Exploring Heterogeneous Language Abilities in Autism Spectrum Disorder: Diagnostic Markers and Comprehension

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AUTHOR DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work acknowledges opinions, ideas and contributions from the work of others, who have all been appropriately cited.

The research presented in Chapter 2 was accepted for publication in Brain Sciences, and has been collaborated on with Paul Engelhardt and Claudia Holmes. The research presented in Chapter 4 has been prepared and submitted to Brain Sciences, pending confirmation from the editor, and was also collaborated on with Paul Engelhardt. The research presented in Chapter 5 was accepted and presented as a poster presentation at the Neurodevelopmental Disorders Annual Seminar (NDAS) at Royal Holloway, London, in 2023. The research presented in Chapter 6 was accepted for publication in the Journal of Autism and Developmental Disorders, and has been collaborated on with Paul Engelhardt and Rita Cersosimo. The research in Chapter 6 was also accepted for oral presentation at the Architectures and Mechanisms for Language Processing (AMLaP) conference in Edinburgh in 2024.

To be able to use the Autism Diagnostic Observation Schedule (ADOS) in this research, the author completed a course with King’s College in July 2021, with certification for clinical reliability.

STATEMENT ON THE IMPACT OF THE COVID-19 PANDEMIC

Parts of this doctoral programme were significantly impacted by the COVID-19 pandemic. My studies began in October 2019, and the main restrictions that came of the pandemic, including national lockdowns and laboratory closures, began in early 2020 and finally fully lifted at the end of 2021. This was a critical period for my studies, and coincided with my plan for data collection. It is partially this which contributed to our plans for the research in Chapter 2, which utilised data that had already been collected. Furthermore, the pilot study for Chapter 4 and the research for Chapter 5 were conducted online as a result of the restrictions. The pandemic severely pushed back my plans for my thesis, and concessions to the research process were made as a result.

ABSTRACT

This thesis explores the breadth and importance of language abilities in individuals with a diagnosis of Autism Spectrum Disorder (ASD). The first half of this thesis sought to explore whether we can use atypical language abilities as diagnostic markers of ASD. The research in Chapter 2 aimed to test and validate the psychometric properties of the Language and Pragmatics Questionnaire (LAPQ), developed for use in children and adolescents as a screening tool for early autism symptoms pertaining to language. We concluded from this study that language abilities in early childhood are important indicators of potential autism, and that this questionnaire is a practical tool with clinical value. Chapter 3 explored whether we can use speech disfluencies as potential diagnostic markers of ASD in adults. Whilst previous research has been promising with the consistency of disfluency rates in autistic individuals, we did not find any significant group differences, suggesting that we cannot use these particular language abilities as diagnostic markers. The second half of this thesis sought to explore whether certain cognitive-level measures of atypical language comprehension can be identified in autistic adults. The research in Chapter 4 explored whether autistic individuals show atypical linguistic prediction. Our pilot study showed no significant group differences but did find some associations with autistic traits. Our main study again showed no significant group differences in terms of the accuracy of linguistic prediction, but we found autistic individuals to be significantly slower with prediction, suggesting a difficulty with the prediction process. Chapter 5 sought to find out whether autistic individuals show superior comprehension of passive implausible sentences. We found that autistic individuals actually showed lower overall levels of comprehension accuracy, despite not being as affected by the hardest sentence condition. Our research in Chapter 6 aimed to explore whether autistic individuals are atypical in their comprehension of novel metaphors utilising a Visual World Paradigm (VWP) where eye-movements were measured. Despite accurately

identifying metaphors, autistic individuals showed online processing in line with the assumptions that they process this type of stimuli in an atypical way. Finally, the thesis is concluded, offering theoretical discussions and opportunities for future research.

LIST OF ABBREVIATIONS

ADHD – Attention Deficit / Hyperactivity Disorder

ADOS – Autism Diagnostic Observation Schedule

ANCOVA – Analysis of Covariance

ANOVA – Analysis of Variance

APA – American Psychiatric Association

AQ – Autism Quotient

ARBQ – Adult Repetitive Behaviours Questionnaire

ASD – Autism Spectrum Disorder(s)

BAPQ – Broad Autism Phenotype Questionnaire

CCC – Child Communication Questionnaire

COVID – Coronavirus Disease

DSM – Diagnostic and Statistical Manual of Mental Disorders

DW – Dwell Time

EPF – Enhanced Perceptual Functioning

FPE – Female Protective Effect

IQ – Intelligence Quotient

L2 – Second Language

LAPQ – Language and Pragmatics Questionnaire

LUI – Language Use Inventory

MEG – Magnetoencephalography

MIE – Metaphor Interference Effect

NHS – National Health Service

ONS – Office for National Statistics

PIA – Predictive Impairment in Autism

PLSI – Pragmatic Language Skills Inventory

PPVT – Peabody Picture Vocabulary Test

PRS-SA – Pragmatic Rating Scale

RT – Reaction Time

SCQ – Social Communication Questionnaire

SD – Standard Deviation

SLI – Specific Language Impairment

SPCD – Social Pragmatic Communication Disorder

ToM – Theory of Mind

TOPL – Test of Pragmatic Language

VWP – Visual World Paradigm

YiPP – Yale in vivo Pragmatic Protocol

CHAPTER 1 – INTRODUCTION

Introduction to Thesis

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder which is included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association [APA], 2013). The symptomology of ASD has attracted the attention of researchers for many years, but first official descriptions of ASD were made by Kanner (1943). The main characteristics of ASD, which tend to be manifested in early developmental periods, include restricted interests, repetitive patterns of behaviour and persistent deficits in social communication and interaction across multiple contexts (APA, 2013). ASD is a spectrum condition, meaning that there is broad and substantial variation in symptom presentation between individuals. For instance, some individuals with more significant impairments may be diagnosed with severe autism, whereas others may display symptoms which are more aligned with the classification of high-functioning Autism or Asperger's syndrome. It is for this reason that ASD is regarded as a highly heterogenous disorder.

Prevalence and Diagnosis

The latest figures for the global prevalence of ASD suggest that 1 in 100 people are affected with the disorder (Zeidan et al., 2022), which is a figure much higher than previous estimates. This may be due to fewer barriers to diagnosis, broadening of diagnostic boundaries, and increased knowledge of ASD in recent decades with subsequent better identification of symptoms in healthcare settings. There have also been an increasing number of epidemiological studies from previously under-represented regions such as Africa and the Middle East (Abubakar, Ssewanyana, de Vries & Newton, 2016; al-Mamari et al., 2019). Furthermore, whereas previously (such as in the early 2000s) there had been significant disparities in prevalence among ethnic minorities living in western cultures, this number has decreased due to increasing access to diagnostic assessments for these groups (Durkin et al., 2017). It is important to consider, however, that there is still substantial variation of ASD prevalence rates between races, ethnicities and sociodemographic statuses, and there are many individuals who may have ASD, but have not had the appropriate access or support to receive a diagnosis.

ASD can be diagnosed across the life span. The earliest age that an individual can receive a diagnosis of ASD is 18-24 months, with certain sensory-motor and social behaviours being indicative of atypical development in line with ASD symptomology at this age (van't Hof et al., 2021; Tanner & Dounavi, 2021). The average age of diagnosis is approximately 5 years old, with symptoms among young children consisting of repetitive and complex mannerisms and movements, unusual eye contact and atypical use of facial expressions, among many others (Özyurt & Eliküçük, 2018). Individuals who display clinically-significant symptoms of autism at this age are more likely to have a greater extent of social difficulties and receive a diagnosis at an earlier age, and perhaps would fall towards the severe autism end of the spectrum throughout the life span (Bent, Dissanayake & Barbaro, 2015; van't Hof et al., 2020). On the other hand, individuals who have a lesser number of significant difficulties, and have a formal diagnosis of Asperger's syndrome or high-functioning autism, are more likely to be diagnosed later (Bent et al., 2015; van't Hof et al., 2021). Therefore, it is reasonable to assume that there is perhaps a negative association between ASD symptom severity and age of diagnosis. Another factor that may affect age of diagnosis includes additional diagnoses. For instance, research has provided evidence to suggest that autistic individuals with comorbid disorders, such having a diagnosis of ADHD, dyslexia or dyspraxia, are more likely to be diagnosed later than individuals without these disorders (Wei et al., 2021; Brett, Warnell, McConachie & Parr; 2016), which perhaps may be due to co-occurring symptoms that make it harder to discriminate between diagnostic boundaries. There is also evidence that sociodemographic factors effect age of diagnosis.

Some research has suggested that autistic females in general are diagnosed later than males (Darcy-Mahoney et al., 2016; Kentrou, de Veld, Mataw, & Begeer; 2019). There are variable trends concerning ethnicity and age of diagnosis, but some research suggests that children from ethnic minorities are diagnosed later than others (Magaña, Lopez, Aguinaga & Morton, 2013; Jo et al., 2015). This may be in part an explanation for the different prevalence rates in these groups mentioned previously. Negative associations have been found between socioeconomic status and age of diagnosis (Emerson, Morrell & Neece, 2016; Thomson et al., 2012), and parental education and age of diagnosis (Bickel, Bridgemohan, Sideridis & Huntington, 2015; Hrdlicka et al., 2016; Manohar, Kandasamy, Chandrasekaran & Rajkumar, 2019), providing strong evidence that barriers to diagnosis are a significant issue for autistic individuals. There is also research suggesting that being the first-born child effects age of diagnosis, with first-born children often receiving a later diagnosis than second or third-born children (Bickel et al., 2015; Mishaal, Ben-Itzchak & Zachor, 2014).

Diagnostic Pathway of ASD

The pathway to receive an Autism diagnosis in the UK is typically comprised of 5 stages: identification and referral, screening and triage, pre-assessment support, diagnostic assessment and post-assessment support (National Health Service [NHS], 2022). Based on descriptions from lead clinicians, the typical journey through the pathway takes approximately 13 hours of dedicated time by healthcare professionals for each referral, and costs about £800 (Galliver, Gowling, Farr, Gain & Male, 2017). These results are based on a "typical" autism referral through the lens of healthcare professionals. In a follow-up study investigating the journey based on the actual experience of children through the pathway, these findings are corroborated, with many reporting waiting times to be a minimum of one year or longer in most services (Male et al., 2023). As of September 2024, the NHS waiting list for an autism diagnosis stands at 204,876 open referrals (NHS, 2024).

The gold standard of diagnosis is a consensus among a multi-disciplinary team (Falkmer, Anderson, Falkmer & Horlin, 2013). However, this consensus can often be a challenging process (Hayes, Ford, Rafeeque & Russell, 2018). Furthermore, a review of the reliability and validity of diagnosis assessments found that many instruments designed to screen and diagnose autism lack a concrete evidence base (Falkmer et al., 2013). Only three instruments, namely the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore & Risi, 2000), the Autism Diagnostic Interview Revised (ADI-R; Lord, Rutter & Le Couteur, 1994) and the Childhood Autism Rating Scale (CARS; Schopler, 1994) had a strong supporting evidence base (Falkmer et al., 2013).

The time-consuming and costly process of an autism diagnosis poses a significant economic burden, and it (most importantly) delays the identification of where support is required for autistic individuals. There is currently an emphasis on the need to identify more efficient approaches in the screening and diagnostic assessment procedures, as well as a larger evidence base for some of the current diagnostic tools and instruments (Hayes et al., 2018; Male et al., 2023).

Gender Differences in ASD

It is well researched that there are significant differences between autistic males and females. Firstly, in regards to prevalence, the median male-to-female ratio of ASD has been estimated to be 4.2:1 (Zeidan et al., 2022), with males being thought to have a significant disproportionate risk of being autistic. Some researchers have suggested that there is a 'female protective effect' (FPE) hypothesis of autism, where females require a greater number of etiological factors in order to display the same degree of affectedness as males (Robinson, Lichtenstein, Anckarsäter, Happé & Ronald, 2013; Werling, & Geschwind; 2013). This, in turn, would suggest that females display more severe symptoms when identified as being autistic. However, the FPE hypothesis suggests that gender is one of the etiological factors which contributes to ASD, rather than taking into account other factors that may affect these different prevalence rates. For instance, it is possible that there is variability of phenotypic expression of ASD between males and females (Wijngaarden-Cremers et al., 2014). Years of biases in research may have contributed to the understanding of ASD being more aligned with the male phenotype, meaning that the diagnostic criteria are inherently biased towards males (Kirkovski, Enticott, & Fitzgerald, 2013; Kreiser & White, 2014; Wijngaarden-Cremers et al., 2014). For instance, research suggesting that females have more significant impairments, such as with intellectual disability (Delobel-Ayoub et al., 2015; van Bakel et al., 2015), may instead be a product of this bias translating to diagnoses being missed in females with a higher IQ (Begeer et al., 2013). This questions the idea that males are at a disproportionate risk of ASD, which is the narrative from years of autism research, and instead suggests that females could be significantly under-represented, leading to less identification of ASD symptoms and perhaps less support.

Research has attempted to investigate how phenotypic expression of ASD may be different between males and females. Some research suggests that autistic males and females show similar symptom severity in the social communication and interaction phenotype, whereas females display less of the restricted interests and repetitive behaviours phenotype than males (Wijngaarden-Cremers et al., 2014). Other studies have found that, whilst females without ASD had significantly better social communication and interaction skills than those with ASD, highlighting a clear atypicality, autistic females still had significantly better skills in this phenotype than autistic males (Wood-Downie, Wong, Kovshoff, Cortese & Hadwin, 2021).

However, more research should aim to investigate the extent of these differences within these phenotypes, and perhaps provide a more fine-tuned understanding of gender differences. In an analysis of items in a measure of the restricted interests and repetitive behaviours phenotype, Antezana et al. (2019) found significant gender differences between parent-report of ASD symptoms of their children (mean age was approximately 10 years old). They found that males displayed significantly more hand and finger complex mannerisms, atypical object usage, preoccupation with parts of an object and fascination or preoccupation with movement than females. Females, on the other hand, displayed significantly more symptoms concerned with pulling their hair and skin, rubbing and scratching themselves, hoarding and saving items, and insistence on sitting in the same place compared with males (Antezana et al., 2019). These item-level differences can possibly suggest that autistic males show more restrictive and stereotyped behaviours, whereas autistic females show more compulsive, self-injurious and insistence on sameness behaviours. However, in a discriminant analysis they found that this particular measure of the restricted and repetitive behaviours phenotype was better at classifying males than autistic females, again supporting the notion that instruments designed to measure ASD symptomology are fundamentally male-biased. In another study examining the effect of gender on ASD symptomology, Conlon et al. (2019) showed that there were significant differences in pragmatic communication between males and females. In a story-telling task, females were found to include more salient story elements than males and they told more richer stories including descriptors of planning or intention (Conlon et al., 2019). These subtle differences in phenotypic expression of ASD may not be as distinguishable with the utilisation of current tools used in diagnostic assessments, which may in part explain the male-dominant ratio of ASD prevalence (Zeidan et al., 2022).

Theories of Autism

Theory of Mind

One theory that has been thought to explain at least some of the phenotypes of ASD is Theory of Mind (ToM; Baron-Cohen, Leslie & Frith, 1985). ToM is the ability to attribute mental states such as intentions, beliefs and desires to ourselves and others (Sabbagh & Bowman, 2018). The ToM account of ASD is a prominent cognitive hypothesis suggesting that autistic individuals may have a lesser ability to attribute mental states to themselves and to others, which would result in atypical comprehensions about the world (Andreou & Skrimpa, 2020; Kaland, Callesen, Møller-Nielsen, Mortensen, & Smith, 2008). It has been observed that autistic individuals experience particular asymmetry between their own knowledge and that of others, and they do not tend to perform as well on ToM tasks in comparison to typical individuals, which has been the case in decades of autism research (David Zelazo, Jacques, Burack & Frye; 2002; Baron-Cohen, 2000). First-order tasks are generally used to measure ToM. Early ToM studies used the 'Sally-Ann' false belief task to measure ToM abilities in children (Baron-Cohen, 2000). In the task, Sally-Ann (a doll) places her marble in a box, and leaves the room. While she is away, Anne (another doll) moves the marble to a different box. When Sally-Ann returns, the participants are asked where she will look for her marble. Supposedly, those with a weakened ToM ability tend to say she will look in the box it was moved to, rather than the box that Sally-Ann had left it in, demonstrating the inability to separate the person's own beliefs to those of others (Szukiel, Gładczuk, Sobaniec & Batruch, 2017). In adults, first-order ToM tasks have involved filling an M&M's container with paper clips, and asking participants what they think is in the container (Kleinman, Marciano & Ault, 2001). After revealing what is actually inside, they are then asked what a third person would think is in there. If they answered M&M's they passed, and if they answered paperclips, they failed. This task evaluates the ability to understand that a person can hold a belief that is contrary to reality, a clear measure of intact or compromised ToM (Kleinman et al., 2001).

ToM impairments in autistic individuals are thought to effect mostly the social communication and interaction phenotype of ASD, as ultimately the ability to understand and reflect on others' points of view, knowledge and beliefs, as well as the ability to have reciprocal social interaction and to comprehend figurative language, is compromised in individuals with an impaired ToM (Boucher, 2012).

The ToM account has been circulated in decades of autism research, with the strong belief that autistic individuals have universal atypical ToM abilities, and that ToM is a well-evidenced theory that explains the phenotypes of ASD (Baron-Cohen, 2002). However, more recently, researchers have questioned the credibility of this theory because some autistic individuals perform well on ToM tasks, and there are other explanations for the observed outcomes in these types of research design (Tager-Flusberg, 2007; Boucher, 2012; Andreou and Skrimpa, 2020). For instance, ToM tasks are usually conducted on young children, around the typical age that a child starts to comprehend false belief, therefore performance on ToM tasks could be affected by delayed language development, which is common in some autistic individuals (Boucher, 2012; Delehanty, Stronach, Guthrie, Slate & Wetherby, 2018). There is also extensive research showing how elements of language acquisition, such as more advanced vocabulary, as well as semantic, grammatical and syntactic knowledge, are associated with performance on ToM tasks (Tager-Flusberg, 2007; Ebert, 2020; Nilsson & de Lopez, 2016). It is therefore possible that, when controlling for these variables, impairment in ToM tasks may not be as prominent between autistic and non-autistic individuals. It is also important to consider that ToM impairments do not necessarily explain the atypical restricted and repetitive behaviours displayed in ASD. Instead, the constraint here is that they only offer a somewhat partial explanation for the social aspects of ASD.

Theory of Prediction

Another more credible theory that has surfaced in more recent years is the theory of prediction account of autism (hypothesis of predictive impairment in autism [PIA]). In an attempt to decipher whether the phenotypes of ASD and their correlates share any underlying cognitive mechanism of causality, ASD has been theorised to be a disorder of prediction (Chambon et al., 2017; Gomot & Wicker, 2012; Sinha et al., 2014). The suggestion by these theorists is that autistic individuals have a domain-general inability to predict the outcome of particular events. Sinha et al. (2014) describe how the diagnostic criteria of ASD can be modelled by a Markov system, which involves the probability of transitioning from one state to another via chains of probability. In a typical individual's brain, an estimation is made on the probability of transitioning from one state to another (the antecedent and the consequence), and the temporal duration of such a process. The theory is that autistic individuals may make significant inaccuracies with this estimation (Sinha et al., 2014). This theory would account for both key markers of ASD. For instance, restricted interests and repetitive behaviours may represent a fundamental and almost instinctual aversion to activities that are unpredictable and potentially unpleasant, leading to a clinically-significant reliance on rituals and routines (Sinha et al., 2014). Similarly, the deficits in social communication and interaction that are characteristic of ASD may be the product of the fear of an inability to predict, and therefore navigate, the dynamic social world (Sinha et al., 2014). An apprehension to engage in social interactions from an early age may result in a dysfunction in social skills which in turn exacerbates the fear of engaging in such interactions, having a downward cyclical effect.

