboratory space at Syracuse University. The study procedures were explained to each participant and their parent or legal guardian, and informed consent and assent forms were signed prior to testing. All consent and assent forms as well as the study procedures used in the current study were approved by Syracuse University's Institutional Review Board. Participants and their parents were first taken through the informed assent and consent procedures and participant's head circumference was measured in order to determine the correct HCGSN Net size. Once the electrode cap was placed, participants were instructed to make themselves comfortable in the testing chair and asked to minimize their movements and blinking while the experiment was in progress. The HCGSN cap was then connected to the amplifier before the experiment began. While child participants were being capped, their parent/guardian filled out the AQ and BASC for their child(ren).

Brief written instructions informed participants that they were about to see pictures and hear sounds of animals. The directions instructed participants to indicate whether the picture and the sound matched after each trial. Participants were asked to press one of two keys to indicate their response; the response keys were clearly labeled on the keyboard provided to participants to minimize memory demands of the task. Participants completed a total of 400 trials, split into two blocks of 200 trials each. Each participant was given the opportunity to take a break in between the two experimental blocks.

Stimuli

Two visual stimuli consisted of a picture of a dog and a picture of a frog (see Figure 1 for visual stimuli). The two auditory stimuli consisted of short audio clips of a dog bark and a frog ribbit. Visual stimuli were presented using MATLAB on a VPixx Technologies® VIEWPixx monitor with a screen resolution of 1920 by 1200 pixels. The auditory stimuli were presented using MATLAB through two BOSE® Companion2, Series II Multimedia Speaker System speakers adjacent to the left and right side of the monitor. Visual and auditory stimuli for each trial were presented simultaneously. Congruent trials consisted of visual and auditory stimuli that matched on the basis of animal (i.e., a picture of a dog presented with the audio of a dog bark and a picture of a frog presented with the audio of a frog ribbit). Incongruent trials were comprised of visual and auditory stimuli that did not match on the basis of animal (i.e., a picture of a dog presented with the audio of a frog ribbit and a picture of a frog presented with the audio of a dog bark). Participants were presented with a total of 400 trials, 200 congruent and 200 incongruent, presented in a randomized trial.

Behavioral Measure

A simple behavioral task was included as part of the experiment in order to ensure that participants were attending to the stimuli throughout the experiment. Participants were instructed to hit one of two keys to indicate whether the trial was congruent or incongruent (‘Y’ for congruent; ‘N’ for incongruent). Reaction time and accuracy were recorded for each trial. As described above, one neurotypical participant was excluded from all analyses due to below-chance accuracy on the behavioral task. Trials with reaction times greater than 5 seconds were discarded, as these delayed responses also indicated that the participant was not attending to the trial. The number of discarded trials per participant ranged from zero to 72 and did not differ

significantly between the groups (M_A = 18.63, SD_A = 23.77, M_{NT} = 19.88, SD_{NT} = 25.05 t(14.74) = 0.11, p = .915)

EEG Recording and Processing

Continuous EEG activity was sampled at a rate of 1024 Hz using Net Station Software from Electrical Geodesics, Inc. (Electrical Geodesics Inc., 2003). All participants were fitted with a HydroCel GSN cap with 128 electrodes on the basis of their head circumference. During EEG recording, all electrodes were referenced to the Cz electrode, located at the apex of the participants' head. Placement of the electrode cap and the Cz reference electrode was standardized by locating the intersection of the sagittal plane between the left and right mastoids (temporal bones located behind each ear) and the coronal plane between the naison (bridge of the nose) and inion (occipital bone at the base of the skull). EEG signals from each electrode were magnified using an amplifier with a band-pass filter of 0.1-30 Hz. Electrical noise from resistance and inductance, also known as impedances, were measured and kept below 50 kΩ (Luck, 2014). During the experiment, triggers designating the precise onset (i.e., the simultaneous presentation of the visual and auditory stimuli) and congruency (i.e., congruent or incongruent) of each trial were marked within the EEG data. These triggers were used in order to time lock the continuous EEG data to the presentation of the stimuli, thus allowing for the analysis of changes in electrical potential that were directly related to the presentation of stimuli.

Subsequent to the EEG recording, the EEG data were processed and analyzed using a combination of EGI, EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) software. First, EEG data were filtered using a band-pass filter of 0.1-30 Hz. Band-pass filtering removed the effects of high- and low-frequency waveforms that were unrelated to changes in brain activity (e.g., large gradual voltage changes due to skin potentials and electrical

frequencies emitted by cellphones and computers). Next, in line with published guidelines and previous research (Duncan et al., 2009), continuous EEG data were re-referenced to the average of the left and right mastoids.

Next, the continuous EEG data were segmented into epochs, creating the individual ERPs for each trial. The EEG data were time-locked to the onset of each trial using triggers that indicated both the precise time the stimuli were presented and the congruency of the multisensory stimuli. Each epoch began 100 ms before the onset of the trigger and ended 650 ms after the trigger onset (Duncan et al., 2009). Following segmentation, baseline correction for each trial was performed at each electrode by subtracting the average voltage of the pre-trigger 100 ms window from the 650 ms post-stimulus waveform. These baseline correction procedures established a near-zero voltage at the onset of the trial trigger, allowing the ERP data to be equated across trials (Luck, 2014). Artifact detection was then performed over the entire 750 ms epoch period in order to mark epochs containing artifacts such as eye blinks, eye movements, and large motor movements, such as jaw clenching. Artifact detection was conducted using a moving peak-to-peak window of 100 ms, moved in a stepwise function of 50 ms over each channel (Keil et al., 2014). Epochs with channels containing more than a 100-microvolt change within the time window were marked for removal. In addition to scripted artifact detection codes, each participant's epoched data were visually inspected for bad channels that require interpolation. Bad channels included those with visible noise, commonly due to high impedance or electrical resistance. Selected channels were interpolated using Spline interpolation (Luck, 2014).

All epochs not marked for removal were averaged together for each participant on the basis of congruency. All participants exceeded the *a-priori* 15% accepted trials cut-off,

indicating that their ERPs met established criteria to reliably reflect the controlled variation in the experiment. Grand average waveforms were created for each group by averaging participants' ERP waveforms in each condition; this averaging allowed for within-group comparisons of ERPs to congruent and incongruent conditions, as well as between-group comparisons of where in the ERP waveform significant differences arose.

Data Analyses

Data Analysis Note

Due to the COVID-19 pandemic and associated restrictions of in-person data collection, the final group of participants was significantly smaller than originally proposed, resulting in reduced statistical power to detect the hypothesized effects. In light of these unexpected constraints, two approaches were taken in order to evaluate the hypotheses of the current study. First, where appropriate, alternative analyses (e.g., using an analysis of covariance [ANCOVA] rather than an analysis of variance [ANOVA]) were conducted to minimize the number of statistical tests and adopt the most parsimonious approach to understanding the data. To inform necessary changes to the data analysis plan, extensive descriptive statistics were conducted to characterize and compare the autistic and neurotypical participant groups across study variables (see Additional Participant Characteristics above). Second, for analysis where there were no viable alternatives to data analysis (i.e., path analyses), analyses were conducted as originally proposed to demonstrate functional competency. Limitations to the interpretation of these results are highlighted in the Discussion.

Behavioral Data Analyses

A MATLAB script was used to obtain behavioral response data for each subject and format the data into a .csv file that was analyzed in *R*. Proportion of correct trials and reaction

times (in seconds) were extracted for each participant. Though BASC-2 Hyperactivity and Attention Problem *t*-scores also differed significantly between the groups, neither variable was included as a covariate in the behavioral response data ANCOVAs because neither were correlated with accuracy (Hyperactivity: $r(23) = 0.08$, $p = .70$; Attention Problems: $r(23) = 0.03$, $p = .89$) or reaction time (Hyperactivity: $r(23) = -0.05$, $p = .81$; Attention Problems: $r(23) = -0.26$, $p = .22$).

Due to age-related changes in accuracy (Votruba & Langenecker, 2013), reaction time (Iida et al., 2010), as well as the significant age difference between the groups (see Additional Participant Characteristics above), ANCOVAs were used to evaluate the effects of independent variables on the data while accounting for age. ANCOVA makes several assumptions about the data, including linearity between the covariate and outcome variable, homogeneity of regression slopes, homoscedasticity, and no significant outliers in the groups.

Accuracy Analysis. For participants' accuracy data, there was a linear relationship between the covariate (age variable) and the outcome variable (accuracy) for each group and condition, as assessed by visual inspection of a scatter plot (see Figure 2). There was homogeneity of regression slopes, as the interaction terms between the covariate (age) and grouping variables (group and condition) were not statistically significant, p's > .05. The Levene's test for equity of variances was not significant ($p > .05$), so assumption of homogeneity of the residual variances for both groups was not violated. Standardized residuals were all less than |3|, indicating that there were no outliers in the accuracy data.

Reaction Time Analysis. Before conducting the reaction time data ANCOVA, checks for ANCOVA assumptions were conducted. There was a linear relationship between the covariate (age variable) and the outcome variable (reaction time) for each group and condition,

as assessed by visual inspection of a scatter plot (see Figure 3). There was homogeneity of regression slopes, as the interaction terms between the covariate (age) and grouping variables (group and condition) were not statistically significant, p's > .05. The Levene's test for equity of variances was not significant (p > .05), so assumption of homogeneity of the residual variances for both groups was not violated. Standardized residuals were all less than |3|, indicating that there were no outliers in the reaction time data.

ERP Analyses

P1 Analysis. Visual P1 responses were analyzed at the Oz electrode (E75), which is a midline electrode located occipitally, over visual regions. This location was chosen because the P1 scalp distribution is typically maximal over the occipital lobe and the experimental stimuli were presented in the center of the screen, thus avoiding any lateralization of the P1 response (Luck, 2014; Luck & Kappenman, 2012). Given that the amplitude (Itier & Taylor, 2004a, 2004b) and latency (Hileman et al., 2011; Itier & Taylor, 2004a) of the P1 component undergo age-related changes, individual P1 time windows were calculated for each participant. First, in order to select unbiased time windows for each participant, a grand-average waveform was created for each participant by averaging ERP responses across conditions (congruent and incongruent). Next, the P1 time window was selected by locating the absolute positive peak in the time window of 50 to 150 ms and calculating 25 ms before and after the peak. For example, if a participant's ERP waveform shows a positive peak at 80 ms, the P1 time window for that participant would be 55-105 ms. This method maximized reliability in the data by ensuring that individual variability is taken into account when selecting the P1 time window (Hileman et al., 2011).

Once the P1 analysis time windows were selected, mean P1 amplitude was calculated and extracted separately for congruent and incongruent trials using the "Mean amplitude between two fixed latencies" function in EEGLAB (Delorme & Makeig, 2004). This function calculated the average voltage between the two latencies (in ms) for each participant. Mean amplitude was chosen as the quantification measure for the P1 amplitude because it is more robust against increases in background noise than other ERP indicators such as peak amplitude or adaptive mean (Clayson et al., 2013). Similar to the behavioral results, due to the known relationships between age and P1 amplitude (Hileman et al., 2011; Itier & Taylor, 2004a, 2004b) RM-ANCOVAs were used to evaluate the effects of group (autistic and neurotypical) and condition (congruent and incongruent) while accounting for group variability in age. Though BASC-2 Hyperactivity and Attention Problem *t*-scores differed significantly between the groups, neither variable was included as a covariate in the P1 mean amplitude ANCOVAs because neither were correlated with P1 mean amplitude (Hyperactivity: $r(23) = 0.17$, $p = .43$; Attention Problems: $r(23) = 0.27$, $p = .22$).

Preliminary checks were conducted to ensure that there were no violations of the assumptions of linearity (see Figure 4), normality of residuals (Shapiro Wilk test $p > .05$), homogeneity of regression slopes (interaction terms between the covariate (age) and grouping variables (group and condition) $p > .05$), and homogeneity of the residual variances (Levene's test $p > .05$). With the neurotypical participant removed prior to data analysis, there were also no cases with standardized residuals greater than |3|, indicating that there were no outliers. The P1 amplitude values were submitted to a mixed RM-ANCOVA with the within-subject factor of condition (congruent and incongruent), the between-subject factor of group (autistic and neurotypical), and the covariate of age.

N400 Analysis. Participants' N400 responses were analyzed at the FCz electrode (E6), which is a frontocentral electrode located on the midline. This location was chosen because the N400 scalp distribution was maximal over the frontocentral region for Russo and colleagues using the same semantic violation paradigm (Russo et al., 2012). Unlike the P1 component, the N400 effect is only apparent when comparing between congruent and incongruent conditions. As such, and based on published guidelines (Duncan et al., 2009), the N400 time window was defined as 300-500 ms. Within this time window, mean N400 amplitudes were calculated and extracted separately for congruent and incongruent trials.

Similar considerations regarding age-related changes to the size of the N400 effect (Kutas & Iragui, 1998) influenced the decision to run variance analyses that included participant age as a covariate. BASC-2 Hyperactivity and Attention Problem *t*-scores were not included as a covariates in the N400 ANCOVAs because neither were correlated with mean N400 amplitude (Hyperactivity: $r(23) = -0.20$, $p = .37$; Attention Problems: $r(23) = -0.19$, $p = .39$). Again, RM-ANCOVAs were used to evaluate the effects of group (autistic and neurotypical) and condition (congruent and incongruent) on the size of the N400 effect while accounting for group variability in participant age.

Preliminary checks conducted to test violations of ANCOVA assumptions confirmed that data relationships were largely linear (see Figure 6), residuals were normally distributed, (Shapiro Wilk test $p > .05$), homogeneity of regression slopes, and homogeneity of the residual variances. No cases with standardized residuals greater than |3|, indicating that there were no outliers in the N400 data. The N400 amplitude values were submitted to a mixed RM-ANCOVA with the within-subject factor of condition (congruent and incongruent), the between-subject factor of group (autistic and neurotypical), and the covariate of age.

Correlation Analyses

First, in order to conduct correlation analyses, ERP difference waves were created to operationalize the size of the ERP amplitude condition differences in a single variable. The size of the P1 effect was operationalized as the difference in the mean amplitudes of the P1 waves to congruent and incongruent trials within the individual time windows selected for each participant (i.e., congruent mean amplitude minus incongruent mean amplitude; see P1 Analyses above). The size of the N400 effect was operationalized in a single variable by subtracting the mean amplitude of the N400 wave to incongruent trials from the mean amplitude of congruent trials (i.e., congruent mean amplitude minus incongruent mean amplitude) in the *a piori* 300-500ms time window.

Relationships between participants' behavioral response data (i.e., accuracy and reaction time), ERP components (i.e., size of the P1 and N400 effects) and the AQ Attention to Detail score were examined using a Spearman rank correlation matrix. Spearman rank correlations were chosen because they are considered appropriate for analyzing scores from rating scales, such as the AQ (Aggarwal & Ranganathan, 2016). Unlike Pearson correlations, Spearman rank correlations do not assume equal variance between groups (Ruscio, 2008) and are considered most appropriate for testing correlations among small samples, which run the risk of non-normally distributed data (Bishara & Hittner, 2017). To further guard against Type 1 error inflation, 95% confidence intervals around the Spearman rho values were calculated to aid in the interpretation of the correlations (Bishara & Hittner, 2017). Spearman rho confidence intervals that do not contain zero provide strong evidence for a significant effect, even when the effect size is small.

Path Analyses

Descriptive analyses were conducted with *R*, Version 1.1.463 (R Development Core Team, 2019). Means, standard deviations, and bi-variate correlations between study variables are presented in Table 6. All study variables were continuous and normally distributed (skewness = -0.53 to 0.87; kurtosis = -1.95 to 1.12), justifying the use of maximum likelihood (ML) estimation in the subsequent path analyses (Hox et al., 2010).

Path analyses were conducted using *Mplus* (Muthén & Muthén, 2017), a structural equation modeling software, to test the two alternative path models' fit to the data. Path analysis was beneficial for the current study because it allowed for the modeling of unidirectional relationships between sets of predictor, mediator, and outcome variables simultaneously in a single model. As such, it was a more efficient way of modeling the hypothesized mediation relationships than a traditional mediation test using multiple regression (Jihye Jeon, 2015).

Significance testing for the mediating effects in each model was conducted by a Sobel first-order test (Sobel, 1982) using the *Mplus* Model Indirect command. The significance tests of mediation were complemented with estimates of 95% bias-corrected bootstrap confidence intervals of the mediating effect based on 20,000 bias-corrected bootstrap resamples. Bootstrapped confidence intervals which do not contain zero indicate significant mediation. The bias-corrected bootstrap method of mediation estimation requires smaller sample sizes to attain better power than a Sobel first-order test and Baron & Kenny's (1986) tests for many conditions (Fritz & MacKinnon, 2007). Additionally, bias-corrected bootstrap methods provide the most statistical power as compared to other resampling methods, such as Jackknife (Mosteller & Tukey, 1977), Monte Carlo, or percentile bootstrap (Efron & Tibshirani, 1993) methods

(MacKinnon et al., 2004). The proportion of the total effect that was mediated by the mediating variable was used as an additional effect size measure (MacKinnon, 2008).

Results

Behavioral Results

Accuracy

Participants' accuracy data were submitted to a mixed repeated measures analyses of covariance (RM-ANCOVAs) with the within-subject factor of condition (congruent and incongruent), the between-subject factor of group (autistic and neurotypical), and the covariate of age. Confirming hypothesized results, the RM-ANCOVA for participant accuracy revealed no main effects of group ($F_{1, 21} = 1.01$, $p = .326$, $\eta^2_G = 0.03$) or condition ($F_{1, 21} = 1.42$, $p = .247$, $\eta^2_G = 0.02$), and no interaction between the factors ($F_{1, 21} = 3.84$, $p = .064$, $\eta^2_G = 0.04$). The covariate of age was significantly related to participants' accuracy ($F_{1, 21} = 13.42$, $p = .002$, $\eta^2_G = 0.34$), and a *post-hoc* correlation analysis confirmed this significant relationship ($r = 0.56$, $p < .001$).

Given the significant influence of age on task accuracy and the large age difference between the groups, the same RM-ANCOVA was run without the 17-year-old autistic participants. Results of this RM-ANCOVA were the same as the full-group analysis in that it revealed neither mains effects of either group ($F_{1, 17} = 0.46$, $p = .506$, $\eta^2_G = 0.02$) or trial condition ($F_{1, 17} = 1.29$, $p = .272$, $\eta^2_G = 0.02$), nor an interaction between group and condition ($F_{1, 17} = 3.06$, $p = .099$, $\eta^2_G = 0.05$) when controlling for participant age. The covariate of age remained significantly related to participants' accuracy ($F_{1, 17} = 18.85$, $p < .001$, $\eta^2_G = 0.46$). These results confirm that although participants' age significantly influenced their task accuracy, the groups did not differ significantly with regards to their behavioral accuracy on the experimental task after controlling for the effects of age.