The PIA hypothesis also explains some of the observed correlates of ASD, including the impairments in ToM tasks previously discussed. An impairment in prediction would make an individual unable to situate an observation about a person or a stimulus in the context of their antecedents or subsequent (Sinha et al., 2014). This theory therefore explains the atypical performance in ToM tasks which is observed in autistic individuals and helps to make up for some of the shortfalls of the ToM account of ASD. The PIA hypothesis also explains the sensory hypersensitivities which are present in approximately 90% of autistic individuals (Leekam, Nieto, Libby, Wing & Gould, 2007) and are even included in the diagnostic criteria for the disorder (APA, 2013). When looking through the lens of the PIA hypothesis, it has been thought that an explanation for the observed sensory hypersensitivities in ASD is that autistic individuals and typical individuals do not code sensory information in the same way (Ward, 2019; Van de Cruys, 2014; Van de Cruys, Perrykkad & Hohwy; 2019). Whereas typical individuals habituate to their environments and to sensory stimuli resulting in future attenuation of the stimuli, autistic individuals are thought to code this information differently, thus experiencing hypersensitivity when exposed to it again (Kleinhans et al., 2009). "Normal" sensory experiences, therefore, are prevented from being attenuated in the way that they are for typical individuals. The PIA hypothesis also explains the distinct and well-researched correlations between anxiety and ASD (Hollocks, Lerh, Magiati, Meiser-Stedman & Brugha, 2019; Baxter, Scott, Vos & Whiteford, 2013; Adams & Emerson, 2021; Avni, Ben-Itzchak & Zachor, 2018). It is possible that states of anxiety in autistic individuals may be the product of the unpredictability of certain environments, especially those of a social nature. This in part may relate to the restricted interest and repetitive behaviours phenotype, as the unpredictability of facing novel environments that result in anxious feelings may be expressed as a fundamental preference for routines, rituals and insistence on sameness (Baribeau et al., 2021).

There is evidence for impaired predictive abilities in autistic individuals (Król and Król 2019; Krogh-Jesperson, Kaldy, Valadez, Carter and Woodward, 2018; Millin et al., 2018). However, like other theories of ASD, it is unclear whether the PIA hypothesis accounts for all observed behaviours in ASD. Results from research are largely dependent on variability in research designs and paradigms, and there are some instances where predictive abilities are not impaired in autistic individuals (Cannon, O'Brien, Bungert & Sinha, 2021).

Theory of Executive Dysfunction

Another prominent theory in decades of autism research is the theory of executive dysfunction in ASD. Executive function is an umbrella term for a set of cognitive processes involved in working memory, planning, focussing attention, mental flexibility, impulse control and more (Hill, 2004; Gilbert & Burgess, 2008). Ultimately, the term "executive function" constitutes the processes leading to the attainment of a particular goal (Gilbert & Burgess, 2008).

There is a large amount of research suggesting that performance on executive function tasks is impaired in autistic individuals in comparison to typical individuals, leading to the general consensus that there is evidence for executive *dys*function in ASD. For instance, a meta-analysis of executive function studies concerned with concept formation, mental flexibility, fluency, planning, response inhibition and working memory revealed consistent evidence of an overall moderate effect size of executive dysfunction in ASD, including across different diagnostic classifications of ASD (Demetriou et al., 2018). Executive dysfunction in ASD has been related to a number of neuropsychological factors, such as functional connectivity, atypicalities in the frontal lobe, and an imbalance of neural exhibition and inhibition circuits (Al-Otaish et al., 2018; Maximo, Cadena & Kana, 2014; Pagnozzi., Conti, Calderoni, Fripp & Rose, 2018). There is strong evidence that executive dysfunction is an endophenotype of ASD, linking genes, brain processes and observed behaviour (Demetriou, DeMayo & Guastella, 2019).

It is clear how impairments in executive function may effect the phenotypes of ASD. Restricted and repetitive behaviours in ASD may be the product of executive function impairments resulting in difficulties with generating new ideas, leading to rigid routines and atypical management when this routine is disrupted. Meta-analyses have found significant associations between the restricted and repetitive behaviours phenotype in ASD and measures of executive functions including set shifting, inhibitory control and planning, as well as more ecologically valid measures such as parental-report ratings of executive function (Iversen & Lewis, 2021). Furthermore, issues with social communication and interaction that are characteristic of ASD could be the product of impaired executive functions, as planning and monitoring actions are a prerequisite for the mentalising and self-awareness that is central to reciprocal social interaction (Jones et al., 2018). Research has found significant associations between social communication symptoms in ASD and executive function tasks, including idea generativity and use of objects, as well as parental-reports of executive functions (Dichter, Lam, Turner-Brown, Holtzclaw & Bodfish, 2009; Hutchison, Müller & Iarocci, 2020). It is also evident how executive function tasks relate to the mentalising that is essential in ToM tasks, which is also intrinsically associated with social communication and interaction (Boucher, 2012; Jones et al., 2018).

Whilst the theory of executive dysfunction has significant evidence to support it, it is important to consider that not all executive functions are impaired in ASD (Demetriou et al., 2018). Furthermore, an issue with executive function tasks is that they have been widely considered as not ecologically valid and therefore not representative of executive function abilities in real life (Martínez-Pernía et al., 2025). Research on executive functions in ASD, therefore, should be cautious about using largely laboratory-based studies to assess these abilities.

Theory of Weak Central Coherence

Central coherence is a term used to describe a particular perceptual-cognitive style, marked by the ability to understand smaller concepts in a larger context and to see “the bigger picture” (Happé, 2021). Weak central coherence, therefore, is marked by an overt focus on the smaller details of things, usually with the caveat of understanding the overall meaning of something or the limited comprehension of it within a broader meaning or context. This is fundamentally related to the local vs global processing dichotomy (Bernardino et al., 2012).

There is evidence to support the idea that autistic individuals have weak central coherence (Happé & Frith, 2006), and have a tendency to focus on the smaller, local details of information. In a study using a shape-integration task, it was found that autistic individuals performed significantly worse than typical individuals, and that this was related to symptom severity in the social communication and interaction phenotype (Olu-Lafe, Liederman & Tager-Flusberg, 2014). In a separate study using a sentence completion task where typical individuals and autistic individuals were matched by IQ, autistic individuals performed significantly worse, suggesting a local processing bias that is independent to intelligence (Booth & Happé, 2010). A meta-analysis of local and global visual processing found that autistic individuals were much slower at global processing than non-autistic control participants (Van der Hallen, Evers, Brewaeys, Van den Noortgate & Wagemans, 2015). It was also found that there was interference in the order for local and global processing tasks: local-global processing was interfered but not the global-local order (Van der Hallen et al., 2015).

The cognitive processes underlying ASD symptomology and the psychological correlates associated with them can be partially explained by markedly weak central coherence. The processing of local features of an environment can account for the inclination towards restricted and repetitive behaviours, which may represent preference for activities, tasks, or hobbies where local processing is paramount. Some research has provided evidence to suggest that repetitive behaviours are related to weak central coherence (Chen, Rodgers & McConachie, 2009; Evans, Elliott & Packard, 2001). The social communication and interaction phenotype of ASD may also be effected by this. A difference in understanding meanings within a larger context, i.e. global processing, would make reciprocal social interactions considerably difficult, especially when taking into consideration non-literal language. To have communication between people, there needs to be consideration of body language, facial expressions and mood, which could potentially explain why autistic individuals may show atypicalities in integrating this information, then ultimately facing problems with their communication. Research has found associations between local processing and social skills (Hill, Varela, Kamps & Niditch, 2014). Other research has found significant associations between social subscales of the Autism-Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001), and performance on a local and global processing task, with greater social difficulty being associated with local processing tendencies over global (Russell-Smith, Maybery, Bayliss & Sng, 2012). Local processing has also been related to ToM tasks (Delli, Varveris & Geronta, 2017; Pellicano, 2010).

Whilst there is evidence for weak central coherence in ASD, there have also been a number of null findings reported (Happé & Booth, 2008). Furthermore, weak central coherence may actually be better explained as Enhanced Perceptual Functioning in ASD (Mottron, Dawson, Soulières, Hubert & Burack, 2006), which is a strength-based approach as opposed to a deficit.

Discussion of Theories

Whilst it may be useful to conceptualise the phenotypes of ASD by categorising them into theoretical frameworks and establishing potential etiological factors which contribute to the disorder, the issue with this approach is that it reduces ASD down to a single theory. In doing this, emphasis is taken away from the complexity of the disorder and the real-life challenges of autistic individuals become less focal. Furthermore, the main themes in these theories are largely deficit-based as opposed to strength-based. Cannon et al. (2021) point out that there is not one single unifying theory of ASD, and attempting to find one may be particularly regressive in terms of helping and supporting the integration of autistic individuals into society. It is also important to note, in this context, that there is no theory which accounts for all atypicalities observed in ASD.

There are clear theoretical links between the ideas discussed here, suggesting that perhaps these theories of ASD may overlap. For example, executive dysfunctions can explain the atypicalities associated with ToM and central coherence. Furthermore, the PIA hypothesis fundamentally relates to ToM and executive functions. It is evident, therefore, that these theories on their own do not solely account for all phenotypes, cognitive processes and symptoms associated with ASD, as well as not being universal across every autistic individual. Instead, they provide an understanding of some of the concepts associated with ASD, but do not explain the wider picture of the disorder. It is therefore beneficial to be sceptical about the connotations that reducing ASD down to these single theories may have on the individuals themselves and the impact that this may have on the stigmatisation of ASD.

Outcomes and Quality of Life

There is huge variability in outcomes for autistic individuals as they progress into adulthood and across the lifespan. Many adults with ASD successfully obtain post-secondary qualifications, gain long-term employment and live independently (Eaves & Ho, 2008; Farley et al., 2009; Shattuck et al., 2012). However, recent data shows that, in the UK, there is still a considerable employment gap for autistic adults, with only 29% of individuals being in some form of employment (ONS, 2021). Furthermore, 79% of autistic individuals are still living with their parents, a figure that exceeds that of other disabilities, and only 3.8% own their own homes (ONS, 2021).

A review of ASD literature regarding social and behavioural outcomes for autistic individuals suggested that outcomes for social integration and independence tend to be poor, with over 50% of individuals relying on family or carers for support with education, living arrangements and employment (Magiati, Tay & Howlin, 2014). This risk of isolation may contribute to, or even be the cause of, significant mental health issues in autistic individuals (Cage, Di Monaco & Newell, 2018). Research has found that autistic individuals are at a disproportionate risk of suffering from mental health problems (Hollocks, Lerh, Magiati, Meiser-Stedman & Brugha, 2019; Huke, Turk, Saeidi, Kent & Morgan, 2013). For example, it is thought that the lifetime prevalence of an anxiety disorder in autistic individuals is 42% compared to 7.3% in non-autistic individuals (Hollocks et al., 2019; Baxter, Scott, Vos & Whiteford, 2013). However, with mental health conditions (anxiety in particular), there is a considerable debate as to whether these disorders are co-occurring (i.e. comorbid), or whether there is substantial phenotypic similarity between the disorders which make classification a challenging process (Zaboski & Storch, 2018).

The inconsistency in outcomes may in part be attributable to specific ASD factors, such as symptom severity and comorbid conditions. However, it is most likely that the main moderator of these outcomes is the impact of external factors such as familial support, access to support services and educational and workplace interventions. It is also important that organisations such as schools and workplaces should strive to have an adaptable and prioritisation approach to autistic individuals, in order to support them and allow them to achieve in these environments. In a systematic review and meta-analysis, it was found that parent-focussed interventions for parents of autistic individuals were particularly effective at increasing well-being for the autistic person and their families (Rutherford et al., 2019). Furthermore, educational and workplace interventions that have been implemented have had considerable success as well (Ledbetter-Cho, O'Reilly, Lang, Watkins & Lim, 2018; Lindsay, Osten, Rezai & Bui, 2021; Remington & Pellicano, 2019; Watkins, Ledbetter-Cho, O'Reilly, Barnard-Brak & Garcia-Grau, 2019).

Ethical Considerations in Autism Research

There are significant ethical considerations when conducting research with autistic individuals, and there has been a major paradigm shift in the way that ASD and other neurodevelopmental conditions have been understood in recent years. The emergence of the neurodiversity movement aimed to change the way that "disorders" are regarded in the general population. The term 'neurodiversity' is generally credited to Judy Singer, a woman diagnosed with Asperger's syndrome (1999), and the movement developed via online groups of autistic people, generally those classified as "high-functioning" (Jaarsma & Welin, 2012). The neurodiversity claim posits there are indeed neurological differences among the human population, and that autism and other neurodevelopmental conditions are a natural variation among humans (Jaarsma & Welin, 2012). The suggestion is that autistic individuals are just different, and they do not have a disability nor are pathological. The claim has significant implications concerned with rights, non-discrimination and other political issues. There are also effects of this claim in healthcare and research as the narrative is moved away from the traditional 'medical model' of ASD (Den Houting, 2019). Individuals who show strong allegiance to the neurodiversity movement want to see ASD as a positive identity, without the associated stigmatisation, which has been shown to have a positive effect on self-esteem and psychological well-being (Cooper, Russell, Lei & Smith, 2023; Cooper, Cooper, Russell & Smith, 2021). Whilst this thesis will be written with an understanding of the neurodiversity movement and the knowledge that autistic individuals possess many strengths, this will not take emphasis away from autistic individuals who face significant challenges in everyday life, which is a common critique of the neurodiversity movement (Russell, 2020). It is also important to retain the narrative that it is not the responsibility of the autistic individual to adapt to "fit into" a neurotypically-structured society, and instead the onus is on society to make accommodations for neurodiverse individuals. This can be accomplished through research which strives to contribute a greater knowledge and understanding of autism, working towards autistic-prioritised outcomes (Leadbitter, Buckle, Ellis & Dekker, 2021).

Recently, there have been discussions over the language used when talking about autistic individuals. The question is whether the terminology used to describe neurodivergent individuals should be identity-first (i.e. "autistic person") or person-first (i.e. "person with autism") (Jaarsma & Welin, 2012). This has implications when it comes to research practice, public policy, societal perceptions and clinical practice. It is the perspective of many autistic individuals and researchers in the field that, whilst using person-first language is undoubtedly well-intended, scholarly writers use identity-first language, to positively contribute to the belief that autism should be seen as a positive identity (Botha, Hanlon & Williams, 2021; Gernsbacher, 2017; Vivanti, 2020). Therefore, in this thesis I will use identity-first language when talking about autistic individuals. The phrases used to previously discuss autism, such as "impairment", "dysfunction", and "disability" will be used sensitively and only when emphasising the challenges that autistic individuals may face. Where possible, the word "atypical" will be used to discuss traits of autistic individuals or research results that are specifically misaligned to those expected in a neurotypical population. In the remainder of this thesis, we often use "non-autistic", "typically-developing" or "control" interchangeably. However, we would like to acknowledge the need for more inclusive language to describe non-autistic people.

Furthermore, it is important to acknowledge the connotations of using the phrase "high-functioning" autism. High-functioning autism is generally a phrase used to describe individuals who display autistic traits in all its phenotypic diversity, but do not have an accompanying intellectual disability (Ghaziuddin & Mountain-Kimchi, 2004). Consequently, the autistic individual "functions" relatively well in society. Whilst I have used the term high-functioning autism to describe some of the participants who have taken part in the research in this thesis to highlight that they function to the same level as neurotypical individuals from an intelligence perspective, I believe that changes should be made to this particular classification. To be "high-functioning" is only a measure in comparison to neurotypical standards, and I would like to remain sensitive to using this phrase to not diminish some of the challenges that autistic individuals still face, despite outwardly "functioning" well.

Language Profile of ASD

Some autistic individuals experience markedly atypical language development. Language development, however, does not explicitly feature in the diagnostic criteria of ASD, where communication issues are described as a product of pragmatic language difficulties rather than as a problem with functional language (APA, 2013). Pragmatic language skills are defined as the use of appropriate communication in social contexts, particularly with understanding intentions and discourse management skills (Landa, 2005). "Functional language" will be used to refer to the extent of verbal communication that an autistic person may possess i.e. are they verbal or non-verbal, or somewhere in between. Structural language skills are concerned with the structure of language, such as the use of vocabulary, phonology, morphemes, syntax, semantics and verbal fluency. It is generally accepted that a universal hallmark of ASD are significant atypicalities in the use of pragmatic language, whereas functional and structural language skills are highly heterogeneous across the spectrum even when intelligence is intact. It is for this reason that language abilities in ASD receive a lot of attention in research. However, a distinction must be made between language abilities related to ASD diagnostic status and language issues that occur due to a co-occurring language disorder, which is the experience of 63% of autistic individuals (Levy et al., 2010). It is unclear whether this is due to phenotypic similarity between ASD symptoms and language disorders, making them difficult to distinguish between for clinical professionals, or due to a genetic vulnerability to comorbid language disorders that ultimately represent a language endophenotype in ASD (Rommelse, Geurts, Franke, Buitelaar & Hartman, 2011). With this in mind, it is important to acknowledge whether atypicalities in functional language skills occur due to inherent and early problems with social communication, the diagnostic hallmark of ASD. In the same way, you cannot ignore the inevitable impact that early problems with functional language skills, such as delayed first-word production (Delehanty et al., 2018; Pry, Petersen & Baghdadli, 2011), will have on the development and the ease of social communication. It is therefore evident that, whilst there is substantial variability in functional language skills in ASD making them distinct to the universally impaired pragmatic language skills, these two areas are not unrelated and continue to interact with each other throughout development and across the lifespan.

Atypicalities in pragmatic and functional language skills are identified in the language production domain (also known as expressive language) and in the language comprehension domain (also known as receptive language). In psycholinguistics, these two areas are generally regarded as distinct anatomical pathways that represent the neural process underlying the production of a sentence, for example, compared with the neural process involved in the comprehension of a spoken or sentence (the Broca-Wernicke-Lichtheim-Geschwind model, Ben Shalom & Poeppel, 2008), although this dichotomy has been challenged (Pickering & Garrod, 2013).

Language Production in ASD

Atypical trends in the production of language are common in autistic individuals, particularly in early childhood. Between 25% and 30% of autistic children are either non-verbal or only minimally verbal (Norrelgen et al., 2015). For some individuals, this persists into later life stages, with some being permanently non-verbal (Koegel, Bryan, Su, Vaidya & Camarata, 2019). For others, language acquisition is significantly delayed compared with typical developmental milestones (Landry & Loveland, 1988). Delays have been reported in autistic infants with first-word production (Delehanty et al., 2018; Matson, Mahan, Kozlowski & Shoemaker, 2010), first phrase production (Anderson et al., 2007; Kenworthy et al., 2012) and first sentence production (Wodka, Mathy & Kalb, 2013). These delays have been associated to later cognitive ability and adaptive skills, suggesting that intervention is crucial when these problems are identified in early developmental periods (Mayo, Chlebowski, Fein & Eigsti, 2013). Smaller expressive vocabularies have also been reported in autistic children (Kjelgaard & Tager-Flusberg, 2001; Miniscalco, Fränberg, Schachinger-Lorentzon & Gillberg, 2012). Some autistic individuals are atypical in their articulation of words and intonation, with a proportion of these individuals having clinically-significant problems in this area (Cleland, Gibbon, Peppé, O'Hare & Rutherford 2010; Shriberg et al., 2001). Semantic development and the use of idiosyncratic words or phrases have also been shown as atypical in autistic populations (Boucher, 2012). Furthermore, an area that has received a lot of research attention is the number and type of disfluencies made during spontaneous speech. There are a number of different types of disfluencies, but “typical” disfluencies, such as filled pauses, repetitions and repairs, have been extensively studied in autism. Generally, there is consensus in the literature that autistic individuals show significant differences in their production rate of filled pauses, such as a lower rate of *um*’s, and *um*/*uh* ratio (Gorman et al., 2016; Lunsford, Heeman, Black & van Santen, 2010). Research has also consistently shown that autistic individuals produce more repetitions (Lake, Humphreys & Cardy, 2011; Shriberg et al., 2001), but the research on repairs is mixed, despite still showing significant group differences (Shriberg et al., 2001; cf. Lake et al., 2011). Disfluencies are suspected to reflect the cognitive processing demands concerned with speech planning (Gorman et al., 2016), and therefore relate to the pragmatic aspects of communication that is a universal challenge in autism. It is important to acknowledge that, with the exception of disfluency research, most studies on language production abilities in ASD are conducted on individuals in infancy or childhood. Few studies follow the rate of progress into adulthood, whilst some report that with intervention, language skills can development at a comparable rate to neurotypical individuals (Brignell et al., 2018). However, the prognosis of language outcomes for autistic individuals is somewhat unclear, with much research suggesting that atypicalities in language production are relatively persistent over time (Tek, Mesite, Fein & Naigles, 2014).

Language Comprehension in ASD

There is evidence to suggest that language comprehension in ASD is atypical, even in instances where language production is intact. Whilst there are many forms and methods of measuring language comprehension in adults, the most basic measure of language comprehension used in young children is analysing how many words a toddler or child understands (Ungerer & Sigman, 1981). Language comprehension is significantly more challenging to measure in autistic children than language production because most measures rely on parent-report. Furthermore, conclusions cannot be based on a typical social interaction, and instead have to rely on the observation of behaviours that indicate comprehension, such as stopping a behaviour when the parent says “no”, for example (Naigles, 2021). This problem is exacerbated for parents of autistic children, who may respond atypically anyway, making conclusions regarding comprehension substantially difficult. There is a significant amount of research suggesting that autistic children are delayed in their receptive language development (Miniscalco et al., 2012; Vanvuchelen, Roeyers & De Weerdt, 2011; Maljaars, Noens, Scholte & van Berckelaer-Onnes, 2012), and that their receptive language is atypical across developmental stages (Kwok, Brown, Smyth & Cardy, 2015). It is unclear whether this is the cause of, or the product of, the atypical socio-pragmatic elements of language associated with ASD. In autistic adults, however, there has also been atypical language comprehension observed, even when comprehension seems intact from a behavioural stand-point. There are multiple subsets of language comprehension that have been extensively studied in autism. For example, figurative language comprehension is thought to be universally atypical in autism due to challenges with theory of mind, mentioned previously (Lampri, Peristeri, Marinis & Andreou, 2024). Other domains of language comprehension have also been shown to be atypical, for example, emotional language and sentence comprehension, but often there are mixed results across different experimental methods (Lartseva, Dijkstra & Buitelaar, 2015; Tager-Flusberg, 1981; Eigsti, de Marchena, Schuh & Kelley, 2011).

Overview

Whilst there is substantial research investigating atypical language production and comprehension in autistic individuals, there is still some areas which require extra clarity and insight. Happé and Frith (2020) state that "language, once such a focus for autism research, is now relatively little studied but important questions remain" (p. 34). We have identified areas where further research is warranted, with an attempt to decipher whether we can use language in the diagnostic assessment of autism, and understand more about language within the diverse autism phenotype.

Introduction to the Thesis

It is evident that autistic individuals show an atypical language profile. We strongly believe that language abilities are an observable measure of autism symptoms, most likely representing the problems with social communication, which are at the centre of the ASD diagnosis, but also perhaps being indicative of a broader language issue in autism. Note that we previously identified issues with current screening and diagnostic instruments used in the autism diagnostic pathway. To identify and screen for language-related issues would have substantial clinical value: when intervention happens early for these types of language problems, evidence shows that outcomes are better, and language-related problems can significantly improve (Sandbank et al., 2020). Furthermore, modern treatment is based on an individualised evidence-based approach targeting problem areas in order to maximise functional independence and quality of life, rather than a “one size fits all approach”. Identifying language-related problems in autistic individuals therefore aligns with this philosophy, leading to two initial goals for the thesis. Firstly, we would like to develop a screening tool for language abilities and pragmatics in children and adolescents, which is easy to administer and time-efficient, as we believe current tools are insufficient in this respect. We aimed to test and validate this tool so that it can be utilised across research, clinical and educational contexts. Furthermore, with the development of this tool, we hoped to increase education about potential “red flags” of autism for parents and caregivers, making the diagnostic process significantly less burdensome.

Furthermore, as we mentioned in our dedicated ‘Language Production in ASD’ section, less obvious language production markers of ASD are sometimes present, but these can be more difficult to identify by an individual and those around them, often resulting in missed diagnoses. This may be exacerbated for individuals classed as “high-functioning” autism, who tend to camouflage or “mask” their symptoms (Cook, Hull, Crane & Mandy, 2021). We identified earlier that disfluency rates are a relatively consistent finding in ASD literature. Therefore, a second aim was to find out whether we could replicate findings from other studies and subsequently establish if we can use disfluencies as diagnostic markers of ASD. If disfluencies can be an observable measure of atypical socio-pragmatic communication and can successfully predict ASD group status, this may have important clinical value. Not only will it corroborate evidence for atypical language production in ASD, but it will allow for easy identifiable language traits that are indicative of autism to a clinically-significant level.

We mentioned previously that some domains of language comprehension are also atypical in autism. However, there are a few gaps in the research which we think warrant further attention. In our 'Theories of Autism' section, we spoke about the PIA hypothesis (Sinha et al., 2014) which aims to explain autism as a disorder of prediction. We believe that, above the other existing theories, this theory has the most credit due to its explanation of a variety of the phenotypes observed in autism. Despite there being a hoard of research investigating predictive abilities in ASD (see Cannon et al., 2021, for a review), there is comparatively little research investigating linguistic prediction in ASD. Therefore, another goal of the thesis is to investigate linguistic prediction in autism, and how it relates to atypical language comprehension and the phenotypes of autism. This could perhaps point to domain-general atypical prediction in autism, providing support for the PIA hypothesis (Sinha et al., 2014).

We noted in our 'Language Comprehension in ASD' section that research has provided evidence to suggest that autistic individuals may comprehend sentences atypically (Tager-Flusberg, 1981). The theory of Enhanced Perceptual Functioning (Mottron et al., 2006), a strengths-based alternative to the theory of Weak Central Coherence (Happé & Frith, 2006), aims to explain that autistic individuals have a detail-focussed cognitive style. In psycholinguistics, non-autistic people tend to struggle with the comprehension of passive implausible sentences due to the inability to compartmentalise the stimulus, instead seeing it as a "whole" with the influence of their pre-conceived expectations of what is common and what is plausible (Ferreira, 2003; Stella & Engelhardt, 2022; Ferreira & Patson, 2007). Based on what we know about autism and the theories mentioned above, it could be fair to assume that autistic individuals will show superior performance in their comprehension of passive and implausible sentences. Another aim of the thesis is to test this hypothesis, and potentially highlight how autistic traits can lead to superior performance in some comprehension tasks.

Lastly, we mentioned that figurative language comprehension has received much research interest (Lampri, Peristeri, Marinis & Andreou, 2024) due its association with the challenges with Theory of Mind that are observed in autism (Baron-Cohen et al., 1985). Among studies measuring the comprehension of metaphors in autistic individuals, there are few studies measuring online cognitive processing of metaphors, particularly utilising a Visual World Paradigm (VWP; Tanenhaus, Spivey-knowlton, Eberhard & Sedivy, 1995). VWP's (Tanenhaus et al., 1995) allow researchers a unique opportunity to measure how individuals implicitly comprehend information by measuring eye-gaze. Another aim of this thesis is to explore novel metaphor comprehension utilising a VWP (Tanenhaus et al., 1995) in autistic adults. This will allow us to understand more about implicit figurative language comprehension in autism, and gain insight into how autistic individuals interpret and process the dynamic world. There is also potential to understand more about what underlies the atypical socio-pragmatic communication phenotype of autism.

To summarise, we have identified various domains of language production and comprehension in autism that have been relatively under-studied or which we believe could have important clinical value. We have therefore established five objectives for the thesis:

1) To test and validate a tool to screen for issues related to language abilities and pragmatics in autistic children and adolescents,
2) To investigate whether disfluencies in speech can be used as a diagnostic marker of autism,
3) To investigate linguistic prediction in autistic individuals and whether we can provide support for the Theory of Prediction (Sinha et al., 2014) within a language domain,
4) To investigate whether autistic individuals show superior performance in the comprehension of passive implausible sentences,

5) To explore novel metaphor comprehension in autism using a VWP (Tanenhaus et al., 1995) eye-tracking task.

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CHAPTER 2 – LANGUAGE AND PRAGMATICS QUESTIONNAIRE

Abstract

The aim of this study was to test and validate a parental-report questionnaire, which assesses language abilities and pragmatics, in children with Autism Spectrum Disorders (ASD). We report two experiments: The first served as the initial test and the second sought to provide the first assessment of convergent validity. In total, we recruited 230 parents, approximately two-thirds had an autistic child. Results of factor analyses showed a consistent factor structure within each subscale, and the internal consistency was excellent for both sub-scales (Cronbach's alpha >.90). Convergent validity was assessed by correlating the results of the questionnaire with two sub-scales of the Autism Quotient questionnaire. The correlations were all greater than .60. The final version of the questionnaire (following exclusion of problematic items) contains 30 items (12 for language abilities and 18 for pragmatics). We conclude that the questionnaire is a concise and practical instrument for use in a variety of contexts for assessing language functioning and communication in children with ASD.

Keywords: Autism Spectrum Disorders, questionnaire validation, language ability, pragmatics, verbal children, social communication

A Parental-Report Questionnaire for Language Abilities and Pragmatics in Children and Adolescents with Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) is characterised by restricted interests, repetitive patterns of behaviour, and persistent deficits in social communication and interaction across multiple contexts (American Psychiatric Association [APA], 2013). It is known that autistic individuals show an atypical language profile. A universal hallmark of ASD is significant impairments in pragmatic aspects of language, including registering, turn-taking, and non-linguistic components, such as eye contact (Eigsti, de Marchena, Schuh & Kelley, 2011). Functional language skills, on the other hand, are highly heterogenous across the spectrum. Many autistic individuals develop average functional language skills in the expected trajectory of typically-developing individuals, with no clinically-significant problems in this area (Friedman & Sterling, 2019; Kjelgaard & Tager-Flusberg, 2001). However, between 25% and 30% of autistic children are either non-verbal or only minimally verbal (Norrelgen et al., 2015). Many autistic children show language acquisition that is incongruent with typical developmental milestones, with the average age of first-word production being 38 months compared to 8-14 months in typically-developing infants (Delehanty, Stronach, Guthrie, Slate & Wetherby, 2018).

There is a strong body of evidence highlighting atypical structural language skills in autistic children and across the lifespan with the use of phonology, morphemes, syntax, and semantics (Kjelgaard & Tager-Flusberg, 2001; Eigsti, Bennetto & Dadlani, 2007; Rapin, Dunn, Allen, Stevens & Fein, 2009; Tek, Mesite, Fein & Naigles, 2014). Significant impairments with these aspects of language functioning contribute to early identification and diagnosis of ASD, with the absence of words often being the primary concern for caregivers who suspect their child may be autistic (Wetherby et al., 2004). Whilst the average age of diagnosis is 5 years old, a diagnosis can be obtained as early as 18-24 months, with social behaviours and language delay being indicative of atypical development in line with ASD symptomology (Özyurt & Eliküçük, 2018; Tanner & Dounavi, 2021; van't Hof et al., 2021).

There are currently no questionnaires for quick and reliable screening of language abilities and pragmatics in children. In this study, we developed an instrument to assess these things in children via parental report, and specifically, designed for use in autistic children. The need for a reliable measure of language abilities and pragmatics to aid in early identification and diagnosis of ASD is clear. Impairments in language acquisition become increasingly problematic over time, and observed atypicalities in social communication, interaction, and behaviour should ideally result in immediate further evaluation (Filipek et al., 1999; Johnson & Myers, 2007). Structural language impairments in typically-developing children are associated with higher levels of anxiety, which progress into adolescence, and children with these impairments can be subject to peer rejection leading to fewer good quality relationships (Asher & Gazelle, 1999). This may be exacerbated for autistic individuals, who are already at a disproportionate risk of bullying, loneliness, and isolation, which can lead to serious mental health problems (Cage, Di Monaco & Newell, 2018; Chamberlain, Kasari & Rotheram-Fuller, 2007; Eroglu & Kilic, 2020). Pragmatic language skills have been shown to negatively predict anxiety levels and subsequent externalising behaviours in autistic children, however there is evidence of a bi-directional relationship here (Rodas, Eisenhower & Blacher, 2017).

Educating caregivers on what verbal and non-verbal language cues to look for when identifying ASD symptoms in infants and children is crucial in predicting outcomes for affected children. This is because age of diagnosis is negatively related to outcomes (Clark, Vinen, Barbaro & Dissanayake, 2018). In addition, when implemented early, interventions have been shown to be effective in improving language skills for autistic children (for a review, see Sandbank et al., 2020). Encouraging parental involvement in this process is central to these more positive outcomes (De Froy, Sims, Sloan, Gajardo & Rollins, 2021; Hampton & Kaiser, 2016; Levy, Kim & Olive, 2006).

In this study, we investigate differences in language abilities and pragmatics between autistic children and typically-developing controls. Secondly, we investigated the psychometric properties (reliability and validity) of the instrument we developed, based on two empirical studies. Convergent validity was assessed, via correlations with Autism-Quotient (AQ) subscales of social skills and communication (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001).

Alternative Diagnostic Instruments

As mentioned previously, we believe that there are insufficient instruments designed for quick and efficient assessment of language abilities and pragmatics in ASD. We have identified some instruments that are frequently used for this purpose.

Social Communication Questionnaire (SCQ; Rutter, Bailey & Lord, 2003)

The SCQ is a 40-item screening instrument designed to assess ASD symptomology in children aged over four years old. The SCQ is quick to administer and can be used on both verbal and non-verbal children. However, clinicians are required to be trained to administer the SCQ, with guidelines suggesting the requirement of either a Bachelor's degree, plus additional training, or a Master's degree. The test kit is approximately £200 and scoring forms also require purchase. It has also been criticised for resulting in a high number of false-positives in clinical diagnoses (Chesnut, Wei, Barnard-Brak, & Richman, 2017; Oosterling et al., 2010). The SCQ does not clearly delineate language abilities and pragmatics into two separate domains. Language abilities and pragmatics are distinct and there are variable presentations of both across the spectrum, so research on language in ASD that does not make this distinction is hard to interpret and draw conclusions from. Furthermore, the cut-off for identification of ASD should be lowered for younger children which it is not, suggesting it is perhaps not as sensitive for this age range.

Child Communication Checklist (CCC-2; Bishop, 2003)

The CCC-2 is a 70-item questionnaire designed to be administered by a caregiver to screen for communication disorders in children aged 4-16 years old. It is quick to administer, well validated and reliable, and has standardised scoring. Again, however, the test kit is expensive (approximately £200) and requires a Bachelor’s or Master’s degree to use it (Pearsons, 2023), making this a significant barrier to access.

Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick & Piven, 2007)

The Broad Autism Phenotype (BAP) is a set of subclinical autistic traits that reflect potential genetic liability to ASD. The BAPQ is a 36 item self-report instrument designed to screen adult relatives of autistic individuals for the BAP across general domains of ASD symptoms: social behaviours, rigid behaviours and interests, and pragmatic communication. It is free to administer and has been shown to have good internal consistency (Sasson et al., 2013). It is a reliable tool for assessing BAPs, but not for identifying ASD itself. We believe that our questionnaire is unique in being a comprehensive focus on language abilities and pragmatics, which are key identifiable symptoms that lead to official diagnosis of ASD. Furthermore, the BAPQ is designed for use in adults, whereas we strongly believe that having the capacity to utilise such a screening instrument with children is necessary when early intervention is critical to outcomes (Clark et al., 2018).

Yale in vivo Pragmatic Protocol (YiPP; Simmons, Paul & Volkmar, 2014)

The YiPP is an assessment tool designed to measured pragmatic language in children and adolescents aged 9-17 years via a semi-structured conversational task with a researcher or examiner. It is known to be a good comprehensive assessment of pragmatic language, however it is relatively time consuming to administer (approximately 30 minutes) and requires training to do so. It has also been known to have a particularly less established research base.

Pragmatic Rating Scale (PRS-SA; Landa, 2013)

The PRS-SA is an assessment tool designed to identify abnormalities with pragmatic use of language in children and adolescents aged 4-18 years old, using semi-natural conversation interactions with a researcher or examiner. Again, it is free and provides a broad coverage of pragmatic language abilities. However, it fails to also consider functional language abilities. Furthermore, it requires two trained blind administrators for post-hoc coding, making the analysis a fairly time-consuming process.

Pragmatics Profile of Everyday Communication Skills (Dewart & Summers, 1996; Almehmadi, Tenbrink & Sanoudaki, 2020)

The Pragmatics Profile of Everyday Communication Skills was originally a 22 question interview designed to detect and subsequently profile communication skills in children aged nine months – ten years. It was then modified to a questionnaire to make it more accessible to administer, however the questionnaire version is not as well validated as the original interview schedule. Again, there is no coverage of functional language abilities in this assessment tool.

Language Use Inventory (LUI; O'Neill, 2007)

The LUI is a standardised parent-report questionnaire for assessing pragmatic language development in children aged 1-4 years old. It consists of 180 items which takes approximately 20-30 minutes to administer. It has a broad research base, is well validated and reliable with standardised scoring. However, it is costly and can only be accessed by professionals with a Bachelor's or Master's degree. The target age range for this tool is also particularly limited.

Test of Pragmatic Language (TOPL-2; Phelps-Terasaki & Phelps-Gunn, 2007)

The TOPL-2 is a norm-referenced tool that assesses pragmatic language skills in children and adolescents aged 6-18 years. It evaluates various social communication skills in context, such as how well students listen, express feelings and make requests. It has a broad research based, is well validated and reliable and has standardised scoring. However, it is costly to administer (around £300), requires the administrator to have a doctorate or licensing, and is time consuming to administer (approximately 40-60 minutes).

Pragmatic Language Skills Inventory (PLSI; Gilliam & Miller, 2006)

The PLSI is a 45 item norm-referenced scale designed to assess pragmatic language abilities in children aged 5-12. It consists of three subscales: personal interaction skills, social interaction skills and classroom interaction skills. It can be administered by a teacher, caregiver or clinician and is quick, taking around 5-10 minutes. However, the test purchaser must have a Bachelor's degree in psychology or a related field, and it costs approximately £110. However, language abilities are not assessed on this scale, only interactions. The target ager range is also relatively small.

Other Tests for Assessing Language

Other tests for assessing language are the Clinical Evaluation of Language Fundamentals and the Test for Reception of Grammar (for a review, see Kelley, Jones, Fein, Goldstein & Beers, 2003). However, again these tests have substantial cost implications and require training to administer. Some studies have also collected spontaneous speech samples (Tager-Flusberg, 2000). The purpose of doing so is to understand whether the individual with ASD is able to communicate with intent, stay on topic, provide sufficient information, and understand humour and irony. Tests for assessing pragmatics include the Test of Pragmatic Language and Comprehensive Assessment of Spoken Language. These tests also have cost implications and require 45 minutes to 1 hour to administer. In addition, these assessments can be challenging to administer to individuals with ASD. This is because it is often difficult for children with ASD to interact with an experimenter, and they may experience motivational and attentional difficulties (Koegel, Koegel & Smith, 1997). Parent-report questionnaires, in contrast, are easy for the individual with ASD, as they allow for the observation of natural behaviour in environments that are familiar and comfortable.

In short, these standardised tests require substantial resources and effort to administer. The process of receiving an ASD diagnosis is often long and complex requiring costly expert clinical assessments. This is often a barrier to diagnosis for some individuals and their families (van't Hof et al., 2021), which is especially problematic when access to early interventions is crucial for outcomes. The capacity of diagnostic services has been stretched, particularly in and following the 2020-2021 COVID pandemic. These issues have led to the need for screening measures designed to quickly and efficiently identify individuals with ASD symptoms, in order to guide referrals to clinical experts. The main goal of this study is not to replace existing measures, but instead, to provide a quick, easy, reliable, and cost-efficient way for researchers and clinicians to assess language abilities and pragmatics.

The Current Study

Two experiments were conducted. Experiment 1 presents the results of the first study using the new questionnaire. The first version of the questionnaire had 34 items containing two sub-scales (language ability and pragmatics). We recruited parents, who had either a typically-developing child or an autistic child. Experiment 1 provided the initial assessment of the questionnaire, in which we examined autistic children in comparison to typically-developing children, as well as the factor structure and internal reliability of each sub-scale. In the second experiment, we revised the questionnaire based on Experiment 1 results. In short, we removed two items and re-ran the questionnaire on a second sample in order to validate the questionnaire. The second experiment also assessed two sub-scales from the AQ, namely social skills and communication. Correlations between these sub-scales and the sub-scales of the language and pragmatics questionnaire provide the first validation of convergent validity. We expected pragmatics to be more impaired than language abilities, given that no individuals in the ASD sample(s) were non-verbal.

Experiment 1

The first study recruited parents in order to provide a first test of our questionnaire. Parents of children completed a few simple demographic questions, and then the language and pragmatics questionnaire. All did so online via Qualtrics. We expected to observe significant differences between autistic children and typically-developing children. This study provided the initial step in demonstrating that the questionnaire operated as intended. The second step in Experiment 1 examined the psychometric properties of the questionnaire. To do so, we conducted factor analyses to assess whether individual items on each sub-scale patterned together. Finally, we assessed the internal reliability.

Methods

Participants

A volunteer sample of 137 parents were recruited. Seventy-seven were the parent (or guardian) of an autistic child, and 60 were the parent of a typically-developing child. The recruitment of parents (or guardians), who had an autistic child was done via local ASD support groups. The group coordinators agreed to circulate the link to the questionnaire via email to their group members. In addition, several personal contacts, who had an autistic child, were approached to take part by email. The recruitment of the parents/guardians, whose child did not have autism, was done via a convenience sample, which involved sending the questionnaire to contacts in a local elementary school (in the southeast region of England). The age and gender information for the children are Table 1, further demographic information in Appendix A.

Table 1

Age and gender for the ASD and control group.