Reaction Time

An RM-ANCOVA was conducted on reaction times for trials in which participants correctly identified the congruence or incongruence of the picture-sound pair. Participant reaction time data were submitted to a mixed RM-ANCOVAs with the within-subject factor of condition (congruent and incongruent), the between-subject factor of group (autistic and neurotypical), and the covariate of age. Again confirming the hypothesized results, the RM-ANCOVA for participant reaction time revealed neither a main effect of group ($F_{1, 21} = 0.77$, $p = .389$, $\eta^2_G = 0.03$) nor an interaction between the factors ($F_{1, 21} = 2.51$, $p = .128$, $\eta^2_G = 0.00$). There was a significant main effect of condition ($F_{1, 21} = 6.98$, $p = .015$, $\eta^2_G = 0.01$), and a *post-hoc* paired *t*-test confirmed that participants' reaction times were significant faster to congruent trials than to incongruent trials ($M_C = 0.95$, $SD_C = 0.35$, $M_I = 1.02$, $SD_{NT} = 0.35$; $t(23) = -3.49$, $p = .002$). The covariate of age was significantly related to participants' reaction time ($F_{1, 21} = 12.68$, $p = .002$, $\eta^2_G = 0.37$), and a *post-hoc* correlation analysis confirmed this significant negative relationship ($r = -0.35$, $p < .001$).

Similar to task accuracy, given the significant influence of age on reaction time and the large age difference between the groups, the RM-ANCOVA was run again without the 17-year-old autistic participants. Results of the RM-ANCOVA without the 17-year-old autistic participants were the same as the full-group analysis. The analysis revealed neither a main effect of group ($F_{1, 17} = 1.34$, $p = .264$, $\eta^2_G = 0.07$) nor an interaction between group and trial condition ($F_{1, 17} = 2.01$, $p = .174$, $\eta^2_G = 0.01$). The main effect of condition was again significant ($F_{1, 17} = 5.28$, $p = .035$, $\eta^2_G = 0.01$) after controlling for participant age, and the covariate of age remained significantly related to participants' reaction times ($F_{1, 17} = 16.60$, $p < .001$, $\eta^2_G = 0.48$). These results confirm that although participants' age significantly influenced the speed of their

responses, the groups did not differ significantly with regards to their reaction times on the experimental task after controlling for the effect of age. As expected, across both groups, participants were faster to respond to congruent trials than to incongruent trials.

ERP Results

P1 Analysis Results

The P1 amplitude RM-ANCOVA revealed no main effect of group ($F_{1, 21} = 0.83$, $p = .374$, $\eta^2_G = 0.03$). Similarly, participants' age was not revealed to be statistically significant, though the effect of age was the largest main effect size and approached the standard cut-off for statistical significance ($F_{1, 21} = 3.98$, $p = .059$, $\eta^2_G = 0.16$). There was a small significant main effect of condition ($F_{1, 21} = 7.83$, $p = .011$, $\eta^2_G = 0.01$) and interaction between group and condition ($F_{1, 21} = 6.23$, $p = .021$, $\eta^2_G = 0.01$); however, *post-hoc* paired *t*-tests did not reveal significant condition differences in the full group ($M_C = 10.13$, $M_I = 9.59$, $SD = 5.81$; $t(24) = 1.52$, $p = .143$), nor in the autistic ($M_C = 8.56$, $M_I = 7.58$, $SD = 5.40$; $t(13) = 1.76$, $p = .103$) and neurotypical ($M_C = 12.37$, $M_I = 12.39$, $SD = 5.53$; $t(9) = -0.06$, $p = .951$) groups separately. Please see Figure 5 for the ERP waveforms for autistic (Panel A) and neurotypical (Panel B) groups for visualizations of the P1 waveform (approximately 50-150ms) at electrode 75.

Due to the large effect size of age on the P1 mean amplitudes and the previously reported findings of age-related changes to P1 amplitude (Hileman et al., 2011; Itier & Taylor, 2004a, 2004b), the P1 RM-ANCOVA was run again without the 17-year-old autistic participants in order to test whether the results held in the originally proposed age-range of participants. Results of this second RM-ANCOVA again revealed no main effect of group ($F_{1, 17} = 0.60$, $p = .448$, $\eta^2_G = 0.03$), and the main effect of age no longer marginally significant ($F_{1, 17} = 1.85$, $p = .192$, $\eta^2_G = 0.10$). Similar to the full-group RM-ANCOVA, the group of participants who were younger than

17-years-old revealed a small significant main effect of condition ($F_{1, 17} = 7.31$, $p = .015$, $\eta^2_G = 0.01$) and a significant interaction between the factors of group and condition ($F_{1, 17} = 5.58$, $p = .030$, $\eta^2_G = 0.01$); again, however, post-hoc *t*-tests did not confirm condition differences in either the combined groups ($M_C = 11.10$, $M_I = 10.52$, $SD = 5.89$; $t(19) = 1.42$, $p = .170$), or either of the autistic ($M_C = 9.83$, $M_I = 8.66$, $SD = 5.90$; $t(9) = 1.71$, $p = .12$) or neurotypical ($M_C = 12.37$, $M_I = 12.39$, $SD = 5.53$; $t(9) = -0.06$, $p = .951$) groups separately.

Though these data are preliminary in that they are from a small sample of participants that vary widely with regards to age, taken together they generally trend towards the hypothesized effects. Specifically, the predicted interaction between group and trial condition was found in both the full-sample of participants, and the smaller sample of participants who fell within the originally proposed age-range. Although these group differences did not hold for the *post-hoc* comparisons, the group means trended in the hypothesized direction in that the autistic participants exhibited larger differences between congruent and incongruent in their average P1 amplitudes than neurotypical participants. Further data collection is necessary to investigate whether these trends continue to be seen in a larger sample.

N400 Analysis Results

Similar to the P1 amplitude results, the N400 RM-ANCOVA revealed no main effects of group ($F_{1, 21} = 2.14$, $p = .158$, $\eta^2_G = 0.08$) or condition ($F_{1, 21} = 0.14$, $p = .708$, $\eta^2_G = 0.00$). There was also no interaction between the factors ($F_{1, 21} = 1.41$, $p = .248$, $\eta^2_G = 0.01$). The effect of age was also non-significant ($F_{1, 21} = 0.03$, $p = .871$, $\eta^2_G = 0.00$). Please see Figure 7 for the ERP waveforms for autistic (Panel A) and neurotypical (Panel B) groups for visualizations of the N400 waveform (300-500ms) at electrode 6. To be consistent with the analysis strategies above, the RM-ANCOVA was run a second time without the 17-year-old participants. This RM-

ANCOVA revealed the same results as the first in that there were no main effects of group ($F_{1, 17}$ = 1.45, p = .245, η^2_G = 0.07), condition ($F_{1, 17}$ = 0.95, p = .344, η^2_G = 0.01), or age ($F_{1, 17}$ = 0.53, p = .475, η^2_G = 0.02), and no interaction between the factors ($F_{1, 17}$ = 1.183, p = .194, η^2_G = 0.01).

Relationship Between Behavioral Responses, ERP Components, and the AQ

For the combined group of participants, participants' accuracy was significantly correlated with their reaction times (r = -0.62, p = .001, 95% CI [-0.89, -0.24]). No other variable correlations were significant for the combined participant group (all p's > .10, see Table 2 for full Spearman rank correlation matrix for the combined group of participants). To test whether relationships between the variables differed for each group, additional Spearman rank correlation matrices were computed separately for the autistic and neurotypical groups.

Interestingly and in contrast to the full-sample, when analyzed separately, the autistic participants' accuracy on the behavioral task was not significantly correlated with their reaction time (r = -0.48, p = .08, 95% CI [-0.97, 0.15]). Additionally, autistic participants' Attention to Detail score on the AQ was significantly positively correlated with the size of their P1 difference wave (r = 0.61, p = .02, 95% CI [0.20, 0.86]). Though significance testing suggested that the size of autistic participants' P1 difference wave was also related to their reaction time on the behavioral task (r = 0.57, p = .03), the 95% confidence interval included zero (95% CI [-0.03, 0.95]), suggesting that this effect is not large enough to interpret with confidence. No other variable correlations were significant for the autistic participant group (all p's > .05, please see Table 3 for full Spearman rank correlation matrix for the autistic participants).

Spearman rank correlations were additionally run on the subset of autistic participants who were less than 17-years-old. Such re-analysis was particularly relevant for analysis including the AQ Attention to Detail variable, as the 17-year-olds completed a self-report

measure of the AQ, whereas parent-report on the AQ was used for participants younger than 17 years. Within this group of ten participants, accuracy was again not significantly correlated with reaction time (r = -0.39, p = .07, 95% CI [-1.00, 0.38]). Though significance testing suggested that the size of autistic participants' accuracy wave was related to their parent-reported levels to attention to detail on the AQ (r = 0.66, p = .03), the 95% confidence interval included zero (95% CI [-0.01, 0.96]), suggesting that this effect is not large enough to interpret with confidence. Further, in this smaller sample of autistic participants, the relationship between their parent-reported Attention to Detail scores on the AQ were not correlated with the size of their P1 difference wave (r = 0.45, p = .09, 95% CI [-0.03, 0.94]). No other variable correlations were significant for the autistic participant group younger than 17 years old (all p's > .05, please see Table 4 for full Spearman rank correlation matrix for the autistic participants).

Within the neurotypical group of participants, accuracy on the behavioral task was significantly correlated with their reaction time (r = -0.90, p < .001, 95% CI [-1.00, -0.63]). No other variable correlations were significant for the neurotypical participant group (all p's > .10, please see Table 5 for full Spearman rank correlation matrix for the neurotypical participants).

Fishers' z-tests were used to empirically validate whether the correlations between the autistic and neurotypical groups differed significantly. First, to test for potential differences between the correlations of the autistic and neurotypical groups with regards to their accuracy and reaction times on the behavioral task, the correlations were transformed into z-scores using Fisher's r-to-z transformation, results in z-scores of 0.52 and 1.47 for the autistic and neurotypical groups, respectively. A z-score based on the difference between these two values and the variance between the two scores was obtained. Using a two-tailed test of significance, the correlation between accuracy and reaction time was found to be significantly different

between the full group of autistic participants and neurotypical groups ($z = 1.98$, $p = .05$). For the subsample of autistic participants who were younger than 17, their accuracy and reaction time correlation did not differ significantly from the full group of autistic participants (z-scores = 0.41 and 0.48, respectively, $z = 0.24$, $p = .81$) but did differ from the neurotypical group's correlation between accuracy and reaction time (z-scores = 0.41 and 1.47, respectively, $z = 2.02$, $p = .04$).

Second, group correlation differences were tested with regards to the relationship between the Attention to Detail score on the AQ and the size of the P1 effect. Correlations were transformed into z-scores using Fisher's r-to-z transformation, results in z-scores of 0.71 and 0.32 for the full group of autistic participants and neurotypical group, respectively. Using a two-tailed test of significance, the correlation between Attention to Detail on the AQ and P1 effect size was found to be significantly different between the full group of autistic participants and neurotypical participants ($z = 2.14$, $p = .03$). For the subsample of autistic participants who were younger than 17, their accuracy and reaction time correlation did not differ significantly from either the full group of autistic participants (z-scores = 0.48 and 0.71, respectively, $z = 0.46$, $p = .64$) or the neurotypical group's correlation between accuracy and reaction time (z-scores = 0.48 and 0.32, respectively, $z = 1.59$, $p = .09$).

Path Analysis Results

Model 1

Based on our previous research, I hypothesized that the relationship between participants' levels of attention to detail and the size of their N400 effect would be mediated by the size of their P1 effect. This mediation was tested in Model 1, in which Attention to Detail was entered as the predictor variable; the size of the P1 effect was entered as the mediator variable, and the

size of the N400 was entered as the outcome variable. Effects of participant sex and age on the mediation and outcome variable were controlled for in the model.

Explained variance of the outcome variable (size of the N400 difference wave) and standardized path coefficients (with standard errors in parentheses) for Model 1 are presented in Figure 8. The effect of participant sex and age on the mediating and outcome variables were controlled for (paths not shown in figure for simplicity). In regard to the indirect path from the predictor to the mediating variable, participants' self-reported level of Attention to Detail was not significantly associated with size of the P1 difference wave (path a; b = 0.11, SE = 0.90, β = 0.30, p = .16). In regard to the indirect path from the mediating variable to the outcome variable, the size of the P1 difference wave was not significantly associated with the size of the N400 difference wave (path b; b = -0.175, SE = 0.68, β = -0.08, p = .79). In regard to the direct path from the predictor variable to the outcome variable, participants' self-reported level of Attention to Detail was not associated with the size of the N400 difference wave (path c'; b = 0.05, SE = 0.22, β = 0.07, p = .77). Significant mediation was not indicated by the Sobel first-order test (b = -0.02, SE = 0.09, β = -0.02, p = .83), and the bias-corrected bootstrapped confidence interval for the overall indirect effect contained zero, indicating that the mediation effect was not significant (95% bias-corrected bootstrapped CI [-0.237, 0.153]). However, as an effect size measure of the mediating effect, 54% of the total effect of participants' level of Attention to Detail on the N400 difference wave was mediated by the size of the P1 difference wave.

Model 2

In addition to Model 1, an alternative path model was tested to provide additional empirical rigor by allowing for model comparisons. That is, in Model 2, the size of the P1 effect was entered as the predictor variable; the size of the N400 effect was entered as the mediator

variable; and the outcome variable was attention to detail trait levels. Explained variance of the outcome variable (Attention to Detail scores) and standardized path coefficients (with standard errors in parentheses) for Model 2 are presented in Figure 9. The effects of participant sex and age on the mediating and outcome variables were controlled for (paths not shown in figure for simplicity). In regard to the indirect path from the predictor to the mediating variable, the size of the P1 difference wave was not significantly associated with the size of the N400 difference wave (path a; b = -0.13, SE = 0.63, β = -0.05, p = .83). In regard to the indirect path from the mediating variable to the outcome variable, the size of the N400 difference wave was not significantly associated with participants' self-reported level of Attention to Detail on the AQ (path b; b = 0.08, SE = 0.36, β = 0.06, p = .82). For the direct path from the predictor variable to the outcome variable, the size of the P1 difference wave was significantly associated with participants' self-reported level of Attention to Detail on the AQ (path c'; b = 0.94, SE = 0.67, β = 0.33, p = .17). No significant mediation effect was indicated by either the Sobel first-order test (b = -0.01, SE = 0.24, β = -0.003, p = .97), or the bias-corrected bootstrapped confidence interval (95% bias-corrected bootstrapped CI [-0.619, 0.382]). Only 1% of the total effect of the size of the P1 difference wave on participants' level of Attention to Detail was mediated by the size of the N400 difference wave.

Model Comparison

Non-nested model comparisons for the two models were based on the Akaike Information Criterion (AIC) and sample-size adjusted the Bayesian Information Criterion (BIC). A 10-point difference in AIC and sample-size adjusted BIC is evidence of a significant model difference in goodness of fit, favoring the model with the smaller AIC and sample size-adjusted BIC values (Burnham & Anderson, 2004).

Model comparisons revealed that Model 2 (AIC = 293.75; sample-size adjusted BIC = 272.63) had poorer model fit values than Model 1 (AIC = 241.53; sample-size adjusted BIC = 220.41). In other words, Model 1 resulted in moderate decreases in AIC (ΔAIC = 52.22) and sample-size adjusted BIC (ΔBIC = 52.22), indicating a significantly better fit to the data.

Discussion

The current study set out to test whether autistic children and adolescents use different information processing pathways, ones which rely more on perceptual processing than cognitive mechanisms, than their neurotypical peers. An additional goal of the current investigation was to examine whether and how these differential pathways to cognition may be related to autistic traits. Though the current study has several limitations, which are mentioned throughout the subsequent sections and discussed more thoroughly in the Limitations section below, the most impactful of these limitations is the smaller than expected sample size as a result of the COVID-19 pandemic. The small sample sizes resulted in underpowered analyses, limiting the ability to detect true effects and make strong conclusions about the data. Where possible, adjustments were made to conduct the most statistically supported analyses and draw preliminary findings with the available data.

Despite these limitations, preliminary findings of the current study are encouraging and support the utility of continued data collection and highlight exciting avenues for future research directions. First, P1 analyses revealed the hypothesized significant interaction between group and condition. Group means trended towards larger early perceptual differences between congruent and incongruent conditions for the autistic participants than the neurotypical participants, suggesting that the autistic participants were processing condition differences earlier than neurotypical participants. Further, amongst the full group of autistic children and adolescents,

Attention to Detail scores on the AQ were significantly correlated with the condition difference of the P1 component. This same relationship was not demonstrated by the group of neurotypical children and adolescents, and such group differences support the conclusion that enhanced perceptual processing may be uniquely related to autistic traits for those on the autism spectrum. Although the path analyses in the current study were underpowered to detect mediation effects, model comparison results provide preliminary support for the hypothesized model (Model 1) in which the relationship between attention to detail and the cognitive ERP component (N400 effect) was mediated by the early perceptual ERP component (the P1 component). The proportion of the total effect that was mediated by the size of the perceptual ERP component (54%) was strikingly similar to the results of our previous study with neurotypical adults (Kaplan-Kahn et al., 2021), in which we reported 57% mediating effect for the same model with adult participants.

In the following discussion, I first review the behavioral results of the ERP task and then examine the ERP findings and their implications within the Enhanced Perceptual Functioning framework. Next, I discuss the relationships between the ERP components and autistic traits with regards to both correlational findings and unidirectional relationships tested in the path analyses. I then consider the clinical implications of the study findings, providing an exploration of theoretical frameworks used to extrapolate such implications. Finally, I address limitations of the current study and provide potential directions for future research.

Behavioral Performance

The behavioral task in the current experiment was used as a manipulation check to ensure that participants were attending to the repeated trials. The data largely supported the hypothesized results. After controlling for participant age, which differed significantly between

the groups, autistic and neurotypical participants did not differ with regards to their accuracy or reaction time on the experimental task. Interestingly, for the combined group, accuracy was negatively correlated with reaction time. This negative correlation is the opposite that would be expected if participants were to exhibit a speed-accuracy trade-off, wherein participants' performance would be worse as they speed up their reactions (i.e., shorter reaction times lead to lower accuracy) and improve as they take more time to respond (i.e., longer reaction times lead to higher accuracy). Rather than a speed-accuracy trade-off, this negative correlation indicates that participants who exhibited faster reaction times tended to also be more accurate. This pattern of data suggests that participants who exhibited overall more engagement with the task tended to answer more accurately than those who were less engaged. The behavioral task was very simple, and longer reaction times likely are more indicative of the participant missing the trial and taking longer to guess on a response.

Enhanced Perceptual Functioning and ERP Results

The Enhanced Perceptual Functioning model of autism (Mottron et al., 2006; Mottron & Burack, 2001) highlights that autistic perceptual processes, such as detection, discrimination, and categorization of stimuli, are generally more accurate and efficient than those of non-autistic peers across a range of perceptual domains including vision (e.g., Jarrold et al., 2005; Kaldy et al., 2016; O'Riordan & Plaisted, 2001), audition (e.g., Bonnel et al., 2003, 2010), tactile (e.g., Nakano et al., 2012), and olfaction (e.g., Ashwin et al., 2014). The framework further highlights that perception plays a greater role in autistic intelligence, including reasoning and problem solving skills (Mottron, 2019). This hypothesis is supported by evidence from neuropsychological studies demonstrating increased recruitment of cortical areas devoted to perceptual processes (Samson et al., 2012) when autistic individuals complete activities such as

matrix reasoning (Soulières et al., 2009) and block design tasks (Bölte et al., 2008), which are both aspects of many commonly used intelligence tests. Electrophysiological evidence advances these findings beyond different *brain regions* to different *time courses* of information processing, with autistic adolescents demonstrating earlier ERP indicators of perceptual discrimination on the same tasks where neurotypical adolescents demonstrate later ERP indicators of cognitive processing (Russo et al., 2012).