	ASD(60)	Control(77)	Significance
Variable	Mean(SD)	Mean(SD)	
Age of child	11.50 (6.35)	10.55 (4.45)	$t(134) = 1.02, p = .31$
Age range of children	3-18 years	3-18 years	
Gender of Child (% male)	46.7	74.0	$t(135) = 3.39, p < .001$

Note. Numbers in parentheses refer to number of participants in each group. SD = standard deviation.

Materials

Language and Pragmatics Questionnaire (LAPQ; Appendix B)

The LAPQ was developed based on reviewing the diagnostic criteria for ASD in children and adolescents (APA, 2013) and other primary references for language and pragmatics in children. Item selection and initial content validation was done by reviewing several empirical studies that examined language impairments in ASD. The questionnaire consisted of two parts: language ability (14 items), for example "my child's first words were delayed", and pragmatics (20 items), for example "my child is able to make eye contact with people and objects". The questionnaire was designed for parents to complete with respect to their child. In each sub-scale, a higher score indicates a lower ability of the child. A 4-point Likert scale ranging from 'Strongly Agree' (coded as 4) to 'Strongly Disagree' (coded as 1) was used to indicate how much parents agreed with each statement. Nine questions were reversed coded (8, 9, 13, 19, 21, 22, 28, 29, 30, 31).

Design and Procedure

Before data collection, ethical approval was granted. Participants were approached by email, asking them whether they would like to take part in the study. Those who decided to take part were able to click on a link, which took them directly to the questionnaire. Before completing the questionnaire, participants were shown the information sheet, which provided an outline of the study, followed by the consent form. The consent form made it clear that participation was voluntary, and participants were free to withdraw at any time, without giving reason. It also informed them to leave blank any questions which they felt uncomfortable answering or were otherwise not applicable. The participants were asked to tick a box to confirm their participation in the study, and provide the last four letters of their surname, along with their date of birth. Following this, participants completed the questionnaire. In addition to the language and pragmatics questions, parents also completed another unrelated questionnaire.

The participants were shown the debrief after completing the questionnaire. This explained what the study was investigating, and provided the researchers contact details, along with information about relevant support groups. The debrief page also offered more information about withdrawal. The last point of withdrawal was one month after participation. If the participants decided that they wanted to withdraw their data, then they could email the last four letters of their surname and their dates of birth to the researcher, so that their data could be removed from the study.

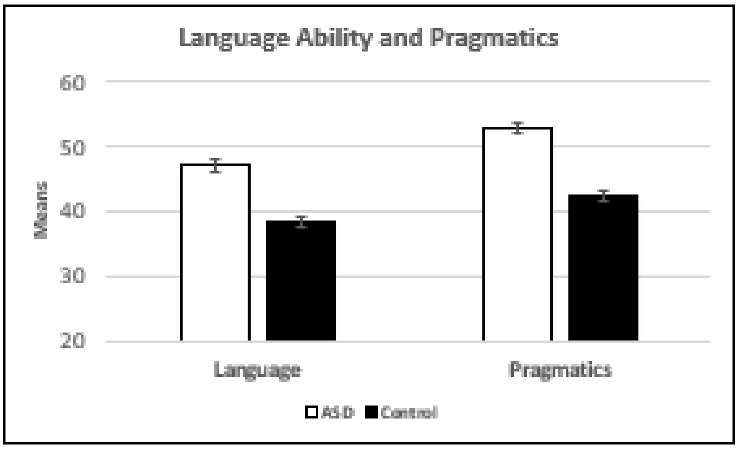
Results

ASD vs. Control

We began the analysis by comparing autistic children to controls. Before, proceeding with the inferential analyses, we checked the data for outliers using +/- 3 SDs from the mean, we also ensured that the data was normally distributed. The means are presented in Figure 1. Independent samples *t*-tests showed significant differences: language ability $t(131) = 6.87$, $p < .001$ ($d = 1.20$) and pragmatics $t(131) = 9.08$, $p < .001$ ($d = 1.58$). As a follow up analysis, we conducted two ANCOVAs with the inclusion of age (of the child) and gender as a covariates. For language abilities, the ASD vs. control effect remained significant $F(1,128) = 36.57$, $p < .001$, $\eta^2 = .22$ but age $F(1,128) = 3.39$, $p = .068$, $\eta^2 = .026$ and gender $F(1,128) = 3.11$, $p = .080$, $\eta^2 = .024$ were not significant. For pragmatics, the ASD vs. control effect remained significant $F(1,128) = 74.76$, $p < .001$, $\eta^2 = .37$, and gender was not significant $F(1,128) = .47$, $p = .495$, $\eta^2 = .004$. However, age was a significant factor with respect to pragmatics $F(1,128) = 13.46$, $p < .001$, $\eta^2 = .095$ (see Figure 2).

Figure 1

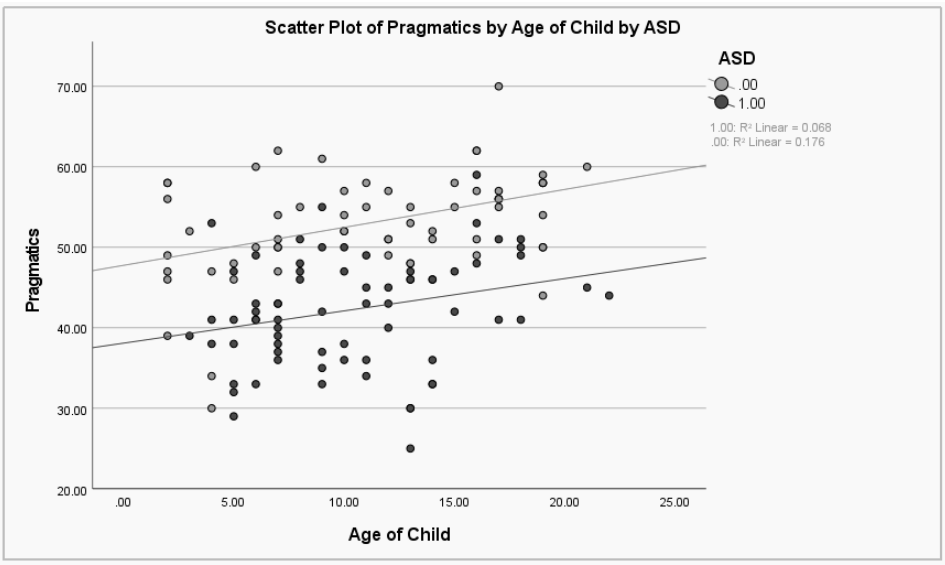
Means for Language Ability and Pragmatics by Group.



Note. Error bars show the standard error of the mean.

Figure 2

Scatterplot of Age by Group Effect on Pragmatics.



Discriminant Analysis

The two groups differed in language abilities and pragmatics. We conducted a discriminant analysis in order to determine whether the results from the questionnaire could be used to predict group classification (ASD vs. control). The results from that analysis showed that 79.5% of control cases were correctly predicted, and 86.7% of ASD cases were correctly predicted. Thus, in total, 82.7% (approximately 4 out of every 5 cases) were correctly predicted (Wilk's $\lambda = .592$).

Psychometric Analysis

Factor Structure

We conducted two factor analyses (one for each sub-scale) using principle components extraction on SPSS to assess the underlying factor structure, and to validate the sub-scale items as loading on the same construct (i.e. language abilities and pragmatics, respectively). Results for the factor analysis on language ability items showed that one item (item 7) did not load significantly on Factor 1. The factor loading of item 7 was -.151. We therefore removed that item. The results for the pragmatics sub-scale likewise showed one item (item 33) that did not load significantly on Factor 1. The factor loading of item 33 was .141. This item was also removed. The results of the two factor analyses (following item removal) are shown in Tables 2 and 3. Both showed that there were three factors, which had Eigenvalues > 1. However, Factor 1 in each analysis accounted for approximately 50% of the variance, and the other two factors accounted for a comparably smaller amount of variance.

For the interpretation of factor loadings, we used the recommendations of Stevens (2002) for determining significance. We interpreted factor loadings of .434 and greater as significant, which we highlighted with grey shading in Table 3. As can be seen in Table 3, all items loaded highly and significantly on Factor 1 for both sub-scales. For language abilities, there were four significant factor loadings on Factor 2 and two significant factor loadings on Factor 3. However, for all five of these "additional" significant factor loadings, the factor loading was numerically lower than the factor loading on Factor 1. In addition, the factor loadings were a mix of positive and negative for Factor 2. Similar results obtained for the pragmatics sub-scale. Thus, this analysis shows that the items load primarily on the same construct (or factor) and show a high degree of overlapping variance.

Internal Consistency

We examined the internal reliability of the items on each sub-scale. We found that Cronbach's alpha for language ability was .90. Similarly, for pragmatics, Cronbach's alpha was .94. This shows excellent internal reliability for both sub-scales.

Table 2

Results of Factor Analyses.

Language Abilities	*Eigenvalue*	*% of Variance*
Factor 1	*5.981*	*46.006*
Factor 2	*1.604*	*12.335*
Factor 3	*1.120*	*8.614*
Pragmatics	*Eigenvalue*	*% of Variance*
Factor 1	*9.558*	*50.308*
Factor 2	*1.458*	*7.673*
Factor 3	*1.040*	*5.475*

Table 3

Factor Loadings: grey highlighting indicates significance.

Language Abilities		*F1*	*F2*	*F3*
Item 1		*.579*	*-.264*	*.517*
Item 2		*.624*	*-.540*	*-.138*
Item 3		*.690*	*-.606*	*-.041*
Item 4		*.553*	*.267*	*.419*
Item 5		*.630*	*-.149*	*-.591*
Item 6		*.794*	*-.214*	*-.121*
Item 7				
Item 8(R)		*.623*	*.527*	*.006*
Item 9(R)		*.713*	*.293*	*.077*
Item 10	*.860*	*-.156*	*.079*	
Item 11	*.615*	*.199*	*.058*	
Item 12	*.742*	*.242*	*-.195*	
Item 13(R)		*.575*	*.449*	*-.363*
Item 14	*.744*	*.044*	*.327*	

Pragmatics		*F1*	*F2*	*F3*
Item 15	*.553*	*.495*	*-.288*	
Item 16	*.769*	*-.386*	*-.154*	
Item 17	*.500*	*-.099*	*.525*	
Item 18	*.754*	*.112*	*-.332*	
Item 19(R)		*.724*	*-.283*	*-.149*
Item 20	*.803*	*-.030*	*.137*	
Item 21(R)		*.864*	*.108*	*.025*
Item 22(R)		*.559*	*-.600*	*-.107*
Item 23	*.710*	*.111*	*-.169*	
Item 24	*.801*	*-.044*	*.276*	
Item 25	*.689*	*-.044*	*-.052*	
Item 26	*.708*	*-.133*	*.299*	
Item 27	*.498*	*.480*	*.253*	
Item 28(R)		*.628*	*.135*	*-.421*
Item 29(R)		*.711*	*.343*	*.179*
Item 30(R)		*.687*	*.058*	*.105*
Item 31(R)		*.680*	*-.034*	*-.019*

Item 32	*.807*	*.200*	*-.091*
Item 33			
Item 34	*.846*	*.055*	*.064*

Discussion

The results of Experiment 1 revealed that the questionnaire showed significant differences between autistic children and typically-developing controls. We also observed that age had a significant effect on pragmatics sub-scale, but results for language ability showed that age and gender were not significant. Moreover, the discriminant analysis showed that approximately 4 out of 5 cases could be correctly predicted just based on the two sub-scales of the questionnaire. This indicates reasonably good diagnostic utility of the questionnaire.

The psychometric analysis of the questionnaire showed that there were two items that did not load on the expected factors (Item 7 – *my child has developed a strong vocabulary in an area of interest very quickly* and Item 31 – *my child makes up their own words*). Results of factor analyses on the remaining 32 items showed that in general Factor 1 (of each sub-scale) accounted for approximately 50% of the variance, and that the other two significant factors showed very few (and inconsistent) significant factor loadings. In short, Factor 1 was substantially larger than Factors 2 and 3, and all items loaded significantly on Factor 1. These results show that the sub-scale questions were highly related to one another and tap into the same underlying construct (i.e. language abilities and pragmatics, respectively). Internal consistency for the sub-scales was good, as alpha's were > .90. We used the revised questionnaire in Experiment 2.

Experiment 2

The purpose of the second study was to provide an initial validation of the questionnaire. We did so by testing a second sample of participants, and by simultaneously having parents complete two sub-scales of the AQ questionnaire (Baron-Cohen et al., 2001). The sub-scales were social skills and communication. The general procedure of Experiment 2 was similar to Experiment 1. To establish convergent validity, a new instrument should be compared to closely related constructs (i.e., a similar questionnaire). For Experiment 2, we examined convergent validity with the AQ.

Methods

Participants

One hundred and twenty-eight parents, all of whom were parents to at least one child, were recruited via opportunity sampling. Exclusion criteria included answering less than half of the questions and answering *no* to the question "is your child verbal". The data from 31 participants was removed because of these exclusions, and thus, the final sample consisted of 97 participants. The age and gender of the 97 children is presented in Table 4. Further demographic information about the sample is presented in Appendix C.

Table 4

Age and Gender for ASD and Control Group.

	ASD(70)	Controls(27)	Significance
Variable	Mean(SD)	Mean(SD)	
Age of child[1]	10.36 (5.67)	6.26 (3.96)	$t(53) = -2.99, p = .004$
Age range of children	3-18 years	3-18 years	
Gender of Child (% male)	67.1	40.7	$t(95) = -1.96, p = .052$

Note. Numbers in parentheses refer to number of participants in each group. [1]48 parents did not report their child's age.

Materials

Language and Pragmatics Questionnaire (Appendix B)

The questionnaire consisted of two parts: language ability (13 statements) and pragmatics (19 statements).

Autism-Quotient (AQ; Baron-Cohen et al., 2001; Appendix D)

The AQ is a self-report measure of autistic traits, consisting of 50 items assessing ASD symptomology in five areas: social skills, attention switching, attention to detail, communication, and imagination. Answers are given on a four-point Likert scale from 'Definitely Agree' to 'Definitely Disagree'. 'Definitely Agree' and 'Slightly Agree' score one point on certain items. 'Definitely Disagree' and 'Slightly Disagree' score one point on other items. Scores on the AQ are summed and can range from 0 to 50 with a higher score indicating that the individual possesses a higher level of ASD traits. For the purposes of the study, the two sub-scales of the AQ were also summed.

Design and Procedure

A recruitment flyer for this study was shared by the researcher on Facebook and LinkedIn. Additionally, it was emailed to the headteachers of local primary schools and published in the closed Charity Facebook page 'SPACE', a support group for parents of children with ASD and other neurodivergent disorders in Hertfordshire. The link to the online study was attached to this flyer. Because this study was conducted at the height of the COVID pandemic, we had a number of participants who were currently awaiting an ASD diagnosis, and thus, were strongly suspected of having ASD. We included these "strongly suspected" cases of ASD in the study.

Participants first read the information sheet, which explained that the aim of the study was to explore the predictors of language development in children with and without ASD and described the measures that would be used. It also explained that the study would take no longer than 20 minutes to complete and participants could withdraw at any point. Participants gave informed consent and confirmed that they were over the age of 18 before giving demographic information based on their child. If participants answered "no" to the question *is your child verbal* they were directed to the end of the study and were advised to email the researcher for the debrief.

Upon completion of the demographic questionnaire, participants were presented with the social skills and communication items from the AQ (see Appendix D) followed by the language abilities and pragmatics items. They were then presented with the debrief, which reiterated the aims of the study and the right to withdraw. Participants were asked one final time to consent to their data being used.

Results

ASD vs. Control

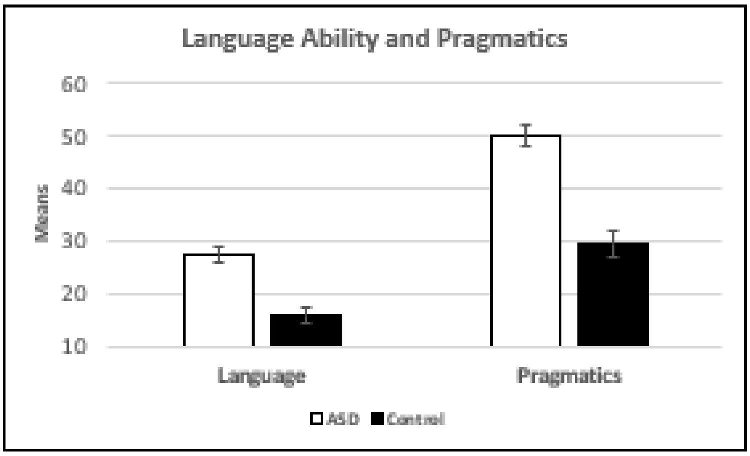
We began the analysis by comparing the ASD participants to controls. The means for both sub-scales are presented in Figure 3. Independent samples *t*-tests showed significant differences: language ability $t(95) = -5.50$, $p < .001$ ($d = -1.25$) and pragmatics $t(95) = -7.13$, $p < .001$ ($d = -1.62$). As a second analysis, we conducted the same analysis but with the inclusion of gender as a covariate. (There were too many missing data points to include age in this analysis.) For language abilities, the ASD effect remained significant $F(1,94) = 25.96$, $p < .001$, $\eta^2 = .22$, but gender was not significant $F(1,94) = 3.26$, $p = .074$, $\eta^2 = .034$. For pragmatics, the ASD effect remained significant $F(1,94) = 45.80$, $p < .001$, $\eta^2 = .33$, and gender was again not significant $F(1,94) = 1.39$, $p = .242$, $\eta^2 = .015$.

Discriminant Analysis

The two groups differed in language abilities and pragmatics. We conducted a discriminant analysis in order to determine whether the results from the questionnaire could be used to predict group classification (ASD vs. control). The results from that analysis showed that 88.9% of controls were correctly predicted, and 82.9% of ASD cases were correctly predicted from the two sub-scales. In total, 84.5% (approximately 4 out of every 5 cases) were correctly predicted (Wilk's $\lambda = .649$).

Figure 3

Means for Language Ability and Pragmatics by Group.



Note. Error bars show the standard error of the mean.

Psychometric Analysis

Factor Structure

We conducted two factor analyses (one for each sub-scale) using principle components extraction on SPSS to assess the underlying factor structure. The results of the factor analyses are shown in Tables 5 and 6. For language abilities, there were two significant factors, and for pragmatics, there were three factors. However, Factor 1 in each analysis accounted for approximately 50% of the variance, and the other factors accounted for a much smaller proportion of variance. For the factor loadings, we interpreted factor loadings of .512 and greater as significant (Stevens, 2002). As can be seen in the Tables below, for language abilities, item 4 did not load significantly on Factor 1. Likewise, for pragmatics items 16 and 22 did not load significantly on Factor 1. We return to these items in the General Discussion, but in the end, we elected to remove Items 4 and 22 from the final version of the questionnaire (Item 4 – *my child does not respond to their own name*; Item 22 – *my child does not use communicative or symbolic gestures*). As in the previous study, there were several significant factor loadings on Factors 2 and 3. The significant ones for language abilities were item 2, 3, and 4. Items 2 and 3 showed negative factor loadings, and item 4 was the item with a non-significant loading on Factor 1. For pragmatics, item 16 showed a significant (negative) loading on Factor 2, item 22 showed a large and significant loading on Factor 3, and item 28 showed a nearly identical positive loading on Factor 2, as compared to Factor 1. Overall, virtually all items showed significant and high factor loadings on Factor 1.

Internal Consistency

We examined the internal reliability of the sub-scales. We found that Cronbach's alpha for the language ability items was .90. Similarly, for the pragmatics items, Cronbach's alpha was .93. These analyses show excellent internal reliability.

Table 5

Results of Factor Analyses.

Language Abilities		
	Eigenvalue	*% of Variance*
Factor 1	*5.989*	*46.069*
Factor 2	*1.587*	*12.206*
Pragmatics		
	Eigenvalue	*% of Variance*
Factor 1	*8.736*	*45.980*
Factor 2	*1.414*	*7.440*
Factor 3	*1.096*	*5.767*

Table 6

Factor Loadings: grey highlighting indicates significance.

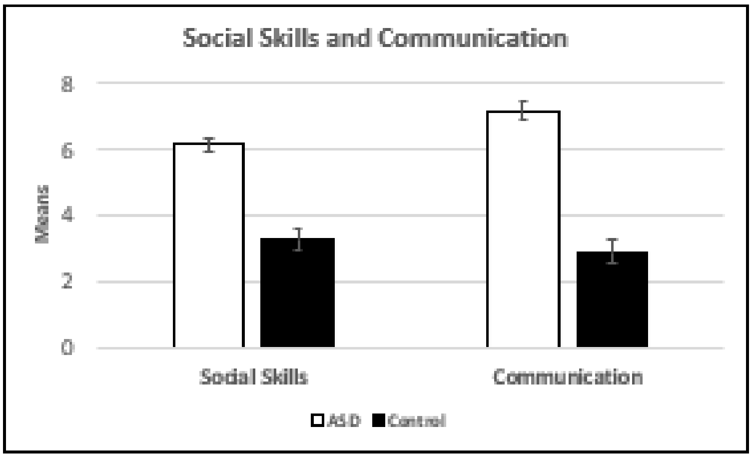
Language Abilities			***Pragmatics***			
	F1	*F2*		*F1*	*F2*	*F3*
Item 1	*.626*	*-.034*	*Item 14*	*.657*	*.246*	*.308*
Item 2	*.754*	*-.546*	*Item 15*	*.612*	*-.288*	*-.073*
Item 3	*.761*	*-.538*	*Item 16*	*.423*	*-.595*	*.099*
~~*Item 4*~~	~~*.418*~~	~~*.624*~~	*Item 17*	*.745*	*.030*	*.073*
Item 5	*.718*	*-.169*	*Item 18(R)*	*.667*	*.176*	*-.251*
Item 6	*.774*	*-.002*	*Item 19*	*.754*	*-.210*	*.026*
Item 7(R)	*.669*	*.288*	*Item 20(R)*	*.755*	*-.071*	*-.072*
Item 8(R)	*.551*	*-.108*	*Item 21(R)*	*.706*	*-.099*	*-.119*
Item 9	*.827*	*-.260*	~~*Item 22*~~	~~*.326*~~	~~*.275*~~	~~*.770*~~
Item 10	*.506*	*.159*	*Item 23*	*.773*	*-.065*	*.028*
Item 11	*.717*	*.437*	*Item 24*	*.705*	*-.415*	*.363*
Item 12(R)	*.604*	*.406*	*Item 25*	*.716*	*.028*	*-.255*
Item 13	*.769*	*.193*	*Item 26(R)*	*.805*	*.008*	*-.076*
			Item 27(R)	*.698*	*.257*	*.093*
			Item 28(R)	*.536*	*.561*	*.024*
			Item 29(R)	*.641*	*.297*	*-.247*
			Item 30	*.756*	*.170*	*-.135*
			Item 31	*.747*	*-.094*	*-.109*
			Item 32	*.661*	*-.239*	*.016*

Concurrent Validity

We observed significant differences between children with ASD and controls for the two AQ sub-scales: social skills $t(95) = -8.64$, $p < .001$ ($d = -1.96$) and communication $t(95) = -10.23$, $p < .001$ ($d = -2.31$) (see Figure 4). Social skills correlated with language ability $r = .60$, $p < .001$ and pragmatics $r = .69$, $p < .001$. Communication correlated with language ability $r = .65$, $p < .001$ and pragmatics $r = .74$, $p < .001$. For both analyses, we expected pragmatics to correlate more highly with the AQ sub-scales as compared to language abilities, and that expectation was confirmed. Thus, the language and pragmatics questionnaire patterns similarly to the AQ, which given that is it designed to assess ASD symptomology, demonstrates good convergent validity.

Figure 4

Means for Social Skills and Communication by Group.



Note. Error bars show the standard error of the mean.

Discussion

The results of Experiment 2 were largely similar to those of Experiment 1. We observed significant differences between autistic children and controls on both language abilities and pragmatics. Both showed nearly identical effect sizes, as compared to Experiment 1. Moreover, the discriminant analysis showed that 4 out of 5 cases could be correctly predicted based on the means of the questionnaire.

The results of the factor analyses also showed similar results as Experiment 1. However, there were a couple of unexpected findings. In particular, two of the items (items 4 and 22) did not show significant factor loadings on "Factor 1". These two items did show significant factor loadings in Experiment 1. Overall, however, the results of the factor analyses did show similar results in terms of the proportion of variance explained, and all of the other items did show significant factor loadings, as compared to the results of the factor analyses in Experiment 1. In terms of reliability, there was again excellent internal reliability for both sub-scales.

The examination of convergent validity with the AQ questionnaire, showed that the language abilities and pragmatics were highly correlated with the social skills and communication sub-scales of the AQ. These correlations mirror the large effects sizes between groups on both the AQ and the language abilities and pragmatics sub-scales, and suggest that both questionnaires tap into similar underlying constructs (i.e. language and communication issues associated with ASD symptomology). In short, we feel that these results demonstrate good convergent validity of our questionnaire.

General Discussion

The current study reports the initial development and validation of the language and pragmatics questionnaire, a new questionnaire that provides a quantitative measurement of individual differences in language abilities and pragmatics in autistic children based on parental report. Language-related problems are common across the lifespan in autistic individuals, and they are easy to screen for in childhood where certain developmental atypicalities, such as language delay, are manifestations of the later social communication difficulties, which are diagnostic characteristics of ASD. Atypical language abilities and pragmatics have long been identified in ASD as being problematic issues. Impairments in abilities within these domains have been related to poorer outcomes in language-specific developmental milestones, educational achievements, and social integration (Delehanty et al., 2018; Wetherby et al., 2004; Asher & Gazelle, 1999; Kim, Bal & Lord, 2018). Importantly, however, these negative outcomes can be mitigated by protective factors, such as age of diagnosis, early intervention, and parental involvement (Clark et al., 2018; Sandbank et al., 2020; De Froy et al., 2021). Therefore, we believe that an instrument that assists in supporting protective factors, and that is specifically designed to quickly and reliably screen for these issues, will be beneficial in better outcomes for autistic individuals, ultimately leading to less debilitation in wider societal contexts.

We investigated this new instrument as a predictor of ASD cases in two samples of children, approximately two-thirds of which had (or were strongly suspected to have) ASD.

Our objective was to determine whether this new questionnaire would be an effective means of screening these two key issues in ASD. Across two samples, we observed significant differences between typically-developing children and autistic children. Moreover, the instrument was shown to have (1) excellent internal reliability (alpha's being .90 or greater), (2) strong predictive validity, given that 4 out of 5 individuals could be correctly classified, and (3) good convergent validity, as assessed via correlations with the AQ questionnaire (correlations > .60). We feel that the main benefit of this questionnaire is the quick and easy administration (i.e. parental report taking approximately 10-12 minutes), and the fact that it is free and does not require a trained researcher to administer. Based on these positive results, we strongly suspect that this questionnaire can be utilised as a screening device in routine clinical assessments, in educational contexts, and for research purposes, similar to the way in which the AQ is so often used in adult samples.

Based on the results of two sets of factor analyses, we proposed to eliminate several questions from the final version of the questionnaire. This leaves 30 questions in the final version (LAP 1.1.0), which is available in Appendix B. Moreover, the factor analyses showed largely consistent results, and that, outside of the four excluded items, all items loaded significantly on Factor 1, which accounted for approximately half of the variance. The one exception to this was item 16 in Experiment 2. We elected to retain this item in the questionnaire given (1) that it did load significantly in Experiment 1 and (2) that the factor loading just missed significance and did not show a significant positive loading on another factor. (Note also that with a larger sample size, the factor loading in Experiment 2 would have been significant.) The results of the factor analyses suggest that items within each sub-scale are doing a reasonably good job of assessing the intended constructs. We also argued that significant factor loading on Factors 2 and 3 did not elucidate any meaningful sub-categories of items. Perhaps, the only exception to this is the significant (positive) factor loadings on Factor 2 (Experiment 1). Item 8 (responsive to speech) and Item 13 (follow directions) would both seem to involve interaction with an interlocuter. We think that this possibility would need to be addressed in future studies, and these items did not pattern, as such, in Experiment 2.

To this point in the discussion, we have focused on the positive results achieved in Experiments 1 and 2. We also think it is important to highlight the aspects of the study that do not completely fit with the overall narrative, and perhaps, lead to further questions and/or open potential issues with the data. The most obvious of these is the missing "age" data in Experiment 2. This was primarily due to the age question appearing at a place in the questionnaire where many parents, simply did not see it. Once the problem was brought to our attention, we changed the placement of this question and made it a required field. The missing age data prevented us from including it in the analyses of Experiment 2, which is unfortunate given there was a significant age effect on the pragmatics sub-scale in Experiment 1 (see Figure 2). With respect to gender, it did not produce a significant effect when included as a covariate in our models. However, it had a larger effect on language abilities, compared to pragmatics, in both Experiments. It is important to note, that the gender effect was inconsistent. In Experiment 1, females tended to show slightly worse language abilities, and in Experiment 2, the reverse occurred. However, gender was not statistically significant, and the mean differences were comparatively less than the between groups analysis. Finally, we think it is important to consider that our ASD samples contained a surprisingly high number of females, which is quite unusual. In fact, our ASD samples had a more even gender split, as compared to our control samples. This is quite unusual for an ASD study.

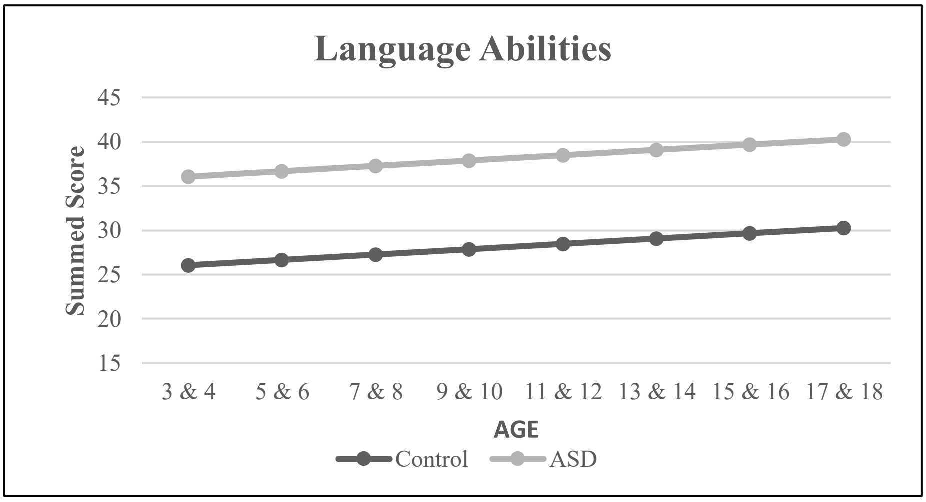
Questionnaire Interpretation

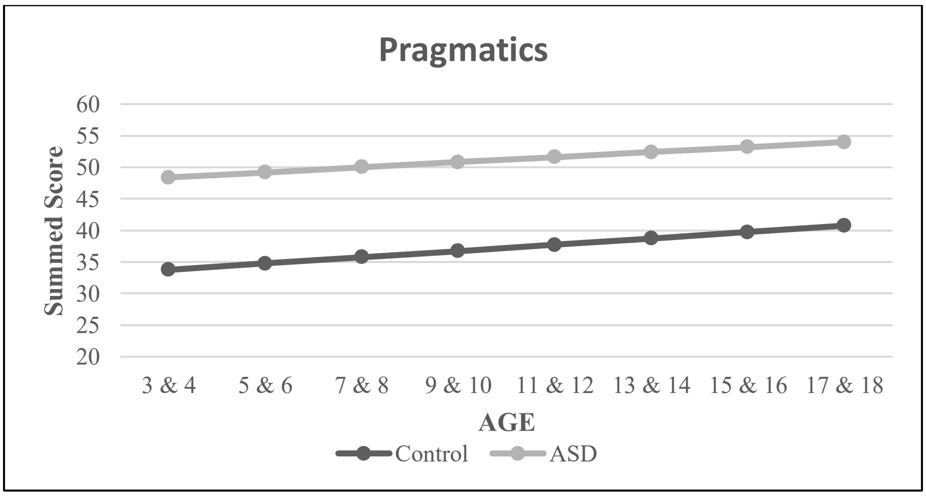
There are a couple of key findings, which need to be addressed with respect to how the questionnaire results for a particular individual can be interpreted. The first is that there were relatively large differences in the means between Experiment 1 and Experiment 2. Essentially, the means for Experiment 1 were higher than those in Experiment 2. We do not think that these differences are a problem because of a couple of key points with respect to the samples. Most importantly the **summed** results for Experiment 2 were based on two fewer items, and hence, means were expected to be lower. Second, the controls for Experiment 2 were substantially younger, and across all of our data, we observed that parents generally rated the language abilities and pragmatics of older children as being worse (more atypical), even for controls, as compared to younger children. At first glance, this is a counterintuitive result given that these abilities should **improve** across the course of development (i.e., become more normalised over time). This is most easily seen in Figure 2, where the slope of the best fit lines are positive. In early language development there is inherently more variability between children, and over the course of development, children become more adultlike. In general, much of language development is completed by the age of 8. Parents, then, likely become more aware of their child's issues as they get older because (1) they have more interactions with their children and those interactions become more adultlike, and (2) they likely have more insights into how their child may or may not differ from other children of the same age. In short, in early childhood parents generally feel better about their child's language and pragmatic abilities, and as time progresses, they can more easily identify, and cast a critical eye, toward deficiencies or issues. Thus, positive sloped lines are likely not as problematic as they would seem at first sight.

Turning to the issue of interpretation, we first had to address that the final version of the questionnaire contains two fewer items than the version used in Experiment 2. Second, we pooled the data from both experiments to determine the expected intercepts and slopes. Essentially, we ran simple regressions, regressing age on language abilities and age on pragmatics. The results from our analyses are presented in Figure 5. As can be seen in Figure 5, we grouped age into two-year bins from 3 to 18 years of age (8 bins in total). Using these figures, a researcher or a clinician should be able to interpret the scores for a particular individual to determine whether they are at risk or not. Scores above the orange line would be a clear indicator of potential ASD symptomology and scores below the blue line would be an indicator of typical development. Individuals falling in the middle would be less clear, but useful information can be gained by proximity to either line.

Figure 5

Interpretation Plots Based on Combined Data from Experiments 1 and 2.





Strengths and Limitations

The main strengths of this study are the large sample size for ASD participants, particularly for females in the ASD group(s), and the clear results relating to group differences. The effect sizes for language abilities was nearly identical for Experiment 1 and Experiment 2, and the pragmatics sub-scales showed even larger effect sizes and again, a high degree of similarity. There are a few limitations, and most are related to Experiment 2. The first is the missing age information in Experiment 2, and relatedly, the substantially younger age of control participants (for those reporting age). Moreover, those younger control participants were given quite low ratings for language abilities (i.e. parents rated the language of their child as being quite "good"). Thus, we ended up with overall lower means for Experiment 2, but particularly on language abilities. We took these factors into account when developing the interpretation figures (see Figure 5).

There are also a few outstanding psychometric issues, which need to be addressed in future studies. Test-retest reliability has not been assessed. Likewise, the divergent validity of the questionnaire remains, at this point, unexplored.

Conclusions

We believe that our questionnaire will be a useful tool because it can be used in both research and clinical settings and assesses (very broadly) the particular language issues experienced by autistic children. Furthermore, because it relies on parental report, its administration takes approximately 10 minutes, which is extremely useful in both research and clinical settings. It could also be easily modified for teacher report, and thus, could be also useful in an educational context, particularly for educators and/or educational psychologists, who would like to highlight language issues in a child for parents. We more than welcome further refinements of this questionnaire, and are happy to cooperate with any research groups, who use it or attempt to improve it.

In summary, this study provides an initial assessment and validation of a new tool for measuring language abilities and pragmatic abilities in children. The instrument was shown, in two experiments, to have more than acceptable psychometric properties. Language is an important skill to success in every aspect of life, and individuals who cannot communicate effectively will experience distress, isolation, and difficulty functioning. Children, particularly those with ASD, need intervention to focus on language, but probably more importantly, on how to communicate effectively. Early intervention for autistic children is crucial in predicting positive outcomes. The instrument reported in this study can be used in the screening process prior to these intervention strategies.

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APPENDIX A

Table A

Demographic Information for Experiment 1.

Variable	Controls (60)	ASD (77)
Gender of parent		
Male	1(1.7)	7(9.1)
Female	59 (98.3)	70(90.9)
Number of children	2.17 (.72)	2.36 (.83)
Age of parent		
18-24	2 (3.3)	1 (1.3)
25-30	0 (0)	3 (3.9)
31-40	15 (25)	28 (36.4)
41-50	38 (63.3)	36 (46.8)
51-50	4 (6.7)	7 (9.1)
61 or over	1 (1.7)	2 (2.6)
Parent's income		
Low	17 (28.3)	29 (37.7)
Low-average	22 (36.7)	32 (41.6)
High-Average	17 (28.3)	12 (15.6)
High	2 (3.3)	4 (5.2)
Household income		
Low	4 (6.7)	11 (14.3)
Low-average	12 (20)	36 (46.8)
High-average	35 (58.3)	24 (31.2)
High	8 (13.3)	5 (6.5)
Parent Education		
Less than school	1 (1.7)	2 (2.6)
GCSE's/A Levels	18 (30)	22 (28.6)
Certificate	4 (6.7)	9 (11.7)
Diploma	6 (10)	16 (20.8)
Bachelor's degree	21 (35)	21 (27.3)
Master's degree	9 (15)	6 (7.8)
Doctoral degree	0 (0)	1 (1.3)

APPENDIX B

Language and Pragmatics Questionnaire (LAP version 1.1.0)

Sex of your child:

Male/Female

Age of your child:

Age of diagnosis:

How to fill out the questionnaire

Below is a list of statements. Please read each statement very carefully and rate how strongly you agree or disagree with it by circling your answer.

Language ability:

1) My child does not speak or uses very limited speech
2) My child's first words were delayed
3) My child was a late speaker compared to children of the same age
4) At some point, my child has been in the low ability reading group at school
5) The teacher has expressed concern about my child's language abilities
6) My child is responsive to the speech of others
7) My child's vocabulary is similar to his/her peers
8) As a parent, I have felt concerned about my child's language development
9) My child has experienced the loss of words they were previously able to say
10) Understanding simple statements and answering questions is hard for my child
11) My child is able to follow directions and find objects that are named
12) Verbal communication is difficult for my child

Pragmatics:

13) Non-verbal communication is difficult for my child
14) My child says things with little or no content or information.
15) I have heard my child imitating learned scripts, such as those heard during television adverts
16) It is difficult for my child to communicate their needs and desires
17) My child is able to stay on topic during conversations and storytelling
18) My child uses odd phrases and choices of words

19) My child is able to change their language appropriately according to the needs of a listener or situation

20) My child is able to initiate and hold fluent conversations

21) My child demonstrates one-sided interactions

22) My child repeats words or phrases without communicative intent

23) My child speaks in an abnormal tone of voice, or with an off rhythm or pitch

24) It is difficult for my child to understand/monitor the emotions of others

25) My child is able to produce emotional language

26) It is not difficult for my child to share their emotions with others

27) My child is able to make eye contact with people and objects

28) Peer interaction is easy for my child

29) My child takes what is said too literally, often missing the humour, irony, and sarcasm

30) My child uses unusual or inappropriate body language, gestures, and facial expressions ---

<u>Scoring:</u>

4 = Strongly agree 3= Agree 2= Disagree 1= Strongly disagree

Reverse scoring for items in blue font

APPENDIX C

Table B

Demographic Information for Experiment 2.