Collectively, these results support the central hypotheses of the Enhanced Perceptual Functioning model of autism; however, they bring to light additional questions of how enhancements in early perceptual processes may influence subsequent cognitive processes among autistic children and adolescents and whether the relationship between these processes may differ for neurotypical individuals. The current study aimed to address these empirical questions by examining ERP differences between autistic and neurotypical children and adolescents when they completed a simple semantic violation task, closely modeled from the paradigm used by Russo et al. (2012). In addition to providing the opportunity for replication, an important and often under-utilized method to increase the confidence in ERP study findings (Luck & Gaspelin, 2017), this approach afforded the novel opportunity to examine relationships between ERP components and test whether these relationship may differ between autistic and neurotypical individuals.

Early Perceptual ERP – The P1

After accounting for the age of participants, which differed significantly between the autistic and neurotypical participants, there were not statistically significant group differences with regards to the mean amplitude of the P1 component. Analyses both with and without the 17-year-old autistic participants, however, revealed the hypothesized significant interaction between

group and condition for mean P1 amplitude values. Although *post-hoc* paired *t*-tests did not reveal significant condition differences for either the autistic or neurotypical groups, the difference condition means was larger in the autistic group (0.98 microvolt difference between congruent and incongruent conditions) than the neurotypical group (0.02 microvolt difference between congruent and incongruent conditions).

Though small sample sizes reduced the power to detect small ERP effects, the ERP waveforms at the occipital electrode also appear to be trending in this hypothesized pattern (see Figure 5). Specifically, the autistic participants (Figure 5a) show larger condition differences in the amplitude of their P1 component (occurring at approximately 50-150 ms) than the neurotypical participants (Figure 5b). This preliminary trend motivates the need for continued data collection in order to see if increased participant numbers will subsequently lead to decreased standard deviation of the mean and greater ability to detect group and condition differences (VanVoorhis & Morgan, 2007). Such results would replicate the findings of Russo et al. 2012, who found that autistic adolescents, but not age- and IQ-matched neurotypical adolescents, showed early perceptual P1 differences between congruent and incongruent conditions in a similar semantic violation paradigm. If the current ERP trends were found to be significant, the current study would provide the first replication of Russo et al. (2012), affording strong support that autistic children and adolescents demonstrate rely on early perceptual processing mechanisms when engaging in this semantic violation task.

From an information processing standpoint (e.g., Lachman et al., 2015; Lindsay & Norman, 2013), such results would appear to be puzzling. The task required participants to perceive the animal pictures and sounds, derive semantic meaning from the stimuli, and determine whether these stimuli matched or mismatched. Implied in this construal of the task is a

two-step process wherein the first step is the perceptual processing of stimuli and the second step is the cognitive computation of this perceptual information. Finding early perceptual condition differences in the ERP waves of autistic participants would seem to run counter to this two-step process, as it implies that autistic individuals were able to make semantic distinctions within a perceptual time window, prior to the deployment of cognitive mechanisms. However, this result would be in-line with the Enhanced Perceptual Functioning model claim that perception plays a greater role in reasoning and intelligence among autistic persons than neurotypical individuals. Here, it is critical to recognize that our understanding of what is involved in "typical" information processing is a result of a knowledge base that is constructed entirely from empirical studies of non-autistic participants. Current models of information processing are, therefore, models of neurotypical information processing, not models of universal or "correct" information processing. As research begins to make progress towards understanding the potentially unique information processing pathways that underlie autistic cognition, we will likely need to re-evaluate many of the principles considered standard in the current canon of information processing theory.

Later Cognitive ERP – The N400

After accounting for the age of participants, there were neither statistically significant group or condition differences with regards to the mean amplitude of the N400 component to congruent and incongruent trials nor any interaction between the two factors. These statistical findings did not support the hypothesized results, in which there was expected to be a significant group by condition interaction. More specifically, it was hypothesized that neurotypical participants would show significant condition differences between the amplitude of their ERP waves in the N400 time-window (300-500 ms, with amplitudes to incongruent trials being more

negative than those of congruent trials) while autistic participants would not show these same condition differences. Results of the analyses did not reveal any main effects of group or condition, nor any interaction between the variables for the ERP amplitudes during the N400 time window.

Examination of the frontal ERP waveforms in the N400 time-window (see Figure 7) reveals that although no effects were significant, the ERP waveforms again appear to trend in the predicted directions. In particular, the neurotypical participants' ERP waves (Figure 7b) demonstrate increased negativity to incongruent stimuli (as compared to congruent stimuli) between 300 ms and 500 ms after the onset of the trial. In contrast, the autistic participants' ERP waves (Figure 7a) appear to demonstrate a weak pattern in the opposite direction, showing increased negativity to congruent stimuli (as compared to incongruent stimuli). As with the P1 discussion above, this preliminary trend of the ERP waveforms in the hypothesized directions is encouraging, particularly given the small sample sizes of the current study, and prompts the call for continued data collection. Increasing the number of participants of both groups will provide increased power to the statistical analyses (Rusticus & Lovato, 2014), resulting in more robust estimates of the ERP effects. Continued data collection should also focus on matching the groups of autistic and neurotypical participants on age in addition to PIQ. Such matching techniques would decrease the need to include covariates, such as age, that are unrelated to the ERP effects of interest.

Relationship Between Perceptual and Cognitive ERP Components

Beyond replicating the results of Russo et al. (2012) in a younger age range, the current study provided the opportunity to test for significant relationships between early perceptual condition differences and later cognitive condition differences in participants' ERP waves. The

relationships between these ERP components, specifically the size of the amplitude differences between congruent and incongruent trials, may offer clues as to how information processing unfolds over time, and whether those pathways differ between autistic and neurotypical individuals. For example, our lab found a significant positive relationship between the size of neurotypical adults' P1 condition difference and the size of their N400 effects (Kaplan-Kahn et al., 2021). In other words, participants who showed larger differences between congruent and incongruent trials in their perceptual processing ERP component also showed larger condition differences in their cognitive processing ERP component. The authors interpreted this positive relationship to be indicative of the type of automatic reliance on higher-order cognitive mechanisms among neurotypical individuals (Mottron et al., 2006) in that any enhancement in perceptual detection was subsequently passed to, and processed by, cognitive mechanisms.

Though the positive relationship between perceptual and cognitive processes amongst neurotypical adults were consistent with some of the hypotheses of the Enhanced Perceptual Functioning model of autism, they could not speak to some of the more central claims of the framework. Namely, the driving argument here is that autistic individuals do *not* demonstrate such an automatic reliance on higher-order cognitive processes due to their enhancement in perceptual functioning (Mottron et al., 2006). To test this claim, a comparison between autistic and neurotypical groups with regards to their relationships between perceptual and cognitive processing is necessary. Data supporting the full argument of the Enhanced Perceptual Functioning model would demonstrate a positive relationship between P1 and N400 effect sizes amongst neurotypical participants, suggesting an automatic relaying of information from perceptual to cognitive processing, and a nonsignificant relationship between these same

variables amongst autistic participants, indicating an uncoupling of the information processing pathway between perceptual and cognitive processes.

Contrary to initial hypotheses, the relationship between the size of participants' condition differences in their P1 amplitudes were not related to the size of their N400 effect for either autistic or neurotypical participants. Further, a Fishers' z test did not indicate a significant difference between the groups with regards to this relationship. This finding may have been due to the small sample sizes, particularly in the neurotypical group where $n = 10$. Continued data collection is necessary to conduct adequately powered analyses and draw definitive conclusions about these data.

Connections Between ERP Components and Autistic Traits

A further aim of the current study was to test initial brain-behavior associations through relating ERP components to levels of autistic traits. Based on previous research associating participants' level of attention to detail with multisensory processing (Stevenson et al., 2017) and condition differences in the P1 components on the same task as used in the current study (Kaplan-Kahn et al., 2021), the Attention to Detail subscale on the AQ was used as a measure of autistic traits in the current study. In line with hypothesized results, Attention to Detail scores were not associated with the size of participants' N400 effect in either the autistic or neurotypical groups. This result replicates previous research from our lab, wherein we did not find significant relationships between attention to detail and the ERP measure of cognitive processing in their group of neurotypical adults (Kaplan-Kahn et al., 2021). In contrast, autistic participants, but not neurotypical participants, showed a significant positive relationship between their levels of attention to detail and the size of the condition difference in their early perceptual ERP (the P1

component). Autistic participants who were rated as exhibiting higher levels of attention to detail also exhibited larger P1 amplitude differences between congruent and incongruent trials.

Interestingly, although the relationship between P1 amplitude condition differences and attention to detail were not found in the small group of neurotypical children and adolescents in the current study, we previously reported a significant positive relationship between these variables in our larger group of neurotypical adults (Kaplan-Kahn et al., 2021). In other words, based on the available data for the current study, the neurotypical children and adolescents do not demonstrate a relationship between their early perceptual ERPs and attention to detail, whereas neurotypical adults and autistic children and adolescents both do. Multiple alternative explanations for this finding are possible at this point. The first is that the sample size of neurotypical children and adolescents is too small and variable to detect an effect, and the result is a Type II error in which the alternative hypothesis is falsely rejected. The second is that there are true developmental differences between neurotypical children/adolescents and adults with regards to their relationship between perceptual processing and levels of attention to detail. Research out of our lab has previously demonstrated paradigms in which autistic children and adolescents demonstrate performance more similar to neurotypical adults than their age- and IQ-matched neurotypical peers (Hagmann et al., 2016). Accordingly, it may be that the relationship between perceptual ERPs and attention to detail becomes stronger over time for neurotypical children and adolescents, whereas for autistic children and adolescents this relationship is significant at earlier ages.

Significant correlations between perceptual processing and autism traits have been reported previously, including in the domains of visual perception (DiCriscio & Troiani, 2018; Lowe et al., 2018), olfaction perception (Barros et al., 2020) and haptic perception (Yaguchi &

Hidaka, 2020). These studies have used behavioral paradigms to demonstrate connections between performance on a perceptual task and autistic traits. The term autistic traits can refer to a wide range of behavioral patterns, ranging from reciprocal social communication behaviors, to special interests and attention to detail; while some studies have related behavioral performance on perceptual tasks to broad and general measures of autistic traits, combining these different behavioral patterns (e.g., DiCriscio & Troiani, 2018; Lowe et al., 2018), others have specifically related performance on perceptual based tasks to attention to detail (e.g., Stevenson et al., 2017).

The current study augments this literature by additionally demonstrating that electrophysiological markers of perceptual processing are related to attention to detail among a group of autistic children and adolescents. Neurophysiological evidence pointing towards the same conclusions as behavioral data offers additional levels of theoretical depth and confidence in the conclusions. Not only are there behavioral differences that are related to a person's level of attention to detail, but such differences are also evidenced at the level of post-synaptic potentials in the brain, which are similarly related to attention to detail for autistic persons. The full group of autistic participants (i.e., ages 6 through 17.9 years) demonstrated a significant positive correlation between their levels of attention to detail and the size of the condition differences in their P1 amplitude. Although this correlation was no longer significant (p = .09) in the group of autistic participants who were younger than 17-years-old, this difference is likely attributable to the smaller sample size (14 vs. 10 participants) and the correlations were not significantly different. Further data collection will help to clarify whether the relationship between attention to detail and early ERP makers of perceptual processing is robustly evidenced in autistic persons.

A correlation between P1 amplitude condition differences and attention to detail is consistent with the Enhanced Perceptual Functioning framework of autism in that the autistic

participants demonstrate a significant link between their early perceptual processes and autistic traits. In summary, early perceptual processing, but not later cognitive processing, is related to autistic traits amongst the current group of autistic children and adolescents. This result points to the conclusion that characteristic autistic processing may prioritize the use of perceptual over cognitive processes and emphasizes the importance of such perceptual processing in autism.

Information Processing Pathways

Beyond correlations, the current study set out to test unidirectional relationships between participants' ERPs and their levels of attention to detail. To accomplish this goal, two path analysis models were tested and compared. These path analyses were the same as those tested in Kaplan-Kahn et al. (2021) based on data from neurotypical adults. Tests of mediation were conducted for each model, and then the models were compared to each other to investigate which model provided a better fit to the available data.

The path analysis models in the current study were considerably underpowered to detect hypothesized mediation effects; thus, it is unsurprising that neither path analysis model demonstrated significant mediation based on either the Sobel first-order tests or bias-corrected bootstrapped confidence intervals. Despite non-significant mediation effects, the model comparison results supported the hypothesis that Model 1, in which the total effect of participants' level of attention to detail on the N400 difference wave was mediated by the size of the P1 difference wave, provided a significantly better fit to the data than Model 2 based on lower AIC and sample-size adjusted BIC values. This result is consistent with our neurotypical adult model comparison, where we similarly found that model fit indices provided stronger support for the same model (Kaplan-Kahn et al., 2021). Further, the proportion mediated statistics (i.e., the proportion of the total effect [predictor variable on outcome variable] that was

mediated by the mediating variable in both models) for both models were strikingly similar to those we reported in Kaplan-Kahn et al. (2021). Specifically, for the group of neurotypical adults we ran, we found that 6% of the total effect (P1 difference wave on attention to detail) was mediated (by the N400 difference wave) in Model 1, but 57% of the total effect (attention to detail on N400 difference wave) was mediated (by the P1 difference wave) in Model 2. In the current study, using the same models, 1% of the total effect (P1 difference wave on attention to detail) was mediated by the mediating variable (N400 effect) in the second model, and 54% of the total effect (attention to detail on N400 difference wave) was mediated by the mediating variable (P1 effect) in the first hypothesized model. To reiterate, these results are preliminary based on the small sample size of the current study; however, such results motivate the need for continued data collection once it is safe to resume in-person testing.

If this study was run on a much larger scale (e.g., 60 participants per group), it would be possible and interesting to test for whether neurotypical and autistic participants show differences in the multiple relationships tested in the path analysis models. For example, one possibility would be to test whether group status (i.e., neurotypical vs. autistic) moderates the indirect path from the size of the P1 condition difference to the size of the N400 condition difference. Neurotypical adults demonstrated a positive correlation, such that greater condition differences in their early perceptual ERPs were predictive of larger condition differences in their later cognitive ERPs. Though no correlation between P1 and N400 sizes were found for either the autistic or neurotypical children and adolescents, one possibility, derived from the Enhanced Perceptual Functioning model, might be that autistic participants do not show a correlation between their perceptual and cognitive ERPs while neurotypical participants do. Such a result would support the Enhanced Perceptual Functioning model of autism in that it would be

indicative of automatic feed-forward from perceptual to cognitive functions in neurotypical persons, whereas autistic persons would achieve the same result without needing to utilize the same cognitive functions.

Clinical Implications

Though the current study uses a basic science approach to elucidate how brain-based markers of perceptual and cognitive processes in neurotypical and autistic children are related to autistic traits, the initial study findings are important pieces of knowledge that can be applied in constructing a larger landscape of clinically relevant implications for autistic children and adolescents. Clinical implications, particularly clinical applications of basic science findings, are highly dependent on the theoretical lens through which one interprets findings. Thus, before delving into clinical implications, a few important framework acknowledgments are discussed.

Theoretical Frameworks

First, stated simply, a large part of our empirical and theoretical understanding of autism is constructed and perpetuated by non-autistic persons. This recognition of historical discipline context is necessary to acknowledge the inherent non-autistic biases and lenses through which much of our academic understanding of autism is written and understood. As increasing numbers of autistic researchers enter the field, their perspectives will provide invaluable insight and balance to aid in our understanding of autism and guide our understanding of how we can apply basic science to inform clinical implications.

The Enhanced Perceptual Functioning framework of autism moves closer to achieving such balance, as its primary authors include both autistic and non-autistic researchers. The model focuses on describing the strengths of autistic individuals and posits hypotheses about how such perceptual processing strengths may contribute to autistic intelligence (Dawson et al., 2007;

Mottron, 2019; Nader et al., 2016). The Enhanced Perceptual Functioning model is focused primarily on describing the phenomena of enhanced perceptual processing in autism with regards to how it is evidenced in behavioral and some brain-based studies. In Marr's terminology (Marr, 1982), Enhanced Perceptual Functioning model proposes a computational-level explanation (i.e., *what* the system does), but does not address how such phenomena are realized on an algorithmic level (i.e., *how* the system functions, what types of information are used, and what processes does it employ to build and manipulate the representations).

To address this level of analysis, researchers have offered a complementary theory using a Bayesian explanation of autistic perception (Pellicano & Burr, 2012; van Boxtel & Lu, 2013; van de Cruys et al., 2014). Their explanation falls at the algorithmic level of analysis because it outlines the inputs (ambiguous sensory information) and mental computations used to arrive at outputs (perceptual processing). Specifically, Pellicano and Burr argue that autistic individuals see the world more accurately because of their perception being less biased by prior experiences. The theory builds on Bayesian statistical decision theory (Kersten & Yuille, 2003; Knill & Pouget, 2004), conceptualizing perception as an unconscious but active process of formulating and testing inferences about the structure of the world (Gregory, 1980) based on a combination of ambiguous sensory input information (the likelihood) and prior experience (the prior) that helps to guide a decision as to which of the numerous perceptual conclusions is most probable. Put differently, using a Bayesian explanation, perception is our 'best-guess' inference from combining a distribution of information from our sensory systems with a distribution of prior likelihood from our past experiences and biases. Pellicano and Burr posit that autistic individuals demonstrate attenuated priors (which they term "hypo-priors"), meaning that they have fewer internal representational constraints that bias or guide the perception of sensory information.

Priors constrain one's perceptual experiences by biasing sensory information towards expected perceptual representations. In essence, priors act as a type of filter, helping us narrow our interpretations of inherently ambiguous sensory information based on the distribution of how probable each interpretation is. If autistic individuals have hypo-priors that are less constrained (i.e., wider distributions of probable outcomes), this may result in autistic individuals experiencing the world as "too real" because of an increased reliance on sensory information (Pellicano & Burr, 2012; van Boxtel & Lu, 2013). One domain where such differences may be particularly salient is attention to detail. Fewer constraints on ways to interpret sensory experiences may result in fewer details being "filtered" out by strong priors. The upshot of these hypo-priors would be that there is more sensory information available for autistic perception. Under this interpretation, it is not so much 'attention' to detail, but 'perception' of detail that may be significantly different in autism.

As an example, visual illusions, such as the Shepard table illusion (see Figure 10), can be understood as our internal representations of the world, based on prior experiences, biasing our perception of visual stimuli towards our prior representation and away from the actual sensory input. Here, our internal representations of three-dimensional space provide strong priors that constrain and bias our perception of the tables as being very different sizes when they are, in fact, identical. Autistic individuals show decreased susceptibility to visual illusions such as the Shepard table illusion (Chouinard et al., 2018), which is consistent with the conclusion that autistic individuals have broader (i.e., less constrained) priors, resulting in a stronger reliance on sensory information and more accurate perceptual representations. Pellicano and Burr offer four hypotheses that result from this Bayesian framework: 1) autistic hypo-priors should sometimes result in more 'accurate' perception (e.g., visual illusions); 2) autistic hypo-priors should impede

performance in situations where priors help resolve ambiguity (e.g., face perception); 3) hypo-priors in autism could cause the often-reported experience of being overwhelmed by sensory information; and 4) autistic hypo-priors may be related to reduced adaptation in autism (Pellicano & Burr, 2012).

The preliminary data presented in the current study are generally consistent with this Bayesian framework of autistic perception in that the autistic children and adolescents show slightly larger differences in their early perceptual ERPs than neurotypical children. These indicators of early perceptual functioning were also significantly related to attention to detail in the full group of autistic participants, suggesting a reliable link between perceptual processing and autistic traits. Interpreting these data within the Bayesian framework, it follows that the autistic trait of attention to detail (or perception of detail) would be related to (and in fact would predict, as suggested by the path analysis Model 2, which demonstrated a significantly better fit to the data in the current study) perceptual processing. As stated above, autistic hypo-priors would result in less constrained perceptual experiences (i.e., fewer sensory details get 'filtered' out by prior distributions) resulting in more information being available for perception of detail.

The purpose of providing an in-depth explanation of this theoretical framework focused on an algorithmic explanation of the data is to be explicit and intentional about the scaffolding used to extrapolate clinical implications from the available data. The frameworks presented here provide theoretical explanations across multiple levels of analysis that lead to a range of potential consequential clinical implications for understanding the experiences of autistic individuals.

Understanding 'Non-Social' Autistic Traits

The data presented from the current study indicate that autistic individuals may utilize perceptual processes to a greater extent than neurotypical individuals in their processing of

stimuli. These data are consistent with autistic hypo-priors in that fewer internal constraints on perception would lead to a greater reliance on incoming sensory signals, which in turn could result in enhancement in perceptual processes. Autistic hypo-priors may be related to some of the non-social autistic traits that are described in the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013), including repetitive behaviors, resistance to change, and hyper- and hyposensitivity to stimuli (Pellicano & Burr, 2012). For example, less specific priors may result in more difficulty filtering out sensory information (e.g., background sounds in a classroom unrelated to the lesson), making it difficult to discriminate incoming sensory cues and attend to only those that are most relevant.

Priors are, in essence, algorithmic short-cuts that aid in the rapid interpretation of sensory information. Under this view, hypo-priors may contribute to explanations of why some autistic individuals may demonstrate the avoidance of change. Prior knowledge gained from past experiences helps to aid in the interpretation of current events by generating predictions based on previous experiences. Thus, experiences that are less constrained by prior knowledge would make it increasingly difficult to generate predictions based on past experiences. Stronger early perceptual signals in autism, as evidenced by the data in the current study, may be beneficial for some aspects of perceptual processing, but may contribute to difficulties in other domains such as predicting change and drawing inferences from past experiences to help interpret current ones.

Particularly within the structure of the Bayesian framework and knowing that the world may be “too real” for many on the autism spectrum (Pellicano & Burr, 2012) may help non-autistic individuals understand an even broader range of autistic behaviors. Having strong priors with regards to sensory and perceptual processing is likely helpful in making sense of the onslaught of sensory information that bombards our systems at any given moment. On the flip

side, weaker priors (i.e., fewer internal constraints) with regards to sensory and perceptual processing could lead to a sense of distress and the often- reported experience of sensory overload. For example, many in the autistic community have stressed the importance of neurotypical people understanding the difference between a “tantrum” and a “meltdown” due to sensory overload (Bennie, 2016; Majumdar, 2019).

Increasingly Accessible Environments

The preliminary data presented in the current study are generally consistent with the idea that perceptual processing differs between autistic and neurotypical children and adolescents and that these processing pathway differences are related to autistic traits. As outlined above, the primary clinical implications of such results are related to a more comprehensive understanding of autistic traits, particularly many of the non-social characteristics of autism. One of the benefits of such understanding is the ability to develop environmental accommodations that make settings more accessible for and inclusive of autistic individuals. It is clear that although enhanced perceptual functioning is related to many strengths of autistic individuals, such processing differences may result in functional impairments within the contexts of environments not structured to support such processing patterns.

Classrooms, for instance, are often structured to be highly stimulating environments. This intentionally stimulating set-up can be seen in many different forms, including arranging different areas of the classroom into ‘workstations,’ putting up brightly colored posters, and having the whole classroom ‘clap-back’ a beat to indicate that they are listening to the teacher. While such a structure may be beneficial for maintaining neurotypical children’s attention, the onslaught of sensory information may be less helpful, or even detrimental, for autistic students. Classroom accommodations such as minimizing non-relevant visuals and sounds, may be helpful

in reducing the amount of sensory stimulation that autistic students' perceptual systems need to process. Additionally, individual strategies that reduce sensory stimulation, such as using noise cancelling headphones, have well-documented benefits (e.g., Pfeiffer et al., 2019; Sarrett, 2018) for students on the autism spectrum. Such accommodations can be easily integrated into inclusive classroom settings, which benefit all students regardless of disability status (e.g., Capp, 2013; Szumski et al., 2017).

Hospitals are another example of highly stimulating environments that can be made more accessible for autistic individuals through environmental accommodations. Autistic individuals and their family members report numerous barriers to healthcare as a result of processing differences (e.g., Muskat et al., 2015; Nicolaidis et al., 2015). Though identifying the mechanisms through which information processing differences arise and subsequently impact broader functioning for autistic individuals is not a prerequisite for making important changes and accommodations to healthcare environments (see https://aaspire.org/projects/improving-hospital-experiences-for-adults-on-the-autism-spectrum/ for an example of ongoing projects), such knowledge may provide further depth towards understanding these experiences through the lens of different perspectives and disciplines.

Limitations and Future Directions

The current study is best interpreted within the context of several limitations, many of which were mentioned in the preceding sections and will be succinctly reiterated here.

Sample Size

First, the final sample of participants included in the analyses was smaller than initially proposed due to the unforeseen need to discontinue in-person data collection due to the COVID-19 pandemic. Adjustments were made to the subsequent statistical methods in order to glean the

most accurate and justified conclusions based on the available data; however, as put by Dr. Steven Luck (originally attributed to Jon Hansen), “there is no substitute for good data” (Luck, 2014, p. 149). Larger sample sizes for both groups of participants will increase statistical power to detect the hypothesized effects (VanVoorhis & Morgan, 2007), allow for autistic and neurotypical participants to be matched on relevant indicators (Russo et al., 2021), both of which will allow for stronger conclusions regarding the relationships tested in the current study. Therefore, the primary future direction for the current study is to continue data collection once it is safe to run extended in-person ERP experiments.

Intelligence Quotient Exclusionary Criteria

A second limitation of the current study is that exclusionary criteria for both groups of participants included having a PIQ of 75 or greater, therefore excluding individuals with intellectual disability. The prevalence of autistic individuals who also have an intellectual disability is estimated to be between 33% and 50% (Charman et al., 2011; Maenner et al., 2020), yet published autism research focuses disproportionately on autistic individuals without intellectual disability (Jack & Pelphrey, 2017; Russell et al., 2019). The current study unfortunately contributes to this growing trend of selection bias in autism research by excluding individuals with an intellectual disability. While there are some methodological challenges in studying the cognitive profiles and neuropsychological processes of individuals with an intellectual disability, such as accounting for meaningful heterogeneity within this population (i.e., not combining individuals with different etiologies for their intellectual disability into a single group), these challenges have known solutions, and the field has an undeniable need for growth in this area. The paucity of autism research that includes autistic individuals with an intellectual disability, particularly in neuroimaging research (Jack & Pelphrey, 2017), limits

researchers' ability to generalize findings to a substantial proportion of individuals on the spectrum. For example, although autistic individuals with an intellectual disability demonstrate significantly faster identification of embedded figures than non-autistic individuals with an intellectual disability (Van Lang et al., 2006), these findings have not been extended to neurophysiological studies. Thus, some of the major principles of the Enhanced Perceptual Functioning model of autism, such as that perceptual processing plays a larger role in intelligence and that enhanced functioning of primary perceptual brain regions account for autistic perceptual atypicalities, remain untested among groups of autistic individuals with an intellectual disability.

Specifically with regards to the current study, it is unknown whether the findings presented here would extend to autistic individuals with an intellectual disability. Evidence that autistic individuals with an intellectual disability exhibit perceptual processing advantages over non-autistic peers with intellectual disability and/or that they recruit brain regions dedicated to perceptual processes during reasoning and problem-solving tasks would provide strong support for the applicability of the Enhanced Perceptual Functioning model across the autism spectrum. A future direction of the current study is to test whether the same electrophysiological markers of early perceptual and later cognitive processing are seen among individuals with an intellectual disability. The current study is at a particular advantage to be used for future research due to the non-verbal nature of the experimental task and that the semantic violation is based on experiential knowledge (i.e., hearing dogs barking) rather than conceptual reasoning (e.g., predicting what picture might come next in a visual narrative). Some previous research provides preliminary evidence that individuals with Down syndrome and intellectual disability demonstrate N400 effects to similar tasks (Elam, 2016); however, research has yet to investigate

the extent to which autistic individuals with intellectual disability show similar or different ERP waveforms to their non-autistic peers. Data that autistic individuals with intellectual disability show similar information processing patterns to autistic persons without accompanying intellectual disability would provide exciting evidence towards the specificity of such processing patterns across the autism spectrum (Nadler et al., 2016).

Experimental Task

Interpretations of the current study are also limited by the specific stimuli used to elicit participant ERPs as well as the specific scales used to quantify autistic traits. To begin with the experimental paradigm, visual and audio stimuli were chosen to be closely modeled from those of Russo et al. (2012) and were the same stimuli used in Kaplan-Kahn et al. (2021). Although such replication is empirically important, particularly for ERP studies which inherently seek to find small effects between conditions, it limits the ability to confidently draw generalized interpretations of the data. For example, would the relationships between the size of the P1 condition difference and the size of the N400 effect change or remain stable for a different experimental task? A potential starting-point for exploring how such ERP effects extend to other tasks is to adapt the types of problem-solving and reasoning tasks used in previous fMRI studies, such as the Raven's Standard Progressive Matrices (e.g., Sahyoun et al., 2010; Soulières et al., 2009). Such tasks would provide compelling complementary data to the finding that autistic individuals recruit cortical *areas* dedicated to perceptual processes in problem solving by overlaying cross-modal data that the *time-course* of these differential processing patterns also aligns with perceptual processing mechanisms. Further, such tasks would advance the evidence base pointing to how perceptual processes support autistic intelligence, as matrix reasoning tasks

are aligned with standard subtests of many common intelligence measures for children and adults (e.g., the WASI-II).

Measure of Autistic Traits

The current study also used a narrow measure of autistic traits as the primary variable of interest. The Attention to Detail subscale of the AQ was chosen for the current study as it has been specifically implicated as related to multisensory processing among autistic individuals (Stevenson et al., 2017) and related to early perceptual processing among neurotypical adults (Kaplan-Kahn et al., 2021). Nevertheless, attention to detail is but one of the myriad of behavioral traits that is included as part of the constellation of strengths and challenges exhibited by many autistic individuals. Future research may expand on the current study by investigating how differential information processing streams are related to broader autistic traits. For example, how might an inclination for utilizing perceptual processes be related to enjoying particular sensory or stimming experiences that are described as useful coping mechanisms by autistic adults (Kapp et al., 2019)?

From Deficits, to Differences, to Diversity

The current study sought to examine the relationships between early perceptual processing, subsequent cognitive processing, and autistic traits in autistic and neurotypical children and adolescents. Though additional data collection is necessary to draw strong conclusions from the study, current empirical trends point towards the hypothesized relationships, demonstrating that autistic individuals exhibit different information processing pathways than their neurotypical peers and that these differential pathways are related to autistic traits. An acknowledgment and awareness of different pathways to cognition challenges researchers to move beyond looking for *deficits*, ways that autistic individuals fail show non-

autistic patterns of processing, and search for a deeper understanding of what these processing pattern *differences* might be. These differences are adaptive for both groups; non-autistic people tend to favor and rely on a relative area of strength (cognitive processing) in reasoning and problem solving, and autistic individuals do the same by utilizing their strengths in perceptual processing to reach the same outcome.

The transition from the scientific search of identifying processing deficits to the empirical endeavor of understanding processing differences (how they develop over time and their clinical implications) has advanced both the rigor of science regarding autism and the social understanding of what it means to be autistic. There is a double-edged potential, however, in recognizing and researching differences, particularly brain-based differences. On the one hand, there is the option to couch these differences as further reasons for "othering." As articulated by Roy Richard Grinker, "if we describe someone…as having a chemical imbalance or abnormal brain circuitry, we risk providing reasons to…see them as permanently damaged; it is the person's brain, and not the social context, that needs to be fixed" (Grinker, 2021, p. 223). On the other hand, a deeper understanding of such information processing differences opens exciting new possibilities to learn more about the different pathways to cognition that we use in making sense of the richness of our world. The challenge then, is to not only do the work of understanding that differences exist but creating space and contributing to social structures that will celebrate such differences as diversity.

Table 1.
Participant Descriptive Statistics

Variable	Group (*n*)	*M* (SD)	Range	*p*-value (Welch's t-test)
Age (years)	Autistic (14)	14.27 (3.13)	8.86-17.97	.028
	Neurotypical (10)	11.24 (3.04)	6.34-16.39	
PRI (standard score)	Autistic (14)	110.71 (13.15)	88-130	.503
	Neurotypical (10)	114.00 (10.45)	98-134	
FSIQ (standard score)	Autistic (14)	104.14 (9.37)	88-122	.002
	Neurotypical (10)	119.50 (10.68)	98-131	
AQ Total Score (raw score)	Autistic (14)	136.71 (13.57)	115-156	< .001
	Neurotypical (10)	102.50 (17.06)	81-130	
AQ Attention to Detail Score (raw score)	Autistic (14)	27.29 (5.36)	20-39	.246
	Neurotypical (10)	25.00 (4.24)	17-30	
BASC-2 Hyperactivity (*t*-score)	Autistic (14)	61.62 (14.79)	36-80	.017
	Neurotypical (10)	47.80 (10.85)	36-69	
BASC-2 Attention Problems (*t*-score)	Autistic (14)	62.38 (9.14)	45-75	< .001
	Neurotypical (10)	45.60 (5.62)	38-56	
BASC-2 Anxiety (*t*-score)	Autistic (14)	62.00 (14.96)	38-85	.266
	Neurotypical (10)	55.63 (12.32)	42-80	

Note. N = 24

Table 2.
Full Participant Group, Means (and Standard Deviations) of Study Variables and Their Spearman Rank Correlations

Variable (range)	***M (SD)***	***r***			
		1.	2.	3.	4.
1. Task Accuracy (0.64-1.00)	0.91 (0.10)	--			
2. Task Reaction Time (0.46-1.70)	0.98 (0.35)	-0.62**	--		
3. AQ Attention to Detail Score (17-39)	26.5 (4.92)	0.17	0.05	--	
4. Mean P1 Amplitude Difference (-2.13-5.05)	0.60 (1.73)	-0.21	0.33	0.26	--
5. Mean N400 Amplitude Difference (-6.03-11.61)	0.69 (4.05)	-0.03	-0.17	0.10	0.04

Note. N = 24.
**p < 0.01

Table 3.
Full Autistic Participant Group, Means (and Standard Deviations) of Study Variables and Their Spearman Rank Correlations

Variable (range)	***M (SD)***	***r***			
		1.	2.	3.	4.
1. Task Accuracy (0.64-0.99)	0.91 (0.10)	--			
2. Task Reaction Time (0.46-1.24)	0.86 (0.25)	-0.48	--		
3. AQ Attention to Detail Score (20-39)	27.29 (5.36)	0.50	0.17	--	
4. Mean P1 Amplitude Difference (-1.22-5.05)	1.09 (1.89)	-0.02	0.57*	0.61*	--
5. Mean N400 Amplitude Difference (-6.03-11.61)	1.00 (4.22)	-0.15	-0.03	-0.03	0.06

Note. N = 14.
*$p < 0.05$

Table 4.
<17-year-old Autistic Participant Group, Means (and Standard Deviations) of Study Variables and Their Spearman Rank Correlations

Variable (range)	***M (SD)***	***r***			
		1.	2.	3.	4.
1. Task Accuracy (0.64-0.99)	0.90 (0.12)	--			
2. Task Reaction Time (0.55-1.24)	0.89 (0.22)	-0.39	--		
3. AQ Attention to Detail Score (20-39)	28.4 (5.89)	0.66*	0.02	--	
4. Mean P1 Amplitude Difference (-0.54-5.05)	1.63 (1.95)	0.25	0.37	0.45	--
5. Mean N400 Amplitude Difference (-6.03-11.61)	1.61 (4.55)	-0.36	0.01	-0.39	0.09

Note. N = 10.
*$p < 0.05$

Table 5.
Neurotypical Participant Group, Means (and Standard Deviations) of Study Variables and Their Spearman Rank Correlations

Variable (range)	***M (SD)***	***r***			
		1.	2.	3.	4.
1. Task Accuracy (0.69-1.00)	0.91 (0.09)	--			
2. Task Reaction Time (0.66-1.70)	1.16 (0.40)	-0.90**	--		
3. AQ Attention to Detail Score (17-30)	25.4 (4.25)	-0.30	0.01	--	
4. Mean P1 Amplitude Difference (-2.13-2.19)	-0.10 (1.26)	-0.55	0.55	-0.31	--
5. Mean N400 Amplitude Difference (-4.63-10.20)	0.24 (3.99)	0.14	-0.31	0.36	-0.05

Note. N = 10.
**$p < 0.01$

Table 6.
Means (and Standard Deviations) of Path Analysis Variables and Their Bivariate Correlation Coefficients

Variable (range)	***M (SD)***	***r***			
		1.	2.	3.	4.
1. Male Sex (0 = Male; 1 = Female)	0.40 (0.50)	--			
2. Age (6.34-16.9)	12.09 (2.92)	-0.44*	--		
3. AQ Attention to Detail Score (17-39)	26.9 (5.23)	0.26	0.02	--	
4. Mean P1 Amplitude Difference (-2.13-5.05)	0.76 (1.83)	-0.17	0.20	0.30	--
5. Mean N400 Amplitude Difference (-6.03-11.61)	0.93 (4.22)	0.01	-0.09	-0.01	0.01

Note. N = 20.
*$p < 0.05$

Figure 1

Visual stimuli used in experimental task. A) Dog stimulus; B) Frog stimulus

A

B.