		Suspected or Diagnosed ASD		No Suspected or Diagnosed ASD	
		N	*Percentage*	*N*	*Percentage*
Child Gender	Male	50	68.5%	12	38.7%
	Female	21	28.8%	19	61.3%
	Other	2	2.7%	0	0%
Child Ethnicity	Mixed/Multiple Ethnic Groups	5	6.8%	4	12.9%
	White	67	91.8%	27	87.1%
	Asian	0	-	-	-
	Black/African/Caribbean	1	1.4%	-	-
Relation to Child	Mother	72	98.6%	28	90.3%
	Father	0		2	6.5%
	Other	1	1.4%	1	3.2%
Parental Qualification Level	GCSEs/O-levels	12	16.4%	5	16.1%
	A-levels	11	15.1%	4	12.9%
	Undergraduate Degree	27	37.0%	8	25.8%
	Postgraduate Degree	20	27.4%	10	32.3%
	PHD	3	4.1%	4	12.9%
Household Income	£10,000-£19,999	9	12.3%	7	22.6%
	£20,000-£29,999	12	16.4%	3	6.5%
	£30,000-£39,999	9	12.3%	5	16.1%
	£40,000-£49,999	9	12.3%	0	0%
	£50,000-£99,999	21	28.8%	14	45.2%
	£100,000+	11	15.1%	2	6.5%
Speech and Language Disorder	Yes	18	24.7%	4	12.9%
	No	55	75.3%	27	87.1%
SLT Input	Yes	44	60.3%	7	22.6%
	No	29	39.7%	24	77.4%
Hours of SLT Input	Less than 5 hours	11	15.1%	2	6.5%
	6-10 hours	10	13.7%	1	3.2%
	21-30	8	11.0%	2	6.5%
	31+ hours	14	19.2%	2	6.5%
Verbal Older Siblings	Yes	35	47.9%	17	54.8%
	No	38	52.1%	14	45.2%

Number of Older Siblings	1	21	28.8%	11	35.5%
	2	9	12.3%	6	19.4%
	3	2	2.7%	-	-
	4+	2	2.7%	-	-
	N/A	1	1.4%	-	-
Read to Child	Yes	73	100%	31	100%
	No	0	-	0	-
Frequency of Reading	Everyday	54	74%	24	77.4%
	2-6 times a week	17	23.3%	6	19.4%
	Less than twice a week	2	2.7%	1	3.2%

APPENDIX D

Social Skills Subscale of the Autism-Quotient

1. My child prefers to do things with others rather than on their own.
2. My child finds social situations easy.
3. My child would rather go to a library than a birthday party.
4. My child is drawn more strongly to people than things.
5. My child finds it hard to make new friends.
6. My child finds it easy to work out what someone is thinking just by looking at their face.
7. My child enjoys social situations.
8. My child finds it difficult to work out people's intentions
9. My child enjoys meeting new people.
10. My child is a good is good at taking care not to hurt other people's feelings diplomat

Communication Subscale of the Autism-Quotient

1. Other people frequently tell my child what they've said is impolite.
2. My child enjoys social chit-chat.
3. When my child talks, it isn't always easy for others to get a word in edgeways.
4. My child struggles to keep a conversation flowing with their peers.
5. My child finds it easy to 'read between the lines' when someone is talking to them.
6. My child knows how to tell if someone listening to them is getting bored.
7. When my child talks on the phone, they are not sure when it is their turn to speak.
8. My child is often the last to understand the point of a joke.
9. My child is good at social chit-chat.
10. People often tell my child that they are going on about the same thing.

CHAPTER 3 – DISFLUENCIES AS A DIAGNOSTIC MARKER

Abstract

The aim of this study was to investigate disfluencies made during speech in autistic adults, specifically filled pauses, repetitions and repairs. Previous literature has been consistent in showing significant differences between autistic individuals and typically-developing individuals in their rates of disfluency production, mainly showing that autistic individuals show significantly less *um*'s during speech and significantly more repairs. We hypothesised that we would replicate results from previous studies, and that we would be able to use these disfluencies as diagnostic markers for ASD in a discriminant analysis. Forty-two participants were recruited to test these hypotheses (20 with ASD and 22 typically-developing controls). Participants speech was analysed from administering the talking elements of ADOS-2 diagnostic interviews. Our results failed to replicate findings from previous studies, suggesting that we cannot use disfluent speech as diagnostic markers of autism. However, we found gender to be significantly correlated with most types of speech disfluency.

Keywords: Autism Spectrum Disorders, disfluency, filled pauses, repetitions, repairs

Speech Disfluencies as a Diagnostic Marker of Autism Spectrum Disorders

Language production in Autism Spectrum Disorder (ASD) is a widely researched area. Whilst atypical functional language is relatively common in autism, with some individuals possessing only minimal verbal skills (Tager-Flusberg, Paul & Lord, 2005), the use of pragmatic language is the only element of communication which is recognised as one of the diagnostic markers of ASD (American Psychiatric Association [APA], 2013). Language production is of fundamental importance in ASD, particularly in infancy and childhood, where language delay is one of the earliest indicators leading to a diagnosis of autism, and language milestones of ASD children tend to be divergent to those of typically-developing children (Eigsti, de Marchena, Schuh, & Kelley, 2011). Some language difficulties experienced by autistic children lessen as they reach adolescence, and they often develop functional language comparable to typically-developing individuals by the time they are adults (Brignell et al., 2018). However, pragmatic language skills remain universally atypical for autistic individuals across the lifespan (Eigsti et al., 2011).

Speech Disfluencies

There have been abnormalities observed in autistic individuals in their language production, even when they do possess functional language (i.e. they are verbal). One area of research that has gained considerable attention is disfluent speech, which is influenced by the pragmatic aspects of speech planning. Speech fluency, in this paper, is considered as the flow of spontaneous speech, and requires coordinated cognitive and linguistic processing to engage in continuous speech with minimal disfluency markers (Lickley, 2017; Pirinen et al., 2024; Starkweather, 1980). There are three types of disfluencies that are referred to as “typical” disfluencies. The first is filled pauses, also named interjections, which are defined as hesitation sounds (*um* or *uh*) that do not contribute to the meaning of the spoken utterance

(Pirinen, 2024). Filled pauses naturally occur in speech and are thought to be a signal of an upcoming delay (Clark & Tree, 2002). The second type of "typical" disfluency is repetitions, which occur when the speaker immediately repeats something they just said (Engelhardt, Alfridijanta, McMullon & Corley, 2017). Clark and Wasow (1998) suggest that it is common for a speaker to repeat a word or phrase to restore continuity following an abandoned utterance, even though it requires extra time and effort. The third type of "typical" disfluency is repairs, also known as false starts or revisions, which occur usually when a speaker changes their mind about what they have said, and corrects themselves with a new word or phrase (Clark & Wasow, 1998; Engelhardt et al., 2017). Speech disfluencies have been related to executive function and intelligence (Choo, Smith & Seitz, 2024; Engelhardt, Nigg & Ferreira, 2013), and have also been investigated in various other clinical subgroups, such as in Attention-Deficit/Hyperactivity Disorder (ADHD) and anxiety (Lee, Sim, Lee & Choi, 2017; Zhao, 2022).

Speech Disfluencies in Autism Spectrum Disorders

Filled Pauses

A large amount of research has explored the rate of filled pauses produced by autistic individuals during spontaneous speech. Gorman et al. (2016) investigated rates of *um* and *uh* produced by autistic children in a large study alongside children with a diagnosis of Specific Language Impairment (SLI), and typically-developing children. Whilst the rate of *uh* production was similar across all groups, autistic children produced significantly less *um*'s than the other two groups. This is particularly interesting considering that SLI is characterised by deficits with structural language, suggesting that filled pauses represent an almost exclusively pragmatic function. Irvine, Eigsti, and Fein (2016) replicated these findings in a sample of children, adolescents and young adults comprising an ASD group, typically-developing group and an "optimal outcome" group (those who received an ASD diagnosis at an early age, but did not meet ASD diagnostic criteria later in life). Irvine et al. (2016) found that, again autistic individuals produced significantly fewer *um*'s, but the same amount of *uh'*s. Considering that early diagnosis of ASD is mostly identified by language markers, it is interesting that the optimal outcome group did not display significant differences to the typically-developing group with the production of filled pauses. We can speculate that, as this group developed functional language and pragmatic language congruent to typically-developing individuals over time (enough to no longer meet diagnostic criteria for ASD), that they tend to produce a comparable rate of filled pauses due to typical pragmatic functioning at the time of the study. Across these studies, two things are worth noting. Firstly, that production of filled pauses, specifically *um*'s, were negatively related to scores on the Social Communication Questionnaire (SCQ, Rutter et al., 2013) but not with executive function, intelligence, or language ability (Irvine et al., 2016). Secondly, that the *um*/*uh* ratio in both of these studies were related to group status and scores on the SCQ, that is, the amount of *um*'s produced relative to the amount of *uh*'s. The *um*/*uh* ratio produced by autistic individuals is a finding that has been relatively consistent across literature (Lawley et al., 2023; Lunsford, Heeman, Black & van Santen, 2010).

This research provides strong evidence that production of filled pauses during spontaneous speech is atypical in autistic individuals. Researchers have suggested that filled pauses are a type of listener-oriented disfluency (Clark & FoxTree, 2002; Fox Tree, 2001; Irvine et al., 2016; Lake, Humphreys & Cardy, 2011; Maclay & Osgood, 1959). These researchers claim that filled pauses, most notably *um*'s, aid listener comprehension during a reciprocal conversation by signalling to the listener that they intend to hold the floor in the conversation but that there is going to be a pause or delay in their speech. Therefore, as ASD is characterised by atypical pragmatic functioning, it is understandable why it has been consistently shown that autistic individuals do not produce as many of these types of disfluencies as typically-developing individuals.

Repetitions

Disfluency research has also looked at the rate of repetitions made by autistic individuals during spontaneous speech. Lake et al. (2011) investigated disfluencies made by autistic adults by looking at language samples from conversations with a researcher who asked general questions related to their interests and hobbies. Lake et al. (2011) found that autistic individuals produced significantly more repetitions in their speech than typically-developing individuals. Shriberg et al. (2001) analysed speech samples from Autism Diagnostic Observation Schedule (ADOS) interviews (Lord, Rutter, DiLavore & Risi, 2000) and found that individuals with high-functioning autism and Asperger's syndrome had significantly higher syllable and word repetitions than the control group. Similarly, Suh et al. (2014) analysed samples from the narrative storytelling element of the Module 3 ADOS interview (Lord et al., 2000) with high-functioning autistic individuals, "optimal outcome" individuals and typically-developing individuals. Suh et al. (2014) found that high-functioning autistic individuals produced significantly more repetitions than the typically-developing group, but there were no significant differences observed with the "optimal outcome" group.

Whilst there has been strong evidence to suggest that autistic individuals produce significantly more repetitions in speech, some research (for example, Engelhardt et al., 2017) has contradicted this finding and found no significant differences between ASD and typically-developing individuals when controlling for individual differences in intelligence and working memory. However, Engelhardt et al. (2017) analysed speech samples in a highly controlled laboratory task, so the production of speech was not necessarily representative of natural conversation.

There is debate in the literature about whether repetitions are a type of listener-oriented or speaker-oriented disfluency, with some suggesting that they are attempts to restore fluency and hold the conversation (Clark & Wasow, 1998), and others suggesting that they benefit the speaker when they experience errors in their plan of speech (Lake et al., 2011).

Repairs

The disfluency research concerning repairs produced by autistic individuals is mixed. In the Shriberg et al. (2001) study, analysed speech samples from ADOS interviews, it was found that autistic individuals produced significantly more repairs than typically-developing individuals. 66% of autistic individuals noted as having Asperger's syndrome and 40% of those identified as having high-functioning autism showed disfluent speech in terms of single-word revisions in more than 20% of their utterances. Furthermore, in the study by Suh et al. (2014) which also looked at individuals in an "optimal outcome" group, there was a significant main effect of group for self-corrections. Those with high-functioning autism and those in the "optimal outcome" group both produced significantly more self-corrections than the typically-developing control group. There were no significant differences between the high-functioning autism group and the "optimal outcome" group.

In contrast, the disfluency study by Lake et al. (2011) found that autistic individuals produced significantly fewer revisions than the control group. Research by Belser and Sudhalter (2001) supports this finding, however the autistic individuals in this study possessed a much lower level of functioning, perhaps highlighting a broader language issue in these specific participants. The autistic participants in the Lake et al. (2011) study were all in the normal range of verbal intelligence.

Repairs in spontaneous speech represent detection of an error in the plan of speech, or when a person changes their mind about what they are going to say (Engelhardt et al., 2017). Because it's unclear how often repairs are produced in speech by autistic individuals, we cannot conclude whether autistic individuals make fewer or more mistakes in spontaneous speech. Furthermore, Lake et al. (2011) suggested that fewer revisions may represent an insufficient ability to detect their own formulation problems, making the speaker less likely to repair the issue for the benefit of the listener. Given the mixed findings on repairs, it remains open as to whether this process occurs more or less frequently in autistic individuals.

The Current Study

A lot of prior research has investigated the production of typical disfluencies in autistic populations, namely filled pauses, repetitions and repairs. Whilst there have been some relatively consistent results across the literature, most notably with *um*/*uh* ratio, *um* production and repetitions, there have been mixed results with regards to repairs. Our study aimed to replicate findings from previous studies, and provide further evidence for areas that remain unclear. Importantly, with these findings, we aimed to determine whether we could use disfluency as diagnostic marker of ASD. Pragmatic communication is the key diagnostic criteria that is used in autism assessments (APA, 2013), but disfluent speech is not currently a factor which is looked at when making diagnostic decisions. If production of speech disfluencies are consistent across autistic individuals, they may be utilised as a measuring, or even screening, tool for these assessments. Disfluency studies would therefore have significant clinical value.

We proposed four hypotheses:

1) *Um*/*uh* ratio can be used to predict ASD group status. For the ASD group, this is expected to be around .5, and is expected to be around .75 for the control group (Engelhardt et al., 2017).
2) Autistic individuals will produce more repetitions, but these will be related to verbal abilities,

3) Autistic individuals will differ from typically-developing individuals in their production of repairs, but we do not know in which direction this will be,
4) A discriminant analysis will allow us to determine group membership based on disfluency rate.

Methods

Participants

Forty-two undergraduate students participated in this study. There were 20 who confirmed a formal diagnosis of ASD, and 22 typically-developing adults who were tested as control participants (see Table 1). All were students at the University of East Anglia (UEA) and were native speakers of English, which was specified in the eligibility criteria for the study. The ASD group were recruited from advertisements that were placed around campus, and also in forums for students in the Neurodivergent Society at UEA (Appendix A). The control group were recruited through the SONA Research Participation System at UEA.

Table 1

Means for demographic variables, vocabulary, and ASD screening measures.

	ASD (20)	Control (22)	Significance
Variable	Mean (SD)	Mean (SD)	
Age	20.0 (1.78)	19.91 (2.52)	$t(40) = 0.13, p = .89$
Gender (% male)	50.0	22.7	$t(37) = 2.06, p < .05$
AQ SS	6.30 (1.89)	2.41 (1.79)	$t(40) = 6.84, p < .001$
AQ AS	8.55 (1.93)	5.32 (2.06)	$t(40) = 5.24, p < .001$
AQ AD	6.80 (2.35)	5.73 (2.55)	$t(40) = 1.41, p = .17$
AQ COM	7.45 (2.61)	3.05 (2.40)	$t(40) = 5.70, p < .001$
AQ IMG	4.95 (2.35)	2.23 (1.60)	$t(40) = 4.23, p < .001$
AQ TOTAL	34.05 (9.14)	18.73 (6.16)	$t(40) = 6.42, p < .001$
PPVT	41.50 (7.54)	40.10 (8.95)	$t(40) = 0.55, p = .59$

Note. Two participants with ASD reported non-binary gender, and one control reported “other” gender. These participants were not included in any gender analysis.

Disfluency Coding

Three types of disfluency were examined: filled pauses, repetitions and repairs. Filled pauses were classed as *um*'s or *uh*'s. Repetitions occur when the speaker repeats a word or a string of words that has no functional benefit. Repairs were defined as when a speaker stops speaking, and starts over with a new word or phrase. The data was coded by an MSc student who was blind to study hypotheses.

Materials

Peabody Picture Vocabulary Test - 4 (PPVT-4)

The PPVT-4 (Dunn & Dunn, 2007) is a tool to assess receptive vocabulary. The researcher aurally presented a target word and participants were asked to choose the image which best illustrated the meaning between four. The reliability range for Form A (the one used in this study) is reported to be from .89 to .97.

Autism-Spectrum Quotient (AQ; Appendix B)

The AQ is a self-report measure of autistic traits (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001), consisting of 50 items assessing ASD symptomology in five areas (social skills, attention switching, attention to detail, communication, and imagination). Answers are given on a four-point Likert scale with the options 'Definitely Agree', 'Slightly Agree', 'Slightly Disagree' and 'Definitely Disagree'. Scores on the AQ are summed and can range from 0 to 50, with a higher score indicating that the individual possesses a higher level of autistic traits. For the purpose of the current study, subscales of the AQ were also summed. Descriptive statistics for total AQ score as well as subscale scores across both the ASD group and the control group can be seen in Table 1.

Autism-Diagnostic Observation Schedule – 2 (ADOS-2)

The ADOS-2 (Lord et al., 2012) is a standardised measure of various behaviours associated with ASD symptomology, used in the diagnostic assessment for ASD. In the current study, semi-structured interviews were administered with questions that were procured from the talking activities in the ADOS-2 Module 4 assessment, which is specifically designed for use with verbally fluent adolescents and adults. Specific subjects were covered in accordance with the ADOS-2, namely ‘current work or school’, ‘emotions’, ‘daily living’, ‘friends, relationships and marriage’, and ‘plans and hopes’ (see Appendix C). As the interview was semi-structured, there was a significant allowance for the conversation to digress. The aim of this was to ensure that the conversations remained as naturalistic as possible.

Procedure

When participants entered the lab, they were given a detailed information sheet to read, and the opportunity to ask any questions about the study. If they were happy to proceed, they were instructed to sign a consent form. Following this, they completed a demographic questionnaire and the AQ, and then the PPVT was administered. This took approximately 20 minutes.

After these preliminary tests, participants completed the talking segments of the ADOS-2 with the researcher. After the task, the participants were given a full debrief by the researcher. They were also given a debrief sheet to take away with them, and the opportunity to ask any questions about the research. Participants were compensated for their time. Those in the ASD group were given a £7 voucher, and those in the control group were given three SONA credits.

Results

Speaking Time

Average speaking time in seconds between the ASD group ($M = 411.55$, $SD = 136.38$) and the control group ($M = 412.96$, $SD = 112.21$) was not statistically significant ($p < .05$), converting to just under 7 minutes each.

Independent Samples *t*-tests

The mean rate of disfluencies broken down by group are presented in Figure 1. A series of independent samples *t*-tests was conducted to determine whether disfluencies produced by individuals in the ASD group were significantly different from the control group (see Table 2). The results of these analyses showed no significant differences for all types of disfluency, measured by disfluency counts and disfluency counts with time speaking adjusted.

Table 2

Results of independent samples t-tests. Effect size (Cohen's D) in parentheses following each p-value.

	Raw Means	Time Adjusted Means
UM's	$t(40) = 1.09$, $p = .28$ (.34)	$t(40) = 1.50$, $p = .14$ (.47)
UH's	$t(40) = 1.67$, $p = .10$ (.52)	$t(40) = 1.45$, $p = .16$ (.45)
Repetition	$t(40) = 1.38$, $p = .18$ (.43)	$t(40) = 1.45$, $p = .15$ (.45)
Repairs	$t(40) = -.42$, $p = .68$ (-.13)	$t(40) = -.54$, $p = .59$ (-.17)
UM/UH Ratio	$t(40) = -.08$, $p = .94$ (-.23)	$t(40) = 1.45$, $p = .16$ (.45)

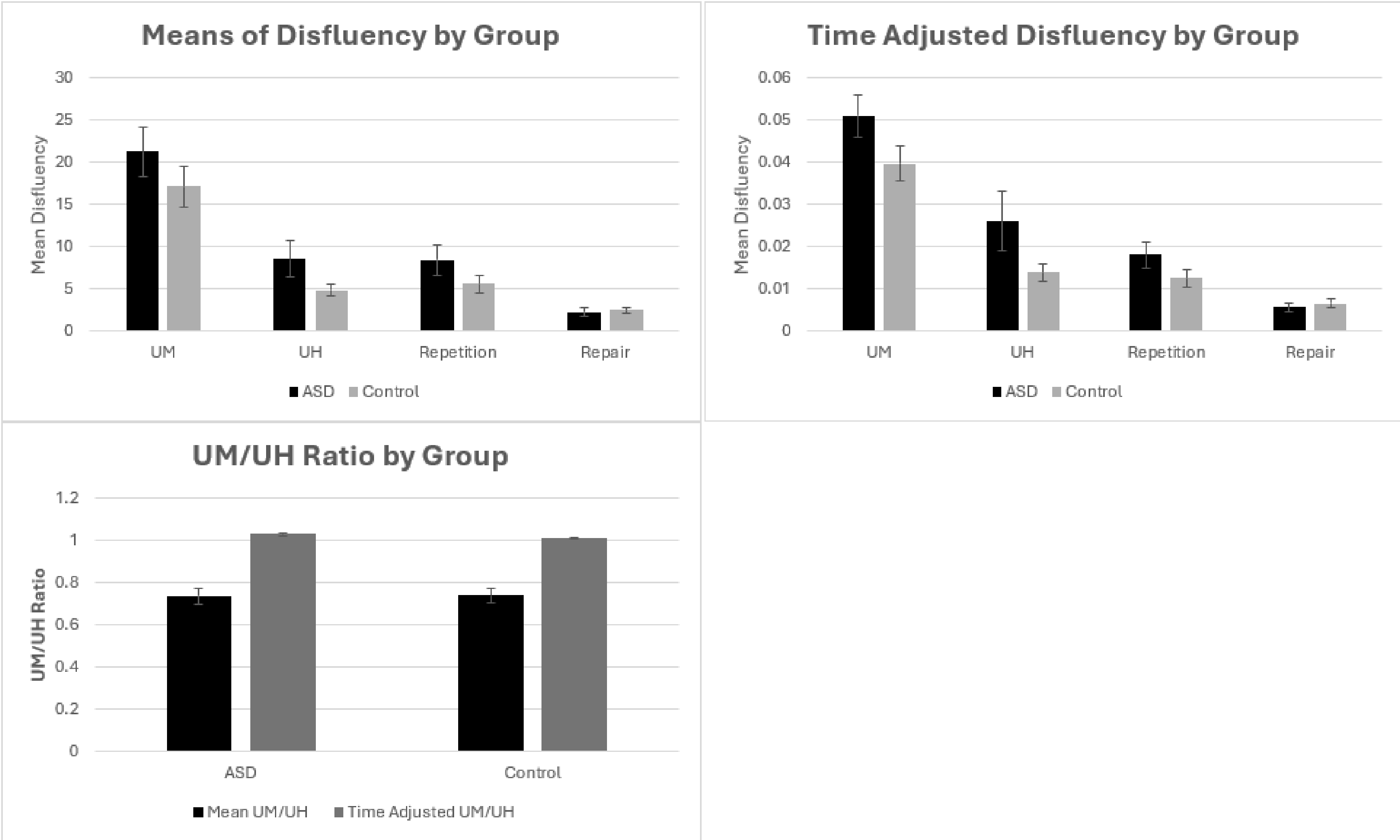

Figure 1. Upper left panel shows the mean rates of disfluency production by group. Upper right panel shows means of disfluency following adjustment for speaking time. Lower left panel shows results for UM/UH ratio. Error bars show the standard error of the mean.

Correlations AQ scores and Demographics

Correlations between demographic variables, AQ scores, and time adjusted disfluency rates are shown in Table 3. There were a couple of notable correlations. First, total AQ score was positively correlated with *um* production, as was the attention-to-detail subscale. This means that a higher level of autistic traits was associated with a higher number of *um*'s produced, as well as having greater attention-to-detail. The communication subscale (in line with ASD symptomology) was also positively correlated with repetitions, meaning that poorer communication skills measured by the AQ were associated with a higher number of repetitions. This was expected (see Hypothesis 2). Interestingly, we found strong correlations with gender, which was positively correlated with all disfluency variables aside from *um's.* Gender was coded male = 1 and female = 0, indicating that males produced more disfluency than did females. They were also more likely to have a higher *um/uh* ratio.

Given that our groups differed gender, and gender was strongly related to disfluency production, we needed to ensure that the group differences with respect to ASD (i.e. the null effect of group) were not unduly influenced by gender. To do so, we ran partial correlations (where gender was the control variable). The results of those analyses showed that the correlations between group and disfluency remained non-significant (all *p's > .13*). The same non-significant result occurred when age was controlled for *um/uh* ratio. The positive correlations between AQ scores and UM production was also inconsistent with our hypotheses.

Table 3

Bivariate correlations between demographic variables, AQ scores, PPVT, and disfluency variables (N = 42).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Age	-	.21	-.02	.19	.06	-.03	.11	.03	.10	.06	.22	.21	.21	.22	.53**
2. Gender		-	-.33*	.32*	.09	-.05	.15	.03	.14	.33*	.05	.44**	.44**	.42**	.34*
3. ASD diagnosis			-	-.73**	-.64**	-.22	-.67**	-.57**	-.71**	-.09	-.23	-.22	-.22	-.22	.09
4. AQ 1 - SS				-	.71**	.17	.77**	.70**	.84**	.22	.23	.21	.21	.27	-.01
5. AQ 2 - AS					-	.39*	.77**	.60**	.87**	.04	.30	.07	.07	.10	-.02
6. AQ 3 - AD						-	.40**	.38**	.57**	.12	.36*	-.16	-.16	.20	.12
7. AQ 4 - CM							-	.63**	.91**	.04	.30	.15	.15	.36*	.01
8. AQ 5 - IM								-	.81**	.04	.16	-.00	-.00	.17	.00
9. AQ Total									-	.11	.34*	.08	.08	.28	.03
10. PPVT										-	.20	.05	.05	.22	.01
11. UmTA											-	-.03	-.03	.28	.15
12. UhTA												-	.1.0**	.37*	.17
13. Um/UhRatioTA													-	.37*	.17
14. RepetitionTA														-	.31*
15. RepairsTA															-

Note. *p < .05, **p < .01. ASD diagnosis coded 0 = ASD and 1 = control. Gender coded 0 = female and 1 = male. TA indicates time adjusted variables.

Discriminant Analysis

With respect to the question of whether disfluency can be used as a diagnostic marker of ASD, we feel that our results strongly indicate that it cannot. The reason for this conclusion is that our results were either in the opposite direction of predictions, or non-significant. This means that this study failed to replicate many if not, all existing studies in the literature. The reason for these failed replications is discussed in detail in the discussion section. Despite these issues, we ran a discriminant analysis anyway, following on from Hypothesis 4.

Using *um/uh* ratio, repetitions, and gender as predictors a discriminant analysis showed that 66.7% of cases could be successfully predicted. For this analysis, we chose Um/Uh ratio and repetitions because these were the two disfluency results that were in the expected direction and were just shy of marginal significance. We also included gender, given that it showed the most consistent and strongest correlations with the disfluency measures. Our conclusion is that accurately predicting group membership in only two-thirds of cases is not of an adequate standard for diagnostic assessment. Moreover, given the variability reported here and the mixed findings between this study and existing literature, also raises concerns about reliability of disfluency rates more generally.

Discussion

There has been consistent research showing that disfluencies are common in autistic individuals. One of the most consistent trends shown across studies (Gorman et al., 2016; Irvine et al., 2016) is that autistic individuals produce significantly fewer *um*'s during spontaneous speech, particularly in relation to the amount of *uh*'s produced (*um/uh* ratio). We predicted that we would replicate these findings with the autistic individuals in our study. However, we found no significant group differences. We also predicted that autistic individuals would produce more repetitions, in line with previous studies (Lake et al., 2010;

Shriberg et al., 2001; Suh et al., 2014), but we did not find any significant differences again. We added the caveat here that repetitions would be related to verbal abilities, based on the Engelhardt et al. (2017) study, but verbal abilities measured by the PPVT in this study were not significantly related to repetitions. Moreover, the correlation between PPVT and repetitions was actually positive, which is in the opposite direction of expectations.

We also predicted that there would be significant differences between the ASD group and the control group in production of repairs, but we were unsure in which direction this would be due to mixed results in the literature (Lake et al., 2010; Shriberg et al., 2001). Again, we found no significant group differences. Finally, we assumed that, because of the consistent findings related to *um* production and *um/uh* ratio, that we could use these types of disfluency to predict ASD group status using a discriminant analysis. As we did not find any significant differences with these measures, it was unlikely that a discriminant analysis would show positive results. Despite this, we conducted the discriminant analysis anyway, and results showed that two-thirds of cases could be accurately prediction, which is (in our opinion) insufficient to argue for disfluency being a useful diagnostic marker of ASD. The discriminant mis-classifications were approximately equal 7 ASD group mis-classifications and 6 control mis-classifications. Given that there are inconsistent results between this study and existing literature, it is fair to assume that there are no significant clinical (diagnostic) implications for disfluencies observed in ASD.

In the results, we noted that there was a significant positive correlation between total AQ score and *um* production, as well as with the attention-to-detail subscale. We could conclude from this that a higher level of autistic traits, not ASD diagnosis, is related to greater production of *um's*. Given that *um* production is generally lower in autistic individuals, there is no clear reason why these correlations were observed. There are two main possibilities. The first is that the sample in the current study was atypical of ASD, perhaps our participants were more high-functioning, leading them to produce *um's* at a similar rate as controls. The second possibility is related to publication bias (i.e. the "file drawer" problem). By this speculation, there are other un-published studies, which show similar to ours that *um* production is more variable, compared to the positive (significant) findings, which have met the criteria for publication in academic journals. The variability in existing studies of *um/uh* ratio ranges from .30 to .70 in ASD samples. The mean is .47. In contrast, for control samples, the range is from .63 to .92, with a mean of .77 (Engelhardt et al., 2017). The results of the current study showed a mean of .737 for ASD and .741 for controls. Thus, the ASD mean in the current study is higher than any other published study in the literature.

Furthermore, we observed that the communication subscale of the AQ was positively correlated with repetitions. The communication subscale of the AQ is indicative of autistic traits in the pragmatic communication domain, meaning that a higher score would suggest more impairments in this area, in line with ASD symptomology. Therefore, this finding can be viewed as evidence as those with poorer pragmatic communication are more likely to make more repetitions, which somewhat aligns with our hypotheses. However, this correlation suggests that is it merely impairments with pragmatic communication which elicit greater production of repetitions in spontaneous speech, and not an overall diagnosis of ASD. Further research is needed to confirm the reliability of this finding. Finally, repairs were not significantly different between groups, despite prior studies showing a difference. The sampling issue mentioned previously is the most likely explanation for this difference.

Disfluency and Gender

We found that gender was correlated with all types of disfluencies, except for *um* production, which was a finding that we did not expect. Specifically, males were more likely to produce all of these types of disfluencies, namely production of *uh*, repetitions, repairs and had a higher *um/uh* ratio. These findings were initially surprising considering that there is no explicit mention of gender being a factor that affected disfluencies in the ASD literature that we examined. However, on further research, the studies that we based our hypotheses on were largely male dominant. For instance, in the study by Lake et al. (2010), 13 out of the 14 ASD participants were male, and the control group were matched on gender. Similarly, all participants in the Shriberg et al. (2001) study were male. The ratio of males to females in the Suh et al. (2014) study was also predominantly male, being 14:1 for the ASD group, and 12:3 and 13:3 for the "optimal outcome" group and typically-developing group respectively. In these studies, despite there being a matched control group in regards to gender, significant differences were found between ASD participants and typically-developing participants. However, in our study there was a low number of males in the control group (n = 5), which excluded creating a matched control group. There were 50% males in the ASD group compared to only 22.7% of males in the control group, and these were significantly different (see Table 1). We could therefore not determine definitively whether our failure to replicate findings from previous studies was driven by these gender differences. Partial correlations show that with gender controlled the group comparisons remained non-significant. It is interesting however that males produced more disfluencies in most measures of typical disfluencies than females, a result which has been found in some studies (Abimanto, Hidayah, Halimah & Umar Al Faruq, 2021; Altıparmak & Kuruoğlu, 2018; Bortfeld, Leon, Bloom, Schober & Brennan, 2001; Shriberg, 1996). However, this non-ASD disfluency literature offers no clear explanation as to why this may be the case.

Validity of Disfluency Measures

At the centre of our assumptions, which formed our hypotheses for the study, was the idea that particular types of disfluency are listener-oriented, and that disfluencies serve a predominantly pragmatic function, making their association to ASD quite clear. Whilst our results do not align with this theory, or at least show that this was not the case for our specific participants, alternative theories of disfluencies may be particularly insightful in explaining our results. Some researchers suggest that disfluencies do not serve a pragmatic function, but instead are a product of a difficulty in planning and production on the behalf of the speaker (Lawley et al., 2023). This claim has been corroborated by Bortfeld et al. (2001), who examined a number of conditions that elicited different planning demands. In all conditions where the planning demands were greater, such as greater topic difficulty and acting as the director in a task, more disfluencies were produced. However, studies finding that disfluencies are related to poorer planning does not necessarily mean that they are not listener-oriented, and these two things cannot be mutually exclusive. A difficulty in planning and production is unequivocally influenced by the demands of the environment. A good example of this is during public speaking, which generally elicits more hesitation disfluencies among socially anxious people (Silber-Varod, Kreiner, Lovett, Levi-Belz & Amir, 2016). However, building on the notion that disfluencies may not serve a pragmatic function, and are purely a by-product of a difficulty in planning speech, then we can perhaps derive from our study that autistic individuals do not display difficulties with the production and planning of speech, at least not in a way that is atypical.

Limitations and Strengths

As mentioned previously, we think the main limitation of this study was the gender imbalance between groups. Given that previous studies on disfluencies in ASD used a predominantly male sample, we think that it would have been beneficial to at least create a gender-matched control group. Our results show a clear effect of gender on most types of disfluencies measured in the study, so this factor is important to acknowledge and rectify in future research. The main strength of this study is that it used a free speech task (question answering), which means that it was as naturalistic as possible. Second, we were able to elicit on average 7 minutes of speech from each participant, which provided a robust dataset for disfluency coding.

Conclusion

Relatively consistent trends in the literature have been observed regarding typical disfluencies made by autistic individuals. We failed to find any significant group differences in the current study. We conclude that this may be largely due to sampling issues or publication biases. Therefore, whilst we tried to establish some clinical value in disfluency research in ASD, we do not think that disfluencies are consistent across all autistic individuals, and therefore, not predictive of ASD group status. We acknowledge that there may be discrepancies in the validity, and importantly reliability, of disfluency measures, but ultimately conclude that these research findings are quite novel by not finding any supporting evidence for the large amount of disfluency research that does find significant group differences between these groups.

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APPENDIX A

Study Advert

APPENDIX B

The Autism-Spectrum Quotient

Please circle your answer to indicate how much you agree with the following statements.

1. I prefer to do things with others rather than on my own.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

2. I prefer to do things the same way over and over again.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

3. If I try to imagine something, I find it very easy to create a picture in my mind.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

4. I frequently get so strongly absorbed in one thing that I lose sight of other things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

5. I often notice small sounds when others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

6. I usually notice car number plates or similar strings of information.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

8. When I'm reading a story, I can easily imagine what the characters might look like.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

9. I am fascinated by dates.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

10. In a social group, I can easily keep track of several different people's conversations.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

11. I find social situations easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

12. I tend to notice details that others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

13. I would rather go to a library than a party.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

14. I find making up stories easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

15. I find myself drawn more strongly to people than to things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

16. I tend to have very strong interests, which I get upset about if I can't pursue.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

17. I enjoy social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

18. When I talk, it isn't always easy for others to get a word in edgeways.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

19. I am fascinated by numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

20. When I'm reading a story, I find it difficult to work out the characters' intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

21. I don't particularly enjoy reading fiction.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

22. I find it hard to make new friends.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

23. I notice patterns in things all the time.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

24. I would rather go to the theatre than a museum.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

25. It does not upset me if my daily routine is disturbed.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

26. I frequently find that I don't know how to keep a conversation going.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

27. I find it easy to "read between the lines" when someone is talking to me.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

28. I usually concentrate more on the whole picture, rather than the small details.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

29. I am not very good at remembering phone numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

30. I don't usually notice small changes in a situation, or a person's appearance.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

31. I know how to tell if someone listening to me is getting bored.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

32. I find it easy to do more than one thing at once.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

33. When I talk on the phone, I'm not sure when it's my turn to speak.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

34. I enjoy doing things spontaneously.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

35. I am often the last to understand the point of a joke.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

36. I find it easy to work out what someone is thinking or feeling just by looking at their face.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

37. If there is an interruption, I can switch back to what I was doing very quickly.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

38. I am good at social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

39. People often tell me that I keep going on and on about the same thing.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

40. When I was young, I used to enjoy playing games involving pretending with other children.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

41. I like to collect information about categories of things (e.g. types of car, types of bird,

types of train, types of plant, etc.).

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

42. I find it difficult to imagine what it would be like to be someone else.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

43. I like to plan any activities I participate in carefully.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

44. I enjoy social occasions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

45. I find it difficult to work out people's intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

46. New situations make me anxious.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

47. I enjoy meeting new people.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

48. I am a good diplomat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

49. I am not very good at remembering people's date of birth.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

50. I find it very easy to play games with children that involve pretending.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

APPENDIX C

ADOS Questions

Can you tell me a bit about yourself?

Are you enjoying university?

What subject are you studying?

What modules do you like the most?

What ones do you not like?

Do you currently have a job?

Is there anything that makes you stressed?

Are you involved in any extra curricular activities?

What are your hobbies?

What are your friends like?

What do you like doing together?

Do you have a partner?

What do you like doing with them?

What kind of stuff do you do to make you happy?

What stuff maybe doesn’t make you happy?

Can you tell me if there’s anything that makes you frightened or anxious?

What are your plans for when you finish university?

What do you plan to do when you’re older / leave university?

CHAPTER 4 – LINGUISTIC PREDICTION

Abstract

Autism Spectrum Disorder has been argued to involve impairment in domain-general predictive ability. There is strong evidence that individuals with ASD have trouble navigating the dynamic world due to an inability to predict the outcome of particular events. There is also evidence that this is apparent across diagnostic criteria of ASD and common among correlates of ASD. However, the question remains as to whether this atypicality in predictive abilities is domain-specific or domain-general, with little research investigating prediction in linguistic measures. The current study investigated whether individuals with ASD show atypicalities in linguistic prediction using a cloze probability task. In Experiment 1, 33 individuals with ASD were compared to 64 typically-developing individuals in an offline cloze task. There was no significant effect of ASD diagnosis on cloze probability. However, individuals with higher levels of autistic traits were significantly more likely to produce lower probability non-modal responses. In Experiment 2, 19 individuals with ASD were compared to 22 typically-developing individuals on a lab-based cloze task, in which we also measured reaction times (i.e., voice onset time). Results showed that individuals with ASD had significantly slower reaction times (~200 ms), but similar to Experiment 1, did not show differences in the cloze probability of responses produced. We conclude that individuals with ASD do show inefficiency in linguistic prediction, as well as which ASD traits most strongly correlate with these inefficiencies.

Key words: Autism Spectrum Disorder, linguistic prediction, cloze probability, voice onset time

Linguistic Prediction in Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by persistent deficits in social communication and interaction, special interests and repetitive patterns of behaviour that tend to manifest in early development (APA, 2013). Autistic individuals tend to have problems throughout the lifespan with language abilities, some pertaining to the universal impairments in pragmatic language (Eigsti, de Marchena, Schuh, & Kelley, 2011), but others being attributed to atypical structural language skills, which are considerably varied across the spectrum (Tek, Mesite, Fein, & Naigles, 2014). Linguistic prediction is an area of psycholinguistics that has been under-studied with autistic individuals but is thought in neurotypical individuals to play a key part in the comprehension of language, which ultimately facilitates communication (Pickering & Garrod, 2007). The current study sought to explore whether autistic individuals differ from neurotypical individuals in their linguistic prediction abilities.

Theory of Prediction in Autism

There is currently no universal theory which accounts for, nor fully encompasses, the phenotypes that are observed in autistic individuals. ASD is known to be a highly heterogeneous disorder, and the main symptomologies that make up the diagnostic criteria of the disorder are phenotypically dissimilar in nature. This has provoked questions as to how they have been classified to ultimately represent ASD, and whether there is one underlying cognitive mechanism that may explain them all.

The hypothesis of Predictive Impairment in Autism (PIA) suggests that autistic individuals experience atypicalities in predictive processing (Lawson, Rees, & Friston, 2014; Sinha et al., 2014; Van de Cruys et al., 2014). In the brain, estimations are made on the probability of transitioning from an antecedent to a consequence. For a typical individual, this estimation is based on “coded” learning experiences. When the individual experiences the same antecedent again, the brain is able to predict the consequence based on how it was previously coded. The PIA hypothesis assumes that autistic individuals may make significant prediction errors, meaning that this system operates in a fundamentally different way to typical individuals (Sinha et al., 2014). According to the theory, these errors can account for symptoms of ASD, which constitute its diverse phenotypic profile.

In order for the PIA hypothesis to have merit, it would need to account for both the key markers of ASD: deficits in social communication and interaction, and restricted and repetitive behaviours (APA, 2013). Deficits in social communication and interaction may occur as the result of the unpredictability of dynamic social environments, where autistic individuals experience atypical processing of social rules and cues, and therefore, navigating these kinds of situations become increasingly difficult, resulting in avoidance (Sinha et al., 2014; Van de Cruys et al., 2014). If this avoidance is manifested in early childhood, then dysfunctional social skills may arise, further fostering the avoidance of such experiences. Restricted and repetitive behaviours may represent an aversion to new, unpredictable activities and experiences, which cause discomfort to autistic individuals, leading to a clinically significant reliance on rituals and routines (Lawson et al., 2014; Sinha et al., 2014). Other correlates of autism can be at least partially explained by atypicalities in predictive processing, such as the links between ASD and Theory of Mind, the observed sensory hypersensitivities, and the high prevalence of anxiety in autistic individuals (Sinha et al., 2014). There is a large body of evidence exploring predictive coding errors of autistic individuals, across experimental paradigms and modalities, including spontaneous gaze (Król & Król, 2019; Krogh-Jespersen, Kaldy, Valadez, Carter & Woodward, 2018), emotion prediction (Palumbo, Burnett & Jellema, 2015), auditory prediction (Millin et al., 2018) and social expectations (Chambon et al., 2017) (for a review, see Cannon, O'Brien, Bungert, & Sinha, 2021).