Figure 2

Behavioral accuracy ANCOVA linearity assumption check

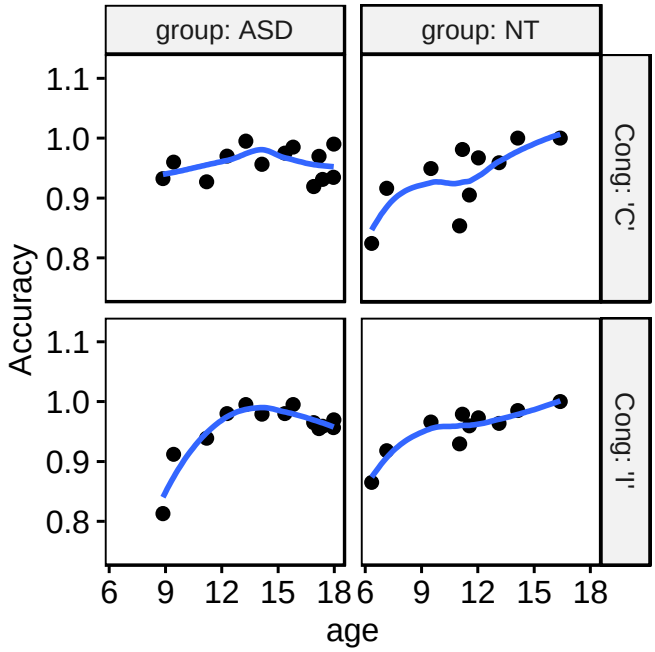


Figure 3

Behavioral reaction time ANCOVA linearity assumption check

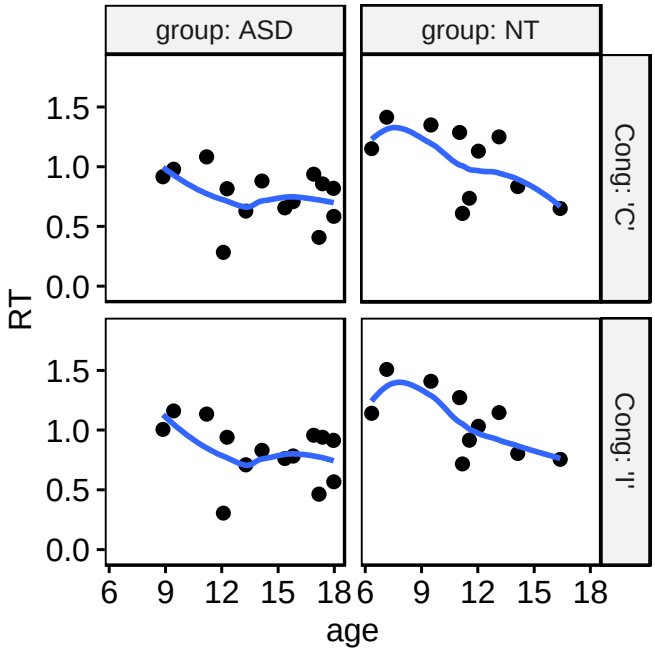


Figure 4

P1 ANCOVA linearity assumption check

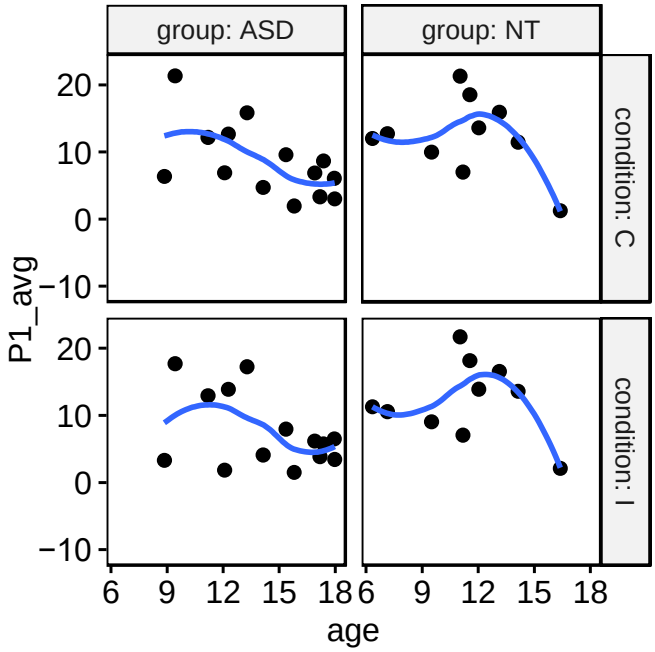
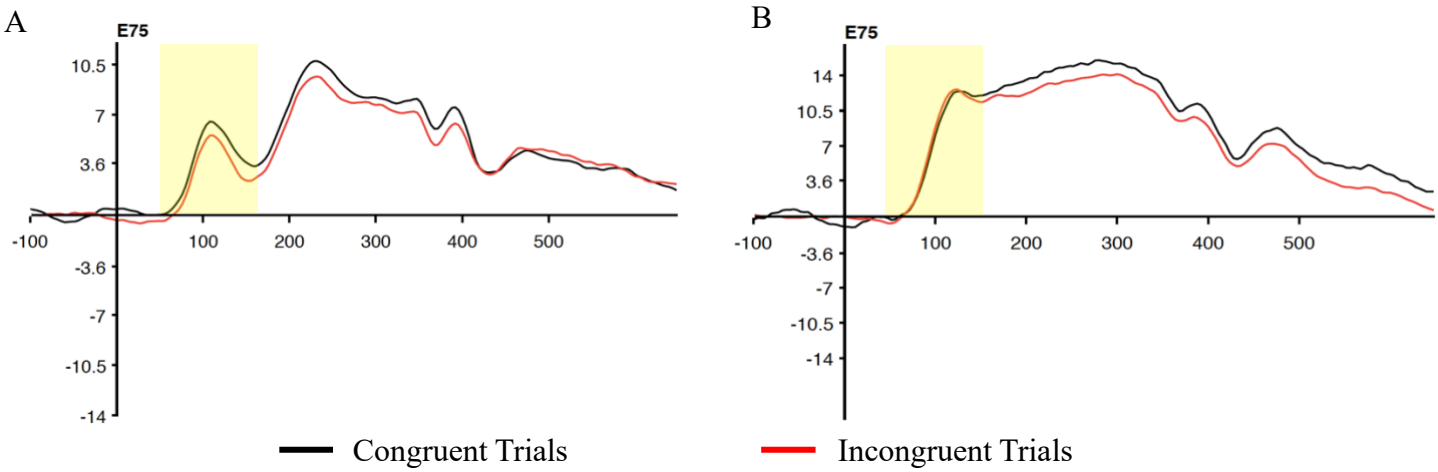


Figure 5

P1 ERP waveforms for autistic participants (panel A) and neurotypical participants (panel B)



Note. Approximate P1 time window (50-100ms) highlighted in yellow.

Figure 6

N400 ANCOVA linearity assumption check

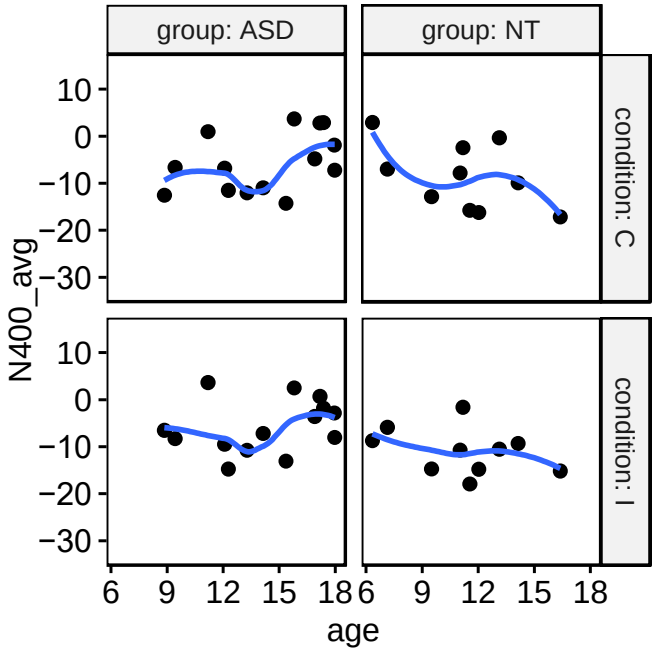
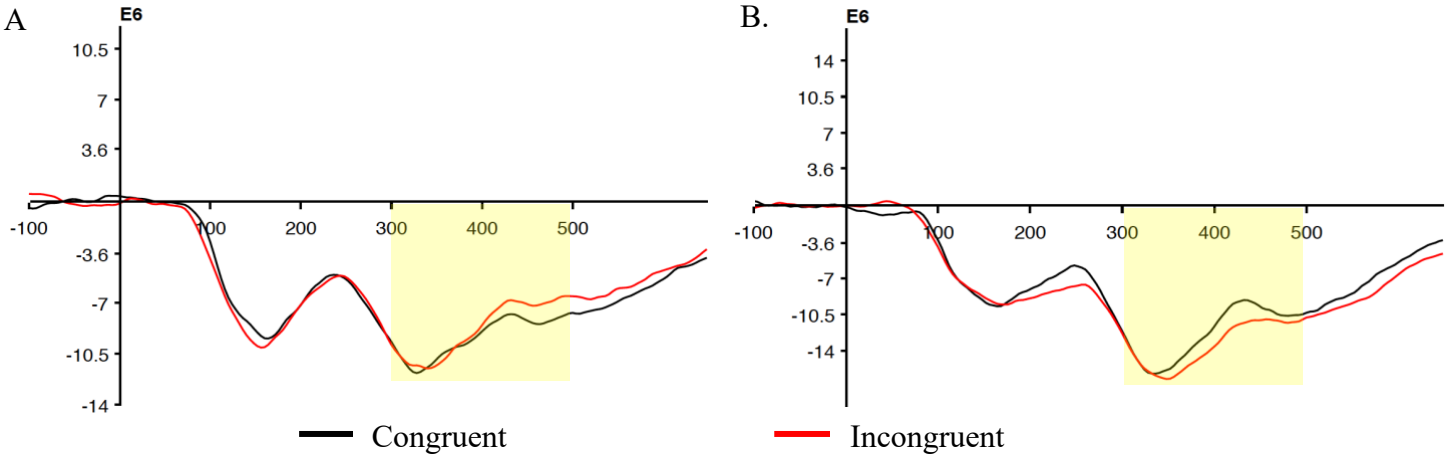


Figure 7

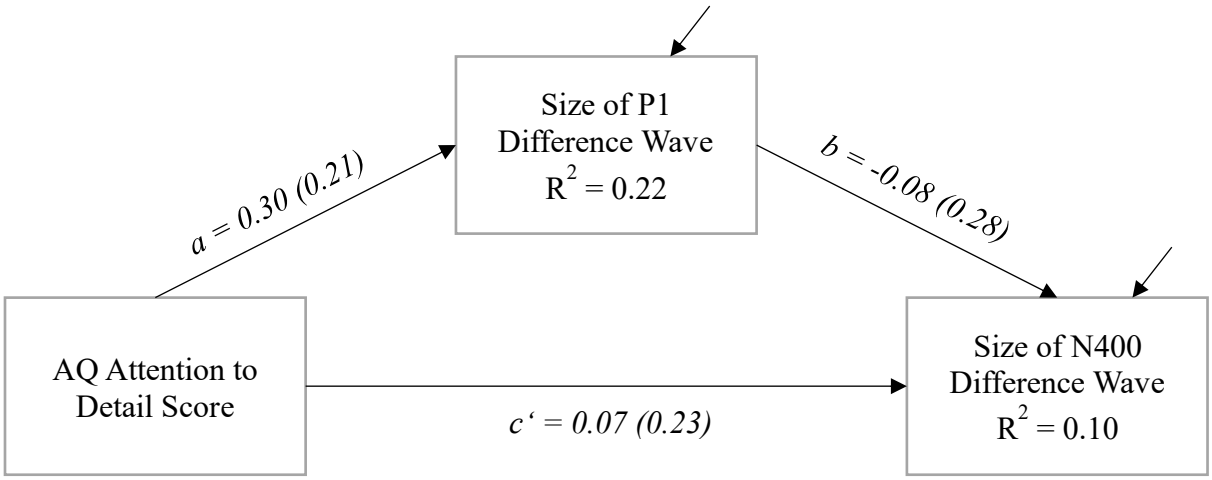
N400 ERP waveforms for autistic participants (panel A) and neurotypical participants (panel B)



Note. A priori N400 time window (300-500ms) highlighted in yellow.

Figure 8

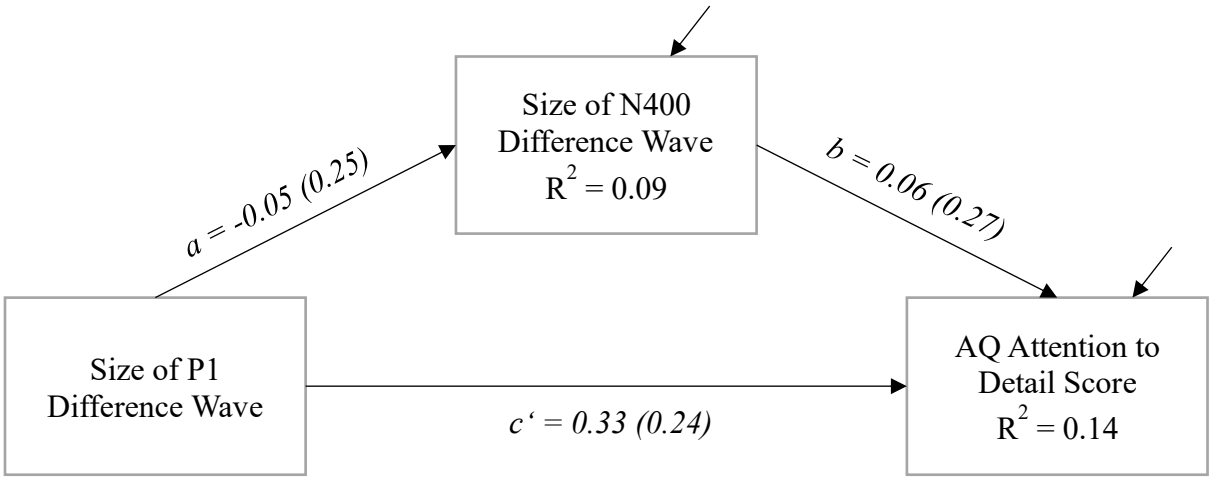
Standardized path coefficients (and standard errors) of Model 1.



Note. The effects of sex and age on the mediator and outcome were controlled for (paths not shown). N = 20.

Figure 9

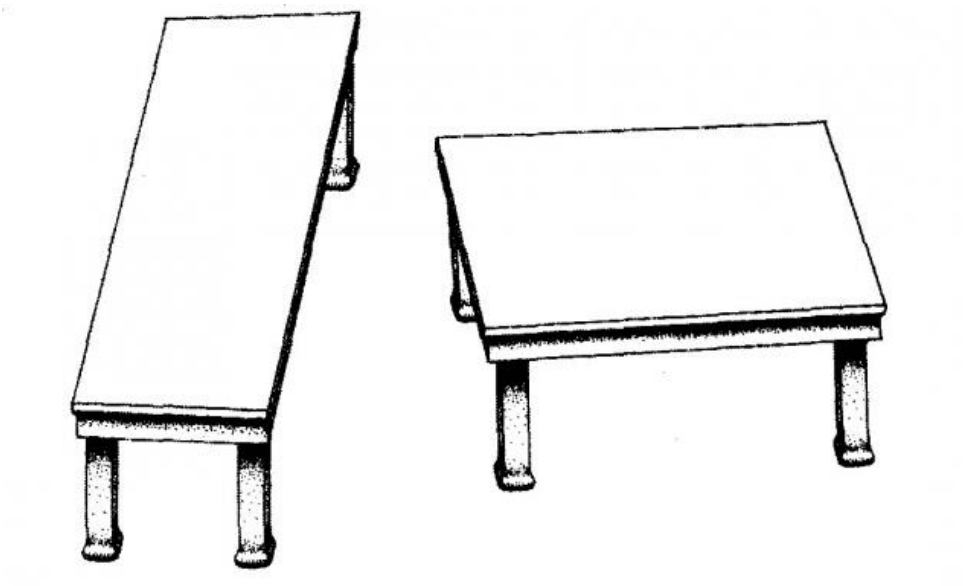
Standardized path coefficients (and standard errors) of Model 2.



Note. The effects of sex and age on the mediator and outcome were controlled for (paths not shown). N = 20.

Figure 10

Shepard's table illusion. The two-dimensional images of the parallelograms are identical; however, the image is consistent with many 3D shapes, the most probable being real tables slanting at about 45º, and in order to be consistent with the identical 2D images, the table-tops are perceived to be of very different dimensions.



References

Aggarwal, R., & Ranganathan, P. (2016). Common pitfalls in statistical analysis: The use of correlation techniques. *Perspectives in Clinical Research*, *7*(4), 187. https://doi.org/10.4103/2229-3485.192046

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)*. American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596.744053

Amoruso, L., Gelormini, C., Aboitiz, F., Alvarez González, M., Manes, F., Cardona, J. F., & Ibanez, A. (2013). N400 ERPs for actions: building meaning in context. *Frontiers in Human Neuroscience*, *7*(March), 57. https://doi.org/10.3389/fnhum.2013.00057

Antshel, K. M., & Russo, N. (2019). Autism Spectrum Disorders and ADHD: Overlapping Phenomenology, Diagnostic Issues, and Treatment Considerations. *Current Psychiatry Reports*, *21*(5). https://doi.org/10.1007/s11920-019-1020-5

Antshel, K. M., Zhang-James, Y., Wagner, K. E., Ledesma, A., & Faraone, S. V. (2016). An update on the comorbidity of ADHD and ASD: A focus on clinical management. *Expert Review of Neurotherapeutics*, *16*(3), 279–293. https://doi.org/10.1586/14737175.2016.1146591

Ashby, F. G., Ennis, J. M., & Spiering, B. J. (2007). A neurobiological theory of automaticity in perceptual categorization. In *Psychological Review* (Vol. 114, Issue 3, pp. 632–656). American Psychological Association. https://doi.org/10.1037/0033-295X.114.3.632

Ashwin, C., Chapman, E., Howells, J., Rhydderch, D., Walker, I., & Baron-Cohen, S. (2014). Enhanced olfactory sensitivity in autism spectrum conditions. *Molecular Autism*, *5*(1), 53. https://doi.org/10.1186/2040-2392-5-53

Aue, T., Lavelle, L. A., & Cacioppo, J. T. (2009). Great expectations: What can fMRI research tell us about psychological phenomena? *International Journal of Psychophysiology*, *73*(1), 10–16. https://doi.org/10.1016/j.ijpsycho.2008.12.017

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: Children's version (AQ-Child). *Journal of Autism and Developmental Disorders*, *38*(7), 1230–1240. https://doi.org/10.1007/s10803-007-0504-z

Baldwin, S. A. (2017). Improving the rigor of psychophysiology research. *International Journal of Psychophysiology*, *111*, 5–16. https://doi.org/10.1016/j.ijpsycho.2016.04.006

Banaschewski, T., & Brandeis, D. (2007). Annotation: What electrical brain activity tells us about brain function that other techniques cannot tell us - A child psychiatric perspective. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *48*(5), 415–435. https://doi.org/10.1111/j.1469-7610.2006.01681.x

Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: Hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1522), 1377–1383. https://doi.org/10.1098/rstb.2008.0337

Baron-Cohen, S., Hoekstra, R. A., Knickmeyer, R., & Wheelwright, S. (2006). The Autism-Spectrum Quotient (AQ) - Adolescent version. *Journal of Autism and Developmental Disorders*, *36*(3), 343–350. https://doi.org/10.1007/s10803-006-0073-6

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient: Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/A:1005653411471

Barros, F., Figueiredo, C., Costa, A., & Soares, S. C. (2020). Sensory Processing in the Autism Spectrum: The Role of Attention to Detail and Somatic Trait Anxiety in the Olfactory Perception of the General Population. *Journal of Autism and Developmental Disorders*, *0123456789*. https://doi.org/10.1007/s10803-020-04711-0

Bennie, M. (2016). *Tantrum vs Autistic Meltdown: What Is The Difference?* Autism Awareness Centre. https://autismawarenesscentre.com/what-is-the-difference-between-a-tantrum-and-an-autistic-meltdown/

Bishara, A. J., & Hittner, J. B. (2017). Confidence intervals for correlations when data are not normal. *Behavior Research Methods*, *49*(1), 294–309. https://doi.org/10.3758/s13428-016-0702-8

Blumberg, S. J., Bramlett, M. D., Kogan, M. D., Schieve, L. a, Jones, J. R., & Lu, M. C. (2013). Changes in prevalence of parent-reported autism spectrum disorder in school-aged U.S. children: 2007 to 2011– 2012. *National Health Statistics Reports*, *65*, 1–12.

Bölte, S., Hubl, D., Dierks, T., Holtmann, M., & Poustka, F. (2008). An fMRI-study of locally oriented perception in autism: Altered early visual processing of the block design test. *Journal of Neural Transmission*, *115*(3), 545–552. https://doi.org/10.1007/s00702-007-0850-1

Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., Burack, J. A., & Mottron, L. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not Asperger syndrome. *Neuropsychologia*, *48*(9), 2465–2475. https://doi.org/10.1016/j.neuropsychologia.2010.04.020

Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A.-M. (2003). Enhanced pitch sensitivity in individuals with autism: a signal detection analysis. *Journal of Cognitive*

Neuroscience, *15*(2), 226–235. https://doi.org/10.1162/089892903321208169

Bottema-Beutel, K., Kapp, S. K., Lester, J. N., Sasson, N. J., & Hand, B. N. (2021). Avoiding Ableist Language : Suggestions for Autism Researchers. *Autism in Adulthood*, *3*(1), 18–29. https://doi.org/10.1089/aut.2020.0014

Braeutigam, S., Swithenby, S. J., & Bailey, A. J. (2008). Contextual integration the unusual way: A magnetoencephalographic study of responses to semantic violation in individuals with autism spectrum disorders. *European Journal of Neuroscience*, *27*(4), 1026–1036. https://doi.org/10.1111/j.1460-9568.2008.06064.x

Brian, J. A., & Bryson, S. E. (1996). Disembedding performance and recognition memory in Autism/PDD. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *37*(7), 865–872. https://doi.org/10.1111/j.1469-7610.1996.tb01482.x

Brosnan, M. J., Gwilliam, L. R., & Walker, I. (2012). Brief report: The relationship between visual acuity, the embedded figures test and systemizing in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *42*(11), 2491–2497. https://doi.org/10.1007/s10803-012-1505-0

Burnham, K. P., & Anderson, D. R. (2004). Multimodel Inference. *Sociological Methods & Research*, *33*(2), 261–304. https://doi.org/10.1177/0049124104268644

Caron, M. J., Mottron, L., Berthiaume, C., & Dawson, M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. *Brain*, *129*(7), 1789–1802. https://doi.org/10.1093/brain/awl072

CDC - Centers for Disease Control and Prevention. (2018). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years — Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *MMWR. Surveillance Summaries*,

67(6), 1–23. https://doi.org/10.15585/mmwr.ss6706a1

Chamberlain, R., McManus, I. C., Riley, H., Rankin, Q., & Brunswick, N. (2013). Local processing enhancements associated with superior observational drawing are due to enhanced perceptual functioning, not weak central coherence. *Quarterly Journal of Experimental Psychology*, *66*(7), 1448–1466. https://doi.org/10.1080/17470218.2012.750678

Charman, T., Pickles, A., Simonoff, E., Chandler, S., Loucas, T., & Baird, G. (2011). IQ in children with autism spectrum disorders: Data from the Special Needs and Autism Project (SNAP). *Psychological Medicine*, *41*(3), 619–627. https://doi.org/10.1017/S0033291710000991

Cheung, C. H. M., Bedford, R., Johnson, M. H., Charman, T., Baron-Cohen, S., Bolton, P., Blasi, A., Davies, K., Elsabbagh, M., Fernandes, J., Gammer, I., Green, J., Guiraud, J., Liew, M., Lloyd-Fox, S., Maris, H., O'Hara, L., Pasco, G., Pickles, A., … Yemane, F. (2018). Visual search performance in infants associates with later ASD diagnosis. *Developmental Cognitive Neuroscience*, *29*, 4–10. https://doi.org/10.1016/j.dcn.2016.09.003

Chouinard, P. A., Royals, K. A., Landry, O., & Sperandio, I. (2018). The shepard illusion is reduced in children with an autism spectrum disorder because of perceptual rather than attentional mechanisms. *Frontiers in Psychology*, *9*(DEC), 1–13. https://doi.org/10.3389/fpsyg.2018.02452

Clayson, P. E., Baldwin, S. A., & Larson, M. J. (2013). How does noise affect amplitude and latency measurement of event-related potentials (ERPs)? A methodological critique and simulation study. *Psychophysiology*, *50*(2), 174–186. https://doi.org/10.1111/psyp.12001

Coderre, E. L., Chernenok, M., Gordon, B., & Ledoux, K. (2017). Linguistic and Non-Linguistic Semantic Processing in Individuals with Autism Spectrum Disorders: An ERP Study. *Journal of Autism and Developmental Disorders*, *47*(3), 795–812. https://doi.org/10.1007/s10803-016-2985-0

Coderre, E. L., Cohn, N., Slipher, S. K., Chernenok, M., Ledoux, K., & Gordon, B. (2018). Visual and linguistic narrative comprehension in autism spectrum disorders: Neural evidence for modality-independent impairments. *Brain and Language*, *186*(June), 44–59. https://doi.org/10.1016/j.bandl.2018.09.001

Coles, M. G. H., & Rugg, M. D. (1995). Event-related brain potentials: An introduction. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of Mind: Event-Related Brain Potentials and Cognition* (pp. 1–26). https://doi.org/10.1093/acprof:oso/9780198524168.003.0001

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. *Neuron*, *48*, 497–507. https://doi.org/10.1016/j.neuron.2005.10.018

Damarla, S. R., Keller, T. A., Kana, R. K., Cherkassky, V. L., Williams, D. L., Minshew, N. J., & Just, M. A. (2010). Cortical underconnectivity coupled with preserved visuospatial cognition in autism: Evidence from an fMRI study of an embedded figures task. *Autism Research*, *3*(5), 273–279. https://doi.org/10.1002/aur.153

Dawson, M., Soulières, I., Gernsbacher, M. A., & Mottron, L. (2007). The level and nature of autistic intelligence. *Psychological Science*, *18*(8), 657–662. https://doi.org/10.1037/a0029984

de Winter, J. C. F. (2013). Using the student's t-test with extremely small sample sizes. *Practical Assessment, Research and Evaluation*, *18*(10), 1–12. https://doi.org/10.7275/e4r6-dj05

Delacre, M., Lakens, D., & Leys, C. (2017). Why psychologists should by default use welch's t-

Test instead of student's t-Test. *International Review of Social Psychology*, *30*(1), 92–101. https://doi.org/10.5334/irsp.82

Delorme, A., & Makeig, S. (2004). EEGLAB: an open sorce toolbox for analysis of single-trial EEG dynamics including independent component anlaysis. *Journal of Neuroscience Methods*, *134*, 9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009

DiCriscio, A. S., & Troiani, V. (2018). The Broader Autism Phenotype and Visual Perception in Children. *Journal of Autism and Developmental Disorders*, *48*(8), 2809–2820. https://doi.org/10.1007/s10803-018-3534-9

Donchin, E., Ritter, W., & McCallum, W. C. (1978). Cognitive psychophysiology: The endogenous components of the ERP. In *Brain Event-Related Potentials in Man* (pp. 349–441). Academic Press. https://doi.org/10.1016/B978-0-12-155150-6.50019-5

Doniger, G. M., Foxe, J. J., Murray, M. M., Higgins, B. A., Snodgrass, J. G., Schroeder, C. E., & Javitt, D. C. (2000). Activation timecourse of ventral visual stream object-recognition areas: High density electrical mapping of perceptual closure processes. *Journal of Cognitive Neuroscience*, *12*(4), 615–621. https://doi.org/10.1162/089892900562372

Duncan, C. C., Barry, R. J., Connolly, J. F., Fischer, C., Michie, P. T., Näätänen, R., Polich, J., Reinvang, I., & Van Petten, C. (2009). Event-related potentials in clinical research: Guidelines for eliciting, recording, and quantifying mismatch negativity, P300, and N400. *Clinical Neurophysiology*, *120*(11), 1883–1908. https://doi.org/10.1016/j.clinph.2009.07.045

Dunn, M. A., & Bates, J. C. (2005). Developmental change in neutral processing of words by children with autism. *Journal of Autism and Developmental Disorders*, *35*(3), 361–376. https://doi.org/10.1007/s10803-005-3304-3

Dunn, M., Vaughan, H., Kreuzer, J., & Kurtzberg, D. (1999). Electrophysiologic correlates of semantic classification in autistic and normal children. *Developmental Neuropsychology*, *16*(1), 79–99. https://doi.org/10.1207/S15326942DN160105

Efron, B., & Tibshirani, R. J. (1993). *An introduction to the bootstrap*. CRC press.

Elam, A. L. (2016). *Semantic Processing in Individuals with Intellectual Disabilities* (Issue May). The Pennsylvania State University.

Electrical Geodesics Inc. (2003). *Net Station Acquisition Technical Manual*. Electrical Geodesics, Inc. http://cb3.unl.edu/dbrainlab/wp-content/uploads/sites/2/2013/12/Acquisition_Manual.pdf

Falter, C. M., Plaisted, K. C., & Davis, G. (2008). Visuo-spatial processing in autism - Testing the predictions of extreme male brain theory. *Journal of Autism and Developmental Disorders*, *38*(3), 507–515. https://doi.org/10.1007/s10803-007-0419-8

Fishman, I., Yam, A., Bellugi, U., Lincoln, A., & Mills, D. (2011). Contrasting patterns of language-associated brain activity in autism and Williams syndrome. *Social Cognitive and Affective Neuroscience*, *6*(5), 630–638. https://doi.org/10.1093/scan/nsq075

Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychological Science*, *18*(3), 233–239.

Ganis, G., Kutas, M., & Sereno, M. I. (1996). The search for "'common sense'": An electrophysiological study of the comprehension of words and pictures in reading. *Journal of Cognitive Neuroscience*, *8*(2), 89–106. https://doi.org/10.1162/jocn.1996.8.2.89

Gliga, T., Bedford, R., Charman, T., Johnson, M. H., Baron-Cohen, S., Bolton, P., Cheung, C., Liew, M., Liew, M., Gammer, I., Salomone, E., Pasco, G., Pickles, A., Davies, K., Maris, H., Ribeiro, H., & Tucker, L. (2015). Enhanced Visual Search in Infancy Predicts Emerging

Autism Symptoms. *Current Biology*, *25*(13), 1727–1730. https://doi.org/10.1016/j.cub.2015.05.011

Gregory, R. L. (1980). Perceptions as Hypotheses. *Philosophical Transactions of the Royal Society of London - Series B: Biological Sciences*, *290*(1038), 181–197.

Grinker, R. R. (2021). *Nobody's Normal: How Culture Created the Stigma of Mental Illness*. W. W. Norton & Company.

Hadad, B. S., & Schwartz, S. (2019). Perception in autism does not adhere to weber's law. *ELife*, *8*, 1–15. https://doi.org/10.7554/eLife.42223

Hagmann, C. E., Wyble, B., Shea, N., LeBlanc, M., Kates, W. R., & Russo, N. (2016). Children with autism detect targets at very rapid rresentation rates with similar accuracy as adults. *Journal of Autism and Developmental Disorders*, *46*(5), 1762–1772. https://doi.org/10.1007/s10803-016-2705-9

Heaton, P., Hermelin, B., & Pring, L. (1998). Autism and pitch processing: A precursor for savant musical ability? *Music Perception: An Interdisciplinary Journal*, *15*(3), 291–305.

Hileman, C. M., Henderson, H., Mundy, P., Newell, L., & Jaime, M. (2011). Developmental and individual differences on the P1 and N170 ERP components in children with and without autism. *Developmental Neuropsychology*, *36*(2), 214–236. https://doi.org/10.1080/87565641.2010.549870

Hoekstra, R. A., Bartels, M., Verweij, C. J. H., & Boomsma, D. I. (2007). Heritability of autistic traits in the general population. *Archives of Pediatrics and Adolescent Medicine*, *161*(4), 372–377. http://archpedi.ama-assn.org/cgi/reprint/161/4/372%5Cnhttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed8&NEWS=N&AN=2007171856

Hox, J. J., Maas, C. J. M., & Brinkhuis, M. J. S. (2010). The effect of estimation method and sample size in multilevel structural equation modeling. *Statistica Neerlandica*, *64*(2), 157–170. https://doi.org/10.1111/j.1467-9574.2009.00445.x

Hubl, D., Bölte, S., Feineis-Matthews, S., Lanfermann, H., Federspiel, A., Strik, W., Poustka, F., & Dierks, T. (2003). Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology*, *61*(9), 1232–1237. https://doi.org/10.1212/01.WNL.0000091862.22033.1A

Iida, Y., Miyazaki, M., & Uchida, S. (2010). Developmental changes in cognitive reaction time of children aged 6-12 years. *European Journal of Sport Science*, *10*(3), 151–158. https://doi.org/10.1080/17461390903515162

Ishida, R., Kamio, Y., & Nakamizo, S. (2009). Perceptual distortions of visual illusions in children with high-functioning autism spectrum disorder. *Psychologia*, *52*(3), 175–187. https://doi.org/10.2117/psysoc.2009.175

Itier, R. J., & Taylor, M. J. (2004a). Effects of repetition and configural changes on the development of face recognition processes. *Developmental Science*, *7*(4), 469–487. https://doi.org/10.1111/j.1467-7687.2004.00367.x

Itier, R. J., & Taylor, M. J. (2004b). Face recognition memory and configural processing: A developmental ERP study using upright, inverted, and contrast-reversed faces. *Journal of Cognitive Neuroscience*, *16*(3), 487–502. https://doi.org/10.1162/089892904322926818

Jack, A., & Pelphrey, K. A. (2017). Annual Research Review: Understudied populations within the autism spectrum – current trends and future directions in neuroimaging research. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *58*(4), 411–435. https://doi.org/10.1111/jcpp.12687

Jarrold, C., Gilchrist, I. D., & Bender, A. (2005). Embedded figures detection in autism and typical development: Preliminary evidence of a double dissociation in relationships with visual search. *Developmental Science*, *8*(4), 344–351. https://doi.org/10.1111/j.1467-7687.2005.00422.x

Järvinen-Pasley, A., Wallace, G. L., Ramus, F., Happé, F., & Heaton, P. (2008). Enhanced perceptual processing of speech in autism. *Developmental Science*, *11*(1), 109–121. https://doi.org/10.1111/j.1467-7687.2007.00644.x

Jassim, N., Baron-Cohen, S., & Suckling, J. (2020). *Sensory perception in autism: an fMRI ALE meta-analysis*. https://doi.org/10.31234/osf.io/p9n2z

Jihye Jeon. (2015). The Strengths and Limitations of the Statistical Modeling of Complex Social Phenomenon: Focusing on SEM, Path Analysis, or Multiple Regression Models. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, *9*(5), 1634–1642. https://pdfs.semanticscholar.org/50a9/a4a1cf87575bbb83b43419102d09fc89f942.pdf

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal in Embedded Figure Test? *Journal of Child Psychology and Psychiatry*, *38*(5), 527–534. https://doi.org/10.1111/j.1469-7610.1997.tb01539.x

Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science*, *12*(6), 1083–1096. https://doi.org/10.1111/j.1467-7687.2009.00855.x

Kaland, N., Mortensen, E. L., & Smith, L. (2007). Disembedding performance in children and adolescents with Asperger syndrome or high-functioning autism. *Autism*, *11*(1), 81–92. https://doi.org/10.1177/1362361307070988

Kaldy, Z., Giserman, I., Carter, A. S., & Blaser, E. (2016). The mechanisms underlying the ASD advantage in visual search. *Journal of Autism and Developmental Disorders*, *46*(5), 1513–1527. https://doi.org/10.1007/s10803-013-1957-x

Kaldy, Z., Kraper, C., Carter, A. S., & Blaser, E. (2011). Toddles with autism spectrum disorder are more successful at visual search than typically developing toddlers. *Developmental Science*, *14*(5), 980–988. https://doi.org/10.1111/j.1467-7687.2011.01053.x.Toddlers

Kaplan-Kahn, E. A., Russo, N., & Park, A. (2021). Pathways of Perceptual Primacy: ERP Evidence for Relationships Between Autism Traits and Enhanced Perceptual Functioning. *PsyArXiv*. https://doi.org/https://doi.org/10.31234/osf.io/3wtec

Kapp, S. K., Steward, R., Crane, L., Elliott, D., Elphick, C., Pellicano, E., & Russell, G. (2019). 'People should be allowed to do what they like': Autistic adults' views and experiences of stimming. *Autism*. https://doi.org/10.1177/1362361319829628

Keehn, B., Brenner, L., Palmer, E., Lincoln, A. J., & Müller, R.-A. (2008). Functional brain organization for visual search in ASD. *Journal of the International Neuropsychological Society*, *14*(2008), 990–1003.

Keil, A., Debener, S., Gratton, G., Junghöfer, M., Kappenman, E. S., Luck, S. J., Luu, P., Miller, G. A., & Yee, C. M. (2014). Committee report: Publication guidelines and recommendations for studies using electroencephalography and magnetoencephalography. *Psychophysiology*, *51*(1), 1–21. https://doi.org/10.1111/psyp.12147

Kemner, C., van Ewijk, L., van Engeland, H., & Hooge, I. (2008). Brief report: Eye movements during visual search tasks indicate enhanced stimulus discriminability in subjects with PDD. *Journal of Autism and Developmental Disorders*, *38*(3), 553–558. https://doi.org/10.1007/s10803-007-0406-0

Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2015). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism*, *20*(4), 442–462. https://doi.org/10.1177/1362361315588200

Kersten, D., & Yuille, A. (2003). Bayesian models of object perception. *Current Opinion in Neurobiology*, *13*(2), 150–158. https://doi.org/10.1016/S0959-4388(03)00042-4

Knill, D. C., & Pouget, A. (2004). The Bayesian brain: The role of uncertainty in neural coding and computation. *Trends in Neurosciences*, *27*(12), 712–719. https://doi.org/10.1016/j.tins.2004.10.007

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *Annual Review of Psychology*, *62*, 621–647. https://doi.org/10.1146/annurev.psych.093008.131123.Thirty

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, *207*, 203–205.

Kutas, M., & Iragui, V. (1998). The N400 in a semantic categorization task across 6 decades. *Electroencephalography and Clinical Neurophysiology - Evoked Potentials*, *108*(5), 456–471. https://doi.org/10.1016/S0168-5597(98)00023-9

Lachman, R., Lachman, J. L., & Butterfield, E. C. (2015). *Cognitive Psychology and Information Processing: An Introduction*. Taylor & Francis.

Laurent, J. P., Denhières, G., Passerieux, C., Iakimova, G., & Hardy-Baylé, M. C. (2006). On understanding idiomatic language: The salience hypothesis assessed by ERPs. *Brain Research*, *1068*(1), 151–160. https://doi.org/10.1016/j.brainres.2005.10.076

Lee, P. S., Foss-Feig, J., Henderson, J. G., Kenworthy, L. E., Gilotty, L., Gaillard, W. D., & Vaidya, C. J. (2007). Atypical neural substrates of Embedded Figures Task performance in

children with Autism Spectrum Disorder. *Neuroimage*, *38*, 184–193. https://doi.org/10.1016/j.neuroimage.2007.07.013

Lindsay, P. H., & Norman, D. A. (2013). *Human Information Processing: An Introduction to Psychology* (2nd ed.). Elsevier Science.

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, *8*(April), 213. https://doi.org/10.3389/fnhum.2014.00213

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism Diagnostic Observation Schedule, Second Edition (ADOS-2)*. Western Psychological Services. https://doi.org/10.1007/BF02211841.

Lowe, M. X., Stevenson, R. A., Barense, M. D., Cant, J. S., & Ferber, S. (2018). Relating the perception of visual ensemble statistics to individual levels of autistic traits. *Attention, Perception, and Psychophysics*, *80*(7), 1667–1674. https://doi.org/10.3758/s13414-018-1580-1

Luck, S. J. (2014). *An Introduction to the Event-Related Potential Technique*. The MIT Press.

Luck, S. J., & Gaspelin, N. (2017). How to get statistically significant effects in any ERP experiment (and why you shouldn't). *Psychophysiology*, *54*(1), 146–157. https://doi.org/10.1111/psyp.12639

Luck, S. J., & Kappenman, E. S. (2012). ERP Components and Selective Attention. In *The Oxford Handbook of Event-Related Potential Components* (pp. 295–327).

MacKinnon, D. P. (2008). *Introduction to Statistical Mediation Analysis. Multivariate Applications Series.* Erlbaum.

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Multivariate Behavioral

Constrained and Unconstrained Multivariate Normal Finite Mixture Modeling of Piagetian Data. *Multivariate Behavioral Research*, *39*(1), 99–128. https://doi.org/10.1207/s15327906mbr3901_4

Maenner, M. J., Shaw, K. A., Baio, J., Washington, A., Patrick, M., DiRienzo, M., Christensen, D. L., Wiggins, L. D., Pettygrove, S., Andrews, J. G., Lopez, M., Hudson, A., Baroud, T., Schwenk, Y., & White, T. (2020). Prevalence of autism spectrum disorder among children aged 8 Years - Autism and developmental disabilities monitoring network, 11 Sites, United States, 2016. *MMWR Surveillance Summaries*, *69*(4). https://doi.org/10.15585/mmwr.ss6706a1

Majumdar, S. (2019). *Stories from the Spectrum: Sumita Majumdar*. National Autistic Society.

Manfredi, M., Cohn, N., Sanchez Mello, P., Fernandez, E., & Boggio, P. S. (2020). Visual and Verbal Narrative Comprehension in Children and Adolescents with Autism Spectrum Disorders: An ERP Study. *Journal of Autism and Developmental Disorders*, *50*(8), 2658–2672. https://doi.org/10.1007/s10803-020-04374-x

Manjaly, Z. M., Bruning, N., Neufang, S., Stephan, K. E., Brieber, S., Marshall, J. C., Kamp-Becker, I., Remschmidt, H., Herpertz-Dahlmann, B., Konrad, K., & Fink, G. R. (2007). Neurophysiological correlates of relatively enhanced local visual search in autistic adolescents. *Neuroimage*, *35*, 283–291. https://doi.org/10.1016/j.neuroimage.2006.11.036

Marr, D. (1982). *Vision: A Computational Approach* (F. and Co. (ed.)).

Matson, J. L., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders*, *5*(1), 418–425. https://doi.org/10.1016/j.rasd.2010.06.004

Maye, J., Werker, J. F., & Gerken, L. A. (2002). Infant sensitivity to distributional information

can affect phonetic discrimination. *Cognition*, *82*(3), 101–111. https://doi.org/10.1016/S0010-0277(01)00157-3

McCleery, J. P., Ceponiene, R., Burner, K. M., Townsend, J., Kinnear, M., & Schreibman, L. (2010). Neural correlates of verbal and nonverbal semantic integration in children with autism spectrum disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *51*(3), 277–286. https://doi.org/10.1111/j.1469-7610.2009.02157.x

Morgan, B., Maybery, M., & Durkin, K. (2003). Weak Central Coherence, Poor Joint Attention, and Low Verbal Ability: Independent Deficits in Early Autism. *Developmental Psychology*, *39*(4), 646–656. https://doi.org/10.1037/0012-1649.39.4.646

Mosteller, F., & Tukey, J. W. (1977). *Data analysis and regression: A second course in statistics*. Addison-Wesley.

Mottron, L. (2019). Detrimental Sensitivity'' framework misses the positive performance, role and autonomy of autistic perception. *Cognitive Neuroscience*, *10*(3), 168–169. https://doi.org/10.1080/17588928.2019.1596073

Mottron, L., Bouvet, L., Bonnel, A., Samson, F., Burack, J. A., Dawson, M., & Heaton, P. (2013). Veridical mapping in the development of exceptional autistic abilities. *Neuroscience and Biobehavioral Reviews*, *37*(2), 209–228. https://doi.org/10.1016/j.neubiorev.2012.11.016

Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In *The Development of Autism: Perspectives from Theory and Research* (pp. 131–148). Lawrence Erlbaum Associates.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism:

Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*(6), 904–913. https://doi.org/10.1111/1469-7610.00174

Mottron, L., Dawson, M., & Soulières, I. (2009). Enhanced perception in savant syndrome: Patterns, structure and creativity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1522), 1385–1391. https://doi.org/10.1098/rstb.2008.0333

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, *36*(1), 27–43. https://doi.org/10.1007/s10803-005-0040-7

Mottron, L., Peretz, I., Belleville, S., & Rouleau, N. (1999). Absolute pitch in autism: A case study. *Neurocase*, *5*(6), 485–501. https://doi.org/10.1080/13554799908402744

Muris, P., Steerneman, P., Merckelbach, H., Holdrinet, I., & Meesters, C. (1998). Comorbid anxiety symptoms in children with pervasive developmental disorders. *Journal of Anxiety Disorders*, *12*(4), 387–393. https://doi.org/10.1016/S0887-6185(98)00022-X

Muth, A., Hönekopp, J., & Falter, C. M. (2014). Visuo-Spatial Performance in Autism: A Meta-analysis. *Journal of Autism and Developmental Disorders*, *44*(12), 3245–3263. https://doi.org/10.1007/s10803-014-2188-5

Muskat, B., Burnham Riosa, P., Nicholas, D. B., Roberts, W., Stoddart, K. P., & Zwaigenbaum, L. (2015). Autism comes to the hospital: The experiences of patients with autism spectrum disorder, their parents and health-care providers at two Canadian paediatric hospitals. *Autism*, *19*(4), 482-490.

Muthén, L. K., & Muthén, B. O. (2017). *Mplus User's Guide* (Sixth Edition). Muthén & Muthén.

Nader, A. M., Courchesne, V., Dawson, M., & Soulières, I. (2016). Does WISC-IV Underestimate

the Intelligence of Autistic Children? *Journal of Autism and Developmental Disorders*, *46*(5), 1582–1589. https://doi.org/10.1007/s10803-014-2270-z

Nakano, T., Kato, N., & Kitazawa, S. (2012). Superior haptic-to-visual shape matching in autism spectrum disorders. *Neuropsychologia*, *50*(5), 696–703. https://doi.org/10.1016/j.neuropsychologia.2011.12.024

Newschaffer, C. J. (2005). National Autism Prevalence Trends From United States Special Education Data. *Pediatrics*, *115*(3), e277–e282. https://doi.org/10.1542/peds.2004-1958

Nicolaidis, C., Raymaker, D. M., Ashkenazy, E., McDonald, K. E., Dern, S., Baggs, A. E., ... & Boisclair, W. C. (2015). "Respect the way I need to communicate with you": Healthcare experiences of adults on the autism spectrum. *Autism*, *19*(7), 824-831.

Niedeggen, M., Rösler, F., & Jost, K. (1999). Processing of incongruous mental calculation problems: Evidence for an arithmetic N400 effect. *Psychophysiology*, *36*, 307–324. https://doi.org/10.1017/S0048577299980149

O'Riordan, M. A. (2004). Superior visual search in adults with autism. *Autism*, *8*(3), 229–248. https://doi.org/10.1177/1362361304045219

O'Riordan, M. A., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders*, *36*(5), 665–675. https://doi.org/10.1007/s10803-006-0106-1

O'Riordan, M. A., & Plaisted, K. (2001). Enhanced discrimination in autism. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *54*(4), 961–979. https://doi.org/10.1080/713756000

O'Rourke, E., & Coderre, E. L. (2021). Implicit Semantic Processing of Linguistic and Non-linguistic Stimuli in Adults with Autism Spectrum Disorder. *Journal of Autism and*

Developmental Disorders. https://doi.org/10.1007/s10803-020-04736-5

Pellicano, E., & Burr, D. (2012). When the world becomes "too real": A Bayesian explanation of autistic perception. *Trends in Cognitive Sciences*, *16*(10), 504–510. https://doi.org/10.1016/j.tics.2012.08.009

Pellicano, E., Gibson, L., Maybery, M., Durkin, K., & Badcock, D. R. (2005). Abnormal global processing along the dorsal visual pathway in autism: A possible mechanism for weak visuospatial coherence? *Neuropsychologia*, *43*(7), 1044–1053. https://doi.org/10.1016/j.neuropsychologia.2004.10.003

Pellicano, E., Murray, M., Durkin, K., & Maley, A. (2006). Multiple cognitive capabilities/deficits in children with an autism spectrum disorder: "Weak" central coherence and its relationship to theory of mind and executive control. *Development and Psychopathology*, *18*(1), 77–98. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed7&NEWS=N&AN=2006117767

Pfeiffer B., Erb S., & Slugg, L. (2019) Impact of Noise Attenuating Headphones on Participation in the Home, Community, and School for Children with Autism Spectrum Disorder, Physical & Occupational Therapy in Pediatrics, 39:1, 60-76, DOI: 10.1080/01942638.2018.1496963

Pijnacker, J., Geurts, B., van Lambalgen, M., Buitelaar, J., & Hagoort, P. (2010). Exceptions and anomalies: An ERP study on context sensitivity in autism. *Neuropsychologia*, *48*(10), 2940–2951. https://doi.org/10.1016/j.neuropsychologia.2010.06.003

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism: A research note enhanced visual search for a conjunctive target in autism. *Journal of Child Psychology and Psychiatry*, *39*(5), 777–783.

Pring, L., Woolf, K., & Tadic, V. (2008). Melody and pitch processing in five musical savants

with congenital blindness. *Perception*, *37*(2), 290–307. https://doi.org/10.1068/p5718

R Development Core Team. (2019). *R: A language and environment for statistical computing* (ISBN 3-900051-07-0). R Foundation for Statistical Computing. http://www.r-project.org

Ring, H. A., Baron-Cohen, S., Wheelwright, S., Williams, S. C. R., Brammer, M., Andrew, C., & Bullmore, E. T. (1999). Cerebral correlates of preserved cognitive skills in autism. *Brain*, *122*(7), 1305–1315. https://doi.org/10.1093/brain/122.7.1305

Ropar, D., & Mitchell, P. (2001). Susceptibility to illusions and performance on visuospatial tasks in individuals with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(4), 539–549. https://doi.org/10.1017/S002196300100717X

Ruscio, J. (2008). Constructing confidence intervals for Spearman's rank correlation with ordinal data: A simulation study comparing analytic and bootstrap methods. *Journal of Modern Applied Statistical Methods*, *7*(2), 416–434. https://doi.org/10.22237/jmasm/1225512360

Russell, G., Mandy, W., Elliott, D., White, R., Pittwood, T., & Ford, T. (2019). Selection bias on intellectual ability in autism research: A cross-sectional review and meta-analysis. *Molecular Autism*, *10*(1), 1–10. https://doi.org/10.1186/s13229-019-0260-x

Russo, N., Kaplan-Kahn, E. A., Wilson, J., Criss, A., & Burack, J. A. (2021). Choices, challenges, and constraints: a pragmatic examination of the limits of mental age matching in empirical research. *Developmental Psychopathology*, *33*, 727–738. https://doi.org/10.1017/S0954579420001480

Russo, N., Mottron, L., Burack, J. A., & Jemel, B. (2012). Parameters of semantic multisensory integration depend on timing and modality order among people on the autism spectrum: Evidence from event-related potentials. *Neuropsychologia*, *50*(9), 2131–2141. https://doi.org/10.1016/j.neuropsychologia.2012.05.003

Rusticus, S. A., & Lovato, C. Y. (2014). Impact of sample size and variability on the power and type I error rates of equivalence tests: A simulation study. *Practical Assessment, Research and Evaluation, 19*(11), 1–10.

Ruthsatz, J., & Urbach, J. B. (2012). Child prodigy: A novel cognitive profile places elevated general intelligence, exceptional working memory and attention to detail at the root of prodigiousness. *Intelligence, 40*(5), 419–426. https://doi.org/10.1016/j.intell.2012.06.002

Rutter, M., LeCouteur, A., & Lord, C. (2003). *Autism Diagnostic Interview, Revised (ADI-R)*. Western Psychological Services.

Ruxton, G. D. (2006). The unequal variance t-test is an underused alternative to Student's t-test and the Mann-Whitney U test. *Behavioral Ecology, 17*(4), 688–690. https://doi.org/10.1093/beheco/ark016

Sahyoun, C. P., Belliveau, J. W., Soulières, I., Schwartz, S., & Mody, M. (2010). Neuroimaging of the functional and structural networks underlying visuospatial vs. linguistic reasoning in high-functioning autism. *Neuropsychologia, 48*(1), 86–95. https://doi.org/10.1016/j.neuropsychologia.2009.08.013

Samson, F., Mottron, L., Soulières, I., & Zeffiro, T. A. (2012). Enhanced visual functioning in autism: An ALE meta-analysis. *Human Brain Mapping, 33*(7), 1553–1581. https://doi.org/10.1002/hbm.21307

Sarrett, J. C. (2018). Autism and accommodations in higher education: Insights from the autism community. *Journal of Autism and Developmental Disorders, 48*(3), 679-693.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24*(4), 613–620.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block

design task copy. *Journal of Child Neurology*, *34*(8), 1351–1364.

Shephard, E., Bedford, R., Milosavljevic, B., Gliga, T., Jones, E. J. H., Pickles, A., Johnson, M. H., & Charman, T. (2018). Early developmental pathways to childhood symptoms of attention-deficit hyperactivity disorder, anxiety and autism spectrum disorder. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *9*, 963–974. https://doi.org/10.1111/jcpp.12947

Shibata, H., Gyoba, J., & Suzuki, Y. (2009). Event-related potentials during the evaluation of the appropriateness of cooperative actions. *Neuroscience Letters*, *452*(2), 189–193. https://doi.org/10.1016/j.neulet.2009.01.042

Shirama, A., Kato, N., & Kashino, M. (2017). When do individuals with autism spectrum disorder show superiority in visual search? *Autism*, *21*(8), 942–951. https://doi.org/10.1177/1362361316656943

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Research*, *49*(22), 2705–2739. https://doi.org/10.1016/j.visres.2009.08.005

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity, and associated factors in a population-derived sample. *Journal of the American Academy of Child and Adolescent Psychiatry*, *47*(8), 921–929. https://doi.org/10.1097/CHI.0b013e318179964f

Smith, H., & Milne, E. (2009). Reduced change blindness suggests enhanced attention to detail in individuals with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *50*(3), 300–306. https://doi.org/10.1111/j.1469-7610.2008.01957.x

Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences*, *7*(8), 343–348. https://doi.org/10.1016/S1364-6613(03)00156-6

Sobel, M. E. (1982). Asymptotic Confidence Intervals for Indirect Effects in Structural Equation Models. *Sociological Methodology*, *13*(1982), 290–312. https://doi.org/10.2307/270723

Soulières, I., Dawson, M., Samson, F., Barbeau, E. B., Sahyoun, C. P., Strangman, G. E., Zeffiro, T. A., & Mottron, L. (2009). Enhanced visual processing contributes to matrix reasoning in autism. *Human Brain Mapping*, *30*(12), 4082–4107. https://doi.org/10.1002/hbm.20831

Spencer, J. P., Perone, S., & Buss, A. T. (2011). Twenty years and going strong: A dynamic systems revolution in motor and cognitive development. *Child Development Perspectives*, *5*(4), 260–266. https://doi.org/10.1111/j.1750-8606.2011.00194.x.Twenty

Stanutz, S., Wapnick, J., & Burack, J. A. (2014). Pitch discrimination and melodic memory in children with autism spectrum disorders. *Autism*, *18*(2), 137–147. https://doi.org/10.1177/1362361312462905

Stevenson, R. A., Toulmin, J. K., Youm, A., Besney, R. M. A., Schulz, S. E., Barense, M. D., & Ferber, S. (2017). Increases in the autistic trait of attention to detail are associated with decreased multisensory temporal adaptation. *Scientific Reports*, *7*(1), 1–10. https://doi.org/10.1038/s41598-017-14632-1

Strandburg, R. J., Marsh, J. T., Brown, W. S., Asarnow, R. F., Guthrie, D., & Higa, J. (1993). Event-related potentials in high-functioning adult autistics: Linguistic and nonlinguistic visual information processing tasks. *Neuropsychologia*, *31*(5), 413–434. https://doi.org/10.1016/0028-3932(93)90058-8

Thomas, B. J., Riley, M. A., & Wagman, J. B. (2019). Information and Its Detection: The

Consequences of Gibson's Theory of Information Pickup. In J. A. Wagman & J. J. C. Blau (Eds.), *Perception as Information Detection: Reflections on Gibson's Ecological Approach to Visual Perception* (pp. 237–252). Routledge.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*, 97–136. https://doi.org/10.1097/00075198-199608000-00002

van Boxtel, J. J. A., & Lu, H. (2013). A predictive coding perspective on autism spectrum disorders. *Frontiers in Psychology*, *4*(JAN), 1–3. https://doi.org/10.3389/fpsyg.2013.00019

van de Cruys, S., Evers, K., van der Hallen, R., van Eylen, L., Boets, B., de-Wit, L., & Wagemans, J. (2014). Precise minds in uncertain worlds: Predictive coding in autism. *Psychological Review*, *121*(4), 649–675. https://doi.org/10.1037/a0037665

Van Lang, N. D. J., Bouma, A., Sytema, S., Kraijer, D. W., & Minderaa, R. B. (2006). A comparison of central coherence skills between adolescents with an intellectual disability with and without comorbid autism spectrum disorder. *Research in Developmental Disabilities*, *27*(2), 217–226. https://doi.org/10.1016/j.ridd.2004.12.005

VanVoorhis, C. R. W., & Morgan, B. L. (2007). Understanding Power and Rules of Thumb for Determining Sample Sizes. *Tutorials in Quantitative Methods for Psychology*, *3*(2), 43–50. https://doi.org/10.1007/BF00510634

Verbaten, M. N., Roelofs, J. W., van Engeland, H., Kenemans, J. ., & Slangen, J. . (1991). Abnormal visual event-related potentials of autistic children. *Journal of Autism and Developmental Disorders*, *21*(4), 449–470.

Votruba, K. L., & Langenecker, S. A. (2013). Factor structure, construct validity, and age- and education-based normative data for the Parametric Go/No-Go Test. *Journal of Clinical and Experimental Neuropsychology*, *35*(2), 132–146.

https://doi.org/10.1080/13803395.2012.758239

Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II)*. NCS Pearson. https://doi.org/10.1177/073428912467756

Witkin, H. A., Ottman, R. K., Raskin, E., & Karp, S. A. (1971). *A manual for the embedded figures test*. Consulting Psychologists Press.

Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening adults for Asperger Syndrome using the AQ: a preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders*, *35*(3), 331–335. https://doi.org/10.1007/s10803-005-3300-7

Yaguchi, A., & Hidaka, S. (2020). Unique Relationships Between Autistic Traits and Visual, Auditory, and Tactile Sensory Thresholds in Typically Developing Adults. *Perception*, *49*(4), 405–421. https://doi.org/10.1177/0301006620907827

ELIZABETH A. KAPLAN-KAHN

kaplankahe@chop.edu 267-261-9889

EDUCATION

Doctoral Candidate, School Psychology (GPA 3.99) Aug. 2016 – Present
Syracuse University, Syracuse, NY (APA, CAEP accredited, NASP approved)
Advisor: Natalie Russo, Ph.D., Licensed Psychologist
Dissertation: *Different Pathways to Cognition: An ERP Investigation of Enhanced Perceptual Functioning and Autism in School-Aged Children*

Predoctoral Internship June 2020 – Present
Children's Hospital of Philadelphia (APA accredited)
Department of Child and Adolescent Psychiatry and Behavioral Sciences
Autism Spectrum Disorders Track

M.S., Psychology (GPA 3.98) Aug. 2016 – Dec. 2018
Syracuse University, Syracuse, NY (APA, CAEP accredited, NASP approved)
Advisor: Natalie Russo, Ph.D., Licensed Psychologist
Thesis: *This is a Question? Prosody, Social Communication, and the N400 Effect*

B.A. with Honors, Cognitive Science (GPA 3.83) Aug. 2010 – Dec. 2013
Johns Hopkins University, Baltimore, MD
Minors: Psychology and Jewish Studies

SCHOLARSHIPS AND AWARDS

Research Excellence Doctoral Fellowship ($19,000)	2019 – 2020
Syracuse University Interdisciplinary Neuroscience Program Travel Award ($500)	2018
Syracuse University Psychology Department Travel Award ($500)	2017 – 2019
Syracuse University Graduate Student Organization Travel Award ($500)	2017 – 2019
Johns Hopkins University Dean's List	2010 – 2013
Carrie K. and Walter H. Church Scholarship	2012 – 2014
Seidman Family Scholarship	2012 – 2014
Harvard University Summer Internship ($1,800)	2013

RESEARCH EXPERIENCE

Center for Autism Research at the Children's Hospital of Philadelphia Aug. 2020 – Present
Predoctoral Researcher through the Leadership Education in Neurodevelopmental and Related Disorders Program
PI: John Herrington, Ph.D. and Benjamin Yerys, Ph.D.

Syracuse University Center for Autism Research and Electrophysiology Aug. 2016 – Present
Graduate Researcher
PI: Natalie Russo, Ph.D., Licensed Psychologist

University of California, Berkeley Language and Cognitive Development Lab Jul. 2015 – Jul. 2016
Researcher and Lab Manager
PI: Mahesh Srinivasan, Ph.D.

Harvard University Lab for Developmental Studies Jun. 2013 – Aug. 2013 -and- Apr. 2014 – Jul. 2015
Summer Research Intern, Researcher and Lab Manager
PI: Jesse Snedeker, Ph.D.

Johns Hopkins Lab for Child Development Dec. 2011 – Mar. 2014
Research Assistant at the Maryland Science Center
PI: Lisa Feigenson, Ph.D.; Mentor: Melissa Kibbe, Ph.D.

The Kennedy Krieger Institute at Johns Hopkins Hospital Jan. 2011 – Dec. 2011
Research Trainee at Center for Genetic Disorders of Cognition and Behavior
PI: Walter Kaufmann, Ph.D.

CLINICAL EXPERIENCE

Syracuse City School District – Ed Smith K-8 Elementary School Sept. 2019 – March 2020
School Psychology Practicum
Supervisors: Lawrence Lewandowski, Ph.D., Licensed Psychologist; Kim Kosakowski, M.S., Licensed School Psychologist

Syracuse University Psychological Services Center May 2018 – April 2020
Student Clinician
Supervisors: Afton Kapuscinski, Ph.D., Licensed Psychologist; Keven Antshel, Ph.D., Licensed Psychologist; Joseph Himmelsbach, Ph.D., Licensed Psychologist; Amy Cambareri, Licensed Psychologist

Upstate Medical University, Department of Pediatrics Sept. 2017 – May 2018
Patient Care Specialist at the Family Behavior Analysis Program
Supervisors: Henry Roane, Ph.D.; Nicole DeRosa, Psy.D., BCBA-D, Licensed Psychologist; William Sullivan, Ph.D.

Upstate Medical University, Department of Pediatrics Sept. 2017 – April 2018
Parent Skills Training Group Leader
Supervisors: Keven Antshel, Ph.D., Henry Roane, Ph.D.

Elmcrest Children's Center Sept. 2017 – Dec. 2017
School Based Mental Health Practicum
Supervisors: Joshua Felver, Ph.D., Licensed Psychologist; Leah Phaneauf, Ph.D., Licensed Psychologist

Syracuse University, Department of Psychology Sept. 2016 – March 2020
Social Skills Group Leader
Supervisor: Kevin Antshel, Ph.D., Licensed Psychologist

TEACHING EXPERIENCE

Syracuse Professional Development Seminar Sept. 2020
Invited Talk: *Surviving the APPIC Application Process*

Syracuse University Neuroscience Research Day April 2020
Invited Talk: *Different Pathways to Cognition: Preliminary ERP Evidence for the Enhanced Perceptual Functioning Model of Autism*

Syracuse University, Department of Psychology June 2019
Invited Talk: *What We Can Learn from Atypical Development: Autism Spectrum Disorder*

Syracuse University, Department of Psychology Aug. 2016 – May 2017
Teaching Assistant for Foundations of Human Behavior (PSY 205)
Supervisor: Shannon Houck, Ph.D.

Syracuse University Center for Autism Research and Electrophysiology Nov. 2016 – Present
Graduate Mentor for Undergraduate Research Assistants
PI: Natalie Russo, Ph.D., Licensed Psychologist

PUBLICATIONS

Manuscripts in advanced preparation

Kaplan-Kahn, E. A., Russo, N., Shea, N., Prawl, A., Hagman, C.E., Kates, W., & Wyble, B. (in prep). Detecting Color Targets in Autism Using RSVP: Brain, Behavior, and Autism Symptom Correlates.

Russo, N., **Kaplan-Kahn, E. A.,** Hagmann, C., Kates, W., & Wyble, B. (in prep). Encoding Latency Advantages do not Translate into Higher Accuracy: Evidence from Single and Dual Target RSVP Tasks and Electrophysiology.

Helminen, E. C., **Kaplan-Kahn, E. A.,** Prussien, K.V., Felver, J. C., & Russo, N. (in prep.). A Scoping Review of Transition Readiness in Adolescents with Sickle Cell Disease: The Potential for School Psychologists to Fill Service Gaps.

Manuscripts published and under review

Kaplan-Kahn, E. A., Russo, N. & Iarocci, G. (submittted). Validating Three Common Self-Report Measures of Social Functioning: Implications for Autism Research.

Russo, N., **Kaplan-Kahn, E. A.**, Lane, K., Enns, J., & Burack, J. A. (under review). Attentional Filtering and Cognitive Load among Children with Fetal Alcohol Spectrum Disorder.

Kaplan, Z., **Kaplan-Kahn E. A.** (under review). Free Lunch and the Magic School Bus: North Carolina's Charter School Policy and Segregation.

Kaplan-Kahn, E. A., Russo, N., & Kellen, D. (under review). This is a Question? Prosody and the N400 Effect.

Cary, E., Pacheco, D., **Kaplan-Kahn, E. A.**, McKernan, E., Prieve, B., & Russo, N. (under review). Timing is Everything: Early and Late Neural Measures of Auditory Habituation and Discrimination in Autism and Their Relationship to Autistic Traits and Sensory Overresponsivity, *Research Square,* https://doi.org/10.21203/rs.3.rs-547935/v1

Kaplan-Kahn, E. A., Russo, N. & Park, A. (2021). Pathways of Perceptual Primacy: ERP Evidence for Relationships with Autism Traits and Enhanced Perceptual Functioning. *PsyArXiv,* https://doi.org/10.31234/osf.io/3wtec

Kaplan-Kahn, E. A., Kopec, J., McKernan, E. P. & Russo, N. (in press). Attention in Individuals with Down Syndrome. In J. Burack, J. Edgin, L. Abbeduto, & J. Busciglio (Eds.), *Oxford Handbook of Down Syndrome and Development*. New York: Oxford University Press.

Taylor, L. E., **Kaplan-Kahn, E. A**., Lighthall, R. A., & Antshel, K. M. (2021). Adult-Emergence ADHD: A New Perspective from a Systematic Review. *Child Psychiatry and Human Development,* https://doi.org/10.1007/s10578-021-01159-w

Russo, N., **Kaplan-Kahn, E. A.**, Wilson, J., Criss, A., & Burack, J.A. (2021). Choices, Challenges, and Constraints: A Pragmatic Examination of the Limits of Mental Age Matching in Empirical Research. *Developmental Psychopathology, Special Issue, 33*(2), 727-738. https://doi.org/10.1017/S0954579420001480

Srinivasan, M., **Kaplan, E. A.**, Dahl, A. (2019). Reasoning about the Scope of Religious Norms: Evidence from Hindu and Muslim Children in India. *Cognitive Development. 90*(6), e783-e802. https://doi.org/10.1111/cdev.13102

Kaplan, E., Levari, T., & Snedeker, J. (2016). Eye tracking and spoken language comprehension. In C. A. Was, F. J. Sansosti, & B. J. Morris (Eds.), *Eye-tracking technology applications in educational research,* (88-105). Hershey, PA: IGI Global, http://doi.org/10.4018/978-1-5225-1005-5.ch005

Gross, S., Chaisilprungraung, T., **Kaplan, E.**, Menendez, J., & Flombaum, J. (2014). Problems for the Purported Cognitive Penetration of Perceptual Color Experience and Macpherson's Proposed Mechanism." In Edouard Machery, Jesse Prinz, and Jurgis Skilters (Eds.), *Perception and Concepts* (BalticInternational Yearbook of Cognition, Logic, and Communication, Vol. 9), New Prairie Press, https://doi.org/10.4148/1944-3676.1085

POSTER PRESENTATIONS

* denotes undergraduate mentee

Kaplan-Kahn, E. A., Yerys, B., Pandey, J., Schultz, R., & Herrington, J. (2021). *The Neurobiology of Face Processing in ASD: Evidence from a Combined fMRI and Eye-Tracking Study*. Poster accepted for the International Society for Autism Research 2021 Annual Meeting, Boston, Massachusetts

Cary, E. L., **Kaplan-Kahn, E. A.**, Masters, E., Matsuba, E., MacKenzie, C., Rodrigues, A., Prieve, B., Pacheco, D., Madrid, A., & Russo, N. (2021). *Relating ASD Traits and Sensory Overresponsivity to Early Electrophysiological Indices of Auditory Processing in Children with and without ASD*. Poster accepted for the International Society for Autism Research, Boston, Massachusetts.

Masters, E. C., McKernan, E., Kopec, J., **Kaplan-Kahn, E. A.**, Cary, E., Matsuba, E., Rodrigues, A., MacKenzie, C., & Russo, N. (2021). The Impact of ADHD Symptoms and Age on Sensory Features in Autism. International Society for Autism Research 2021 Annual Meeting, Boston, MA

Cary, E., **Kaplan, E. A.**, Russo, N., Masters, E. & Matsuba, E. (2020). *Mindfulness and the MMN*. International Society for Autism Research 2020 Annual Meeting, Seattle, Washington – Cancelled due to COVID-19 Pandemic.

Kaplan, E. A., Cary, E., Masters, E., Matsuba, E. & Russo, N. (2020). *Pathways of Perceptual Primacy: ERP Evidence for Relationships between Autism Traits and Enhanced Perceptual Functioning.* International Society for Autism Research 2020 Annual Meeting, Seattle, Washington – Cancelled due to COVID-19 Pandemic.

Kaplan, E. A., Russo, N. & Kellen, D. (2019). *This is a Question? Prosody, Social Communication, and the N400 Effect.* Central New York Psychological Association Spring 2019 Meeting, Syracuse, NY.

McKernan, E. P., Kopec, J., **Kaplan, E. A**., Koelmel, E. L., Masters, E. C. & Russo, N. (2019). *Individuals with higher levels of autistic traits are less susceptible to social conformity on a perceptual decision-making task.* International Society for Autism Research 2019 Annual Meeting, Montreal, Canada.

Bryant, E.M.*, Mercan, N. E.*, **Kaplan, E. A.**, & Russo, N. (2018). *Is Socialization Standardized? A Correlational Analysis of Three Social Functioning Scales*. Syracuse University Department of Psychology Department Annual Undergraduate Poster Session, Syracuse, NY.

Kaplan, E. A., Russo, N., Kopec, J., McKernan, E. P., Koelmel, E. L., & Prawl, A. M. (2018). *EEG Correlates of the Attentional Blink: Relationship to Autism Symptoms.* International Society for Autism Research 2018 Annual Meeting, Rotterdam, Netherlands.

Kopec, J., Russo, N., McKernan, E. P., **Kaplan, E. A.**, Koelmel, E. L., & Prawl, A. M. (2018). *Children and Adults with Autism Detect Rapidly Presented Temporal Information More Accurately than Typically Developing Individuals.* International Society for Autism Research 2018 Annual Meeting, Rotterdam, Netherlands.

McKernan, E. P., Russo, N., Kopec, J., **Kaplan, E. A.**, Koelmel, E. L., & Prawl, A. M. (2018). *The Relationship of Sensory Overresponsivity to Amplitude Discrimination.* International Society for Autism Research 2018 Annual Meeting, Rotterdam, Netherlands.

Salvati, J.*, Velázquez López, S.*, **Kaplan, E. A**., Columna, L., & Russo, N. (2017). *Physical Activity Interventions and the Implications for Adaptive Behavior in Children with Autism*. Syracuse University Department of Psychology Department Annual Undergraduate Poster Session, Syracuse, NY.

McKernan, E. P., Russo, N., Burnette, C., **Kaplan, E. A.,** Kopec, J., Shea, N., & Kates, W. R. (2017). *ASD Concordance of Twins Across DSM-IV-TR and DSM-5 Diagnostic Criteria.* International Meeting for Autism Research, San Fransisco, CA.

Shea, N., Payne, E., McKernan, E. P., Kopec, J., **Kaplan, E. A.,** Antshel, K., Kates, W. R., & Russo, N. (2017). *The Relationship Between Socialization and Externalizing Problems in ASD and VCFS*. International Meeting for Autism Research, San Fransisco, CA.

Perry, P.*, **Kaplan, E. A.**, & Srinivasan, M. (2016) *One Word, Two Different Meanings: How do Preschoolers Understand Ambiguous Language?* U.C. Berkeley Department of Psychology Undergraduate Poster Session, Berkeley, CA.

Srinivasan, M., Mughairy, S., **Kaplan E.**, & Dahl, A. (2015). *Preschoolers' reactions to novel moral and conventional norm violations.* 9th Biennial Meeting of the Cognitive Development Society, Columbus, OH.

Silver, S.*, Varhol, A.*, **Kaplan, E.,** & Snedeker, J. (2013). *Prosody and Pragmatics in Children with Autism.* Harvard Psychology Department Undergraduate Conference, Cambridge, MA.

Kaplan, E., Snedeker, J., Lee, E. K., Brookhyser, T. (2013). *Prosodic and Pragmatic Training in Highly Verbal Children with Autism.* Harvard Psychology Department Undergraduate Conference, Cambridge, MA.

PROFESSIONAL DEVELOPMENT

Decolonizing Psychology Training Virtual Conference 2021
Teachers College, Columbia University

Leadership Education in Neurodevelopmental and Related Disorders (LEND) Program 2020 – 2021
Children's Hospital of Philadelphia

Autism Diagnostic Observation Schedule (ADOS-2) Advanced Research Training 2019
Weill Cornell Medical College, Department of Psychiatry, White Plains, NY

Women in Science and Engineering Future Professionals Program 2018 – 2020
Syracuse University

Trauma-Focused Cognitive Behavioral Therapy Online Training 2018
11 continuing education contact hours through The Medical University of South Carolina

Safer People, Safer Spaces Training 2018, 2019
Syracuse University, LGBT Resource Center

Future Professoriate Program 2017 – 2020
Syracuse University, Department of Psychology, Syracuse, NY

Autism Diagnostic Observation Schedule (ADOS-2) Clinical Training 2017
Weill Cornell Medical College, Department of Psychiatry, White Plains, NY

Women in Science and Engineering Writing Workshop 2017, 2019
Syracuse University, Syracuse, NY

GRANT APPLICATIONS

Autism Speaks – Postdoctoral Fellowship – Submitted March 2021 2021
Grant title: *Integrating Quality of Life Goals into Healthcare: A Community-Partnered Research Approach*

National Association of School Psychologists – Graduate Student Research Grant – funded, $1,000 2019
Grant title: *Enhanced Perceptual Functioning in Children on the Autism Spectrum – An ERP Investigation*

National Institutes of Health – Ruth L. Kirschstein Predoctoral Individual NRSA – unfunded 2018
Grant title: *Expectations and Emphasis: Understanding the Roles of Semantic and Prosodic Processing in Social Communication and Implications for Adolescents with Autism Spectrum Disorder*

PROFESSIONAL SERVICE

Department Service

Psychology Action Committee Co-President 2019 – 2020
Psychology Graduate Committee for Diversity and Inclusion 2019 – 2020

Diversifying Psychology Weekend Graduate Student Liaison	2018 – 2019
Syracuse University Be-Well Mental Health Expo	2018
Psychology Action Committee Events Coordinator	2016 – 2019

Program Service

School Psychology Faculty-Graduate Student Liaison	2018 – 2020
School Psychology Graduate Student Admissions Panel	2017 – 2020
School Psychology Professional Development Committee	2017 – 2018
School Psychology Communications Committee	2016 – 2017

Ad Hoc Reviewer

- *Journal of Child and Family Studies*
- *Journal of Developmental and Physical Disabilities*
- *American Journal on Intellectual and Developmental Disabilities*

MEMBERSHIPS

Society for Research in Child Development	Present
American Psychological Association, Division 53 (Society of Clinical Child and Adolescent Psychology)	Present
National Association of School Psychologists	Present
International Society for Autism Research	Present
American Psychological Association, Division 16 (School Psychology)	Present
Cognitive Development Society	2015 – 2017
National Society of Collegiate Scholars	2012 – 2014