Linguistic Prediction

If there were domain-general predictive impairments in autistic individuals, then we would expect this impairment to be evident in linguistic prediction tasks. Linguistic prediction is thought to play a key role in the comprehension of language by contributing to conversational skills and correct conduct, ultimately aiding the efficiency of communication (Curcic, Andringa & Kuiken, 2019; Lupyan & Clark, 2015; Verhagen, Mos, Backus, & Schilperoord, 2018). The basic idea is that the comprehension system predicts a linguistic unit before receiving the bottom-up input: the speaker does not wait to hear the whole stimulus, but makes an estimation on the following word based on the characteristics of the preceding words (Pickering & Garrod, 2013; Garrod & Pickering, 2015). For example, if a speaker said the sentence "I am going to eat the… ", the listener would be reasonable to predict that, based on the lexical information provided (i.e. the verb *eat*), the speaker was going to consume an edible object, rather than an inedible object continuation (e.g. *scissors*). Thus, the listener would expect a food-related noun (an edible object) to occur next in the string (e.g. *sandwich*). Problems with linguistic prediction have an impact on language comprehension and are subsequently suspected to be a fundamental part of language acquisition (Rabagliati, Gambi, & Pickering, 2016). This has been evident across studies with neurotypical individuals, who experience processing difficulties, such as longer reading times, when ambiguous bottom-up input is incongruent to their top-down "coded" expectations (e.g. Bonhage, Mueller, Friederici, & Fiebach, 2015; Ito, Corley, Pickering, Martin, & Nieuwland, 2016; Kuperberg & Jaeger, 2016; Kutas & Federmeier, 2011; Rayner, 1998; Ryskin, Levy, & Fedorenko, 2020). On the other hand, it is common for individuals with poorer literacy skills to face problems with linguistic prediction, which is evident in lower-level readers, individuals with dyslexia, and second language (L2) processing (Engelhardt, Yuen, Kenning, & Filipovic, 2021; Fernandez, Engelhardt, Patarroyo, & Allen, 2020; Huettig & Brouwer, 2015; Ito, Martin, & Nieuwland, 2017; Mani & Huettig, 2012; Mishra, Singh, Pandey, & Huettig, 2012).

Given that autistic individuals show an atypical language profile, it would be reasonable to question whether issues with linguistic prediction occur in this population. However, given the body of evidence surrounding linguistic prediction in neurotypical individuals, these associations have the potential to be *bi-directional*. If atypical predictive processes occur in language, as they occur for other aspects of the ASD phenotypic profile (in accordance with the PIA hypothesis, Sinha et al., 2014), this may result in poorer language comprehension. This would ultimately affect conversational skills potentially contributing to deficits in social communication and interaction, which are at the centre of the ASD diagnosis, and would provide support for a domain-general predictive impairment in ASD. On the other hand, as poorer language abilities tend to result in issues of effectively utilising predictive processes, it may be the case that results found concerning atypical linguistic prediction abilities in autistic individuals instead corroborate evidence for a broader language issue in ASD, rather than a difficulty with prediction itself. This would then contribute to the trend in ASD research of language abilities being a notable confound. However, we believe that the latter argument can be refuted by controlling for language abilities in prediction research, making fairer and more meaningful comparisons between autistic individuals and typically-developing control participants.

Evidence for Impaired Linguistic Prediction in ASD

There is some evidence for impaired linguistic prediction in autistic individuals. Prescott et al. (2022) investigated predictive language processing using an eye-tracking paradigm, finding that, whilst autistic children engaged in similar predictive processes by making anticipatory eye-movements to target nouns, the effect size was larger in neurotypical individuals. Huettig et al. (2023) similarly employed an eye-tracking paradigm to investigate eye movements in children in a look-and-listen task. Participants were presented with spoken sentence stems and subsequently shown two objects: one that was semantically appropriate and one unrelated distractor. Results showed that neurotypical children successfully utilised predictive processes by showing preferential eye movements to the target object, whereas this was significantly reduced in autistic children. Zhao et al. (in press) investigated linguistic prediction in autistic individuals using a cloze probability task, where participants were tasked with completing a sentence stem with the word that they thought "best fit" the sentence. Zhao et al. (in press) found that autistic individuals produced significantly less frequent words than neurotypical participants. These studies provide evidence for impaired linguistic prediction in autistic individuals. However, it is important to note that some of these results were modulated by language abilities. Autistic individuals in Prescott et al. (2022) had significantly lower scores on a measure of expressive communication. Likewise, autistic individuals in Zhao et al. (in press) had significantly lower scores on a vocabulary test. This is particularly problematic when, as pointed out by Andreou and Lymperopoulou (2022), language production and wider vocabulary knowledge are key factors in the ability to successfully engage predictive processes in language comprehension.

Evidence for Intact Linguistic Prediction in ASD

Other evidence attests to intact linguistic prediction in autistic individuals. Bavin, Kidd, Prendergast, and Baker (2016) used an eye-tracking task to investigate the processing of sentences containing bias and neutral verbs in children with and without ASD. Results showed that children on the autism spectrum showed preferential eye movements to the biasing verbs compared to the neutral verbs, and there were no significant differences between groups, providing evidence that predictive processes were being utilised to the same effect as they are for typically-developing control participants. However, Bavin et al. (2016) found that this process was significantly slower for the ASD group. Zhou, Zhan, and Ma (2019) also used the visual world paradigm to test autistic and typically-developing Mandarin-speaking children. Zhou et al. (2018) found that autistic children showed predictive eye-movements to target areas during real-time sentence comprehension using neutral and biased verbs, and this was just as quick as it was for typically-developing children. However, autistic children made less fixations back to the target object after the initial presentation. Zhou et al. (2018) suggested that this was due to problems maintaining visual attention, which is common in autistic participants (Mo, Liang, Bardikoff, & Sabbagh, 2019; Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008). Utilising a different modality, Brennan, Lajiness-O'Neill, Bowyer Kovelman, and Hale (2019) used MEG to investigate the mechanisms underlying behavioural outcomes from eye-tracking data. They found that autistic children were able to engage in predictive sentence comprehension, while listening to an audiobook story, shown by neuromagnetic signals that quantify prediction in terms of surprisal. These results were not affected by verbal abilities, which were significantly lower in the ASD group.

Discussion of Evidence

Based on this evidence, a few points are worth contemplating. Firstly, that the breadth of studies investigating linguistic prediction in ASD are considerably limited and varied, with no universal consensus on whether prediction in this population is impaired in comparison to typically-developing individuals. Some studies finding evidence for impaired linguistic prediction in autistic individuals are weakened by a failure to control for differences in language abilities (Prescott et al., 2022; Zhao et al., 2018). Those finding evidence for intact, or at least comparable, linguistic prediction in ASD noted some subtle differences, which can be attributed to longer processing times in autistic individuals (e.g. Bavin et al., 2016). This is consistent with other evidence highlighting similar comprehension accuracy for behavioural measures in autistic individuals, but differences in the processing of stimuli when analysing online data (Sansosti, Was, Rawson, & Remaklus, 2013). It is therefore important to consider whether predictive coding errors are ultimately defined by inaccuracies made in the final comprehension of the linguistic input, or whether the prediction process itself is temporally bound. For example, if the person is given unlimited time to predict something, and then predicts it correctly, this would reflect inefficient prediction rather than an impairment. We can therefore assume that there is perhaps not an *impairment* in predictive abilities for autistic individuals, but that their predictive abilities are *atypical*, questioning the PIA hypothesis which adopts the stance that there is broad domain-general predictive impairment in ASD that is consistent across experimental paradigms. This is something that should be explored in more depth.

The Current Study

We believe that investigating the mechanisms that may be at play which could potentially provide better understanding of the diverse ASD phenotype is valuable because it can guide well-informed interventions, ultimately laying the foundations for better adjustments made for individuals in this population. There is currently no strong evidence for impaired linguistic prediction in autistic individuals, yet the PIA hypothesis is still prominent in discussions concerning ASD phenotypes. We aimed to investigate whether linguistic prediction is atypical in autistic individuals.

Linguistic prediction has been assessed in many psycholinguistic studies using a cloze probability task (Engelhardt et al., 2021; Engelhardt, Filipović & Hawkins, 2024; Staub, Grant, Astheimer & Cohen, 2015). The purpose of the task is to investigate how individuals predict the end of a sentence (Arcuri, Rabe-Hesketh, Morris & McGuire, 2001). Sentence stems with a cloze probability of less than 0.5 are classed as low constraint sentences, and therefore, do not afford much (or very little) prediction. Those with a cloze probability of 0.5 or above are classed as high-constraint sentences (Staub et al., 2015). In short, high-constraint sentences are more predictable than low-constraint sentences, as evidenced by higher mean cloze probability. In the current study, we focused our analysis only on high-constraint sentences. Comprehension for sentences is much more difficult when the sentence has a lower predictability, and this can be assessed by looking at the production norms for each item. Therefore, cloze probability has traditionally been the gold standard measure of prediction in psycholinguistics.

To our knowledge there is only one study (Zhao et al., in press) that utilised a cloze probability task in autistic individuals. Given that these kinds of tasks are an irrefutable measure of linguistic prediction, and are not bound by the limitations of visual attention that are common in other linguistic prediction tasks used in this area of research (Zhou et al., 2018; Brennan et al., 2019), we believe that it is particularly valuable to measure cloze probabilities in this population. The study by Zhao et al. (in press) found significant differences in the number of frequent responses produced between autistic participants and typically-developing control participants. However, these participants were not matched on language abilities, the importance of which we reviewed above. We conducted two studies, the first was an online (internet based) study to find out whether autistic individuals differ to typically-developing individuals in their overall cloze probability responses. This served to decipher any obvious disparities in predictive abilities in a low-demand task with no experimenter present. The second study replicated the first in a lab setting using the auditory modality, and we also measured reaction times. The current study was guided by three broad research questions.

1. Is there evidence for an impairment in linguistic prediction among autistic individuals?

2. Is this impairment shown in overall lower cloze probability of the words produced or by slower processing times?
3. Are impairments in linguistic prediction apparent when controlling for differences in language abilities (i.e., a vocabulary measure)?

Experiment 1

In this experiment, we compared ASD participants to typically-developing controls in an online study. Participants read sentence stems and completed the sentence (by typing) the word that they thought was the "best" or most natural continuation. We hypothesized that autistic individuals would produce significantly lower cloze probability responses (Zhao et al., in press), and would do so across the critical high-constraint items and that the same pattern would hold for both modal and non-modal responses. In a second set of analyses, we examined the correlations between cloze probabilities and Autism Quotient (AQ) score (as measures of traits of autism). The second set of analyses examined ASD traits via a continuum approach. However, the direction of the hypothesis was the same, higher ASD traits (higher AQ score) would be negatively related to cloze probability. Finally, we conducted two sets of regression analyses, to determine whether (1) significant effects held when age and gender were included in statistical models, and (2) which of ASD symptom clusters linguistic prediction was more related to.

Methods

Participants

The target sample for the current study were individuals with a university-level education, who were recruited via social media platforms with a formal diagnosis of ASD. These participants were all high-functioning autistic individuals. Typically-developing individuals who did not have a formal diagnosis of ASD were also recruited as controls. In total, 109 participants took part in the study. All participants were native speakers of British

English. Participant exclusions included age below 18 or above 60 years, which resulted in the removal of seven control participants. We also examined Autism Quotient (AQ) scores, and trimmed outliers on (1) the upper end of the distribution for controls (i.e., elimination of false negatives) and (2) the lower end of the distribution for the ASD group. This led to the further removal of two participants from the control group and three participants from the ASD group. Thus, 12 participants were excluded in total. Note that gender "significance" (Table 1) was calculated by excluding the "other" or "un-reported" participants.

ASD Group

Thirty-three individuals had a diagnosis of ASD. The age range of participants with ASD was 18-59 years (M = 30.76, SD = 12.31). There were five males, 21 females, and seven other/un-reported.

Control Group

There were 64 control participants. The age range of the control group participants was 18-60 years (M = 34.03, SD = 12.30). There were 15 males and 49 females. Table 1 shows the means for demographic variables and AQ scores.

Table 1

Means and inferential tests for demographic variables, AQ scores, and repetitive behaviours.

	ASD(33)	Control(64)	Significance
Variable	Mean(SD)	Mean(SD)	
Demographic Variables			
Age	30.76 (12.31)	34.03 (12.30)	$t(95) = -1.24, p = .22$
Gender (% male)	15.2	23.4	$t(95) = 2.78, p < .01$
Autism Quotient			
AQ SS	7.12 (1.71)	2.94 (2.08)	$t(95) = 9.96, p < .001$
AQ AS	9.06 (1.00)	4.42 (2.27)	$t(95) = 11.19, p < .001$
AQ AD	7.30 (2.17)	5.39 (2.24)	$t(95) = 4.02, p < .001$
AQ COM	7.52 (2.09)	2.38 (2.03)	$t(95) = 11.70, p < .001$
AQ IMG	5.33 (2.07)	2.48 (1.60)	$t(95) = 7.51, p < .001$
AQ TOTAL	36.33 (5.88)	17.61 (7.00)	$t(95) = 13.16, p < .001$
Repetitive Behaviours			
ARBQ	38.61 (7.01)	27.08 (5.80)	$t(95) = 8.63, p < .001$

Note. Numbers in parentheses indicate number of participants. SD = standard deviation, AQ = Autism Quotient, ARBQ = Adult Repetitive Behaviours Questionnaire.

Recruitment Strategy

Participants were recruited via advertisements on social media, mainly through Facebook (this study took place during the height of the worldwide COVID-19 pandemic.) The ASD group was recruited on pages designed specifically for individuals with ASD to take part in research. There was no incentive given, other than to help the programme of research. Participants were given the researchers contact details in the initial advertisement so that they could ask any questions before taking part. The link provided in the advertisement took the participants directly to Qualtrics, where the study was completed.

Materials

Autism-Spectrum Quotient (Baron-Cohen et al., 2001; Appendix A)

The AQ is a self-report measure of autistic traits, consisting of 50 items assessing ASD symptomology in five areas (social skills, attention switching, attention to detail, communication, and imagination).

Answers are given on a four-point Likert scale with the options ‘Definitely Agree’, ‘Slightly Agree’, ‘Slightly Disagree’ and ‘Definitely Disagree’. Scores on the AQ are summed and can range from 0 to 50, with a higher score indicating a higher level of autistic traits. For the purposes of the current study, subscales of the AQ were also summed, providing a total AQ score. Descriptive statistics for total AQ score, as well as subscale scores, across both the ASD group and the control group are reported in Table 1. Cronbach’s alpha of the AQ for the current study was $\alpha = 0.90$, demonstrating high internal consistency.

Adult Repetitive Behaviours Questionnaire 2 (ARBQ-2A; Barrett et al., 2015; Appendix B)

The ARBQ is self-report measure of repetitive behaviour in adults, consisting of 20 items assessing two domains: insistence on sameness and repetitive motor behaviours. The questionnaire is separated into five sections.

For sections 1-4, answers are given on a three-point Likert scale, with the options ‘Never or rarely’ (scoring 1), ‘Mild or occasional’ (scoring 2) and ‘Marked or notable’ (scoring 3). For section 5, the answer is given on a three-point Likert scale, with the options ‘A range of different and flexible self-chosen activities’ (scoring 1), ‘Some varied and flexible interests but commonly choose the same activities’ (scoring 2) and ‘Almost always choose from a restricted range of repetitive activities’ (scoring 3). Answers are summed and scores can range from 20-60. A higher score indicates that the person has a higher level of repetitive behaviours.

Cloze Probability Task

The sentence stems used for the current study were derived from materials used in Arcuri et al. (2001) (see Table 2 for examples). From the 152 sentence stems, 100 were randomly selected for critical items in the current experiment (50 – high constraint and 50 – low constraint. Low vs. high constraint items were determined by the most frequent word provided for each stem. Items with the highest word $< .50$ were classified as low constraint, and items with the highest word > .05 were classified as high constraint. There were an additional three items, which were used a practice trials.

Table 2

Example stimuli, with cloze probabilities from Arcuri et al. (2001).

In the distance, they heard the _______.
Cloze Probabilities: noise (.32), thunder (.10), birds (.06), scream (.06)
The hunter shot a large _______.
Cloze Probabilities: deer (.78), lion (.06), bear (.06)
John wisely chose to pay the _______.
Cloze Probabilities: bill (.50), debt (.08), taxes (.04), man (.04)

At night, the old woman locked the _______.
Cloze Probabilities: door (.76), basement (.04)

Design and Procedure

The design of the study consisted of a single independent variable: group (ASD vs. control), which was between participants. The main dependent variable was the mean cloze probability for the 50 high-constraint items. The calculation of cloze probability followed the typical procedure. For example, if there are 33 out of 100 people who complete the sentence stem "*the airplane went into a* ____" with the word "*spin*", this would make the cloze probability of the sentence 0.33. These cloze probabilities were determined, based on the responses provided by participants in the current study (i.e. we determined cloze probabilities by assessing the responses to each item across participants). Second, we then calculated the average cloze probability for each participant across the set of 50 critical (high-constraint) items. Third, we classified responses based on whether they were modal or non-modal (Staub et al., 2015). Modal responses are the most frequent word provided for each stem. Returning to the example above, if *spin* was the most frequent word produced, then that response would be classed as "modal". All other responses would be classed as non-modal. By this classification scheme, responses were divided into two categories, and by definition, the non-modal responses have lower cloze probability compared to the modal responses. We again, calculated the mean cloze probability by averaging across items for each participant. Thus, each participant in the study had (1) an overall cloze probability mean, (2) a modal cloze probability mean, and (3) a non-modal cloze probability mean. These three scores were the dependent variables in the analysis.

If participants were interested in taking part in the study, they were asked to click the link, which took them directly to Qualtrics. Participants first had the opportunity to read an information sheet and then they clicked a consent box. Participants then proceeded to the study. They first completed some demographic questions, then the AQ (Baron-Cohen et al., 2001; Appendix A). Following these, they did the repetitive behaviours questionnaire (Appendix B). This took approximately 15 minutes. Participants were then instructed to click forward to the experimental cloze probability task. For the cloze task, participants were instructed to read an incomplete sentence stem, and type the word that they thought "best fit" the sentence. In each sentence, the final word of the sentence was missing. In total, there were 100 sentences (50 critical high-constraint items and 50 low-constraint filler items). This took approximately 15 minutes to complete. After the experimental task, participants were shown the debrief.

Results

Data Analysis Plan and Data Preparation

The data analysis plan had two main components. The first was to compare the groups (ASD vs. control) on the mean cloze probability for the full set of critical items, using an independent samples *t*-test. We also examined the mean of "modal" and the mean of "non-modal" responses, again using independent samples *t*-tests. We expected that modal responses would have higher mean cloze probabilities compared to non-modal responses. The second component of the analysis examined the correlations between the various ASD trait measures and dependent variables in the cloze task. We followed up the correlations, with two sets of multiple regressions. The first set of multiple regressions examined total AQ scores, age, and gender regressed onto cloze probabilities. The second set of multiple regressions examined the AQ communication subscale, the ARBQ repetitive behaviours measure, age, and gender. The purpose of the second set of analyses was to ascertain whether prediction effects were associated with the two main (DSM) diagnostic symptom clusters of ASD. Prior to statistical analyses, the dependent variables were assessed for outliers and for normal distribution (i.e. that skew value was less than two times the standard error). For this experiment, the standard error was .246, and the skew was less than +/- .418. Missing data (due to incomplete responses) constituted less than one percent of trials (i.e., 0.7%).

Independent Samples T-tests

Independent samples *t*-tests were calculated to determine whether the groups differed on overall cloze probability, modal cloze probability, and non-modal cloze probability (see Table 3). Results showed no significant differences. Thus, there was no evidence of group differences in terms of the cloze probability (i.e. linguistic prediction).

Table 3

Results of independent samples t-tests. Effect size (Cohen's D) in parentheses following each p-value.

	ASD(33)	Control(64)	Significance (Cohen's D)[1]
	Mean(SD)	Mean(SD)	
Overall Cloze	.36 (.06)	.37 (.07)	$t(95) = -.77, p = .22$ (-.16)
Modal	.60 (.03)	.59 (.04)	$t(95) = 1.33, p = .09$ (.28)
Non-Modal	.10 (.02)	.11 (.03)	$t(94) = -.77, p = .22$ (-.17)

Note. [1]Significance is reported at the one-tailed level. Numbers in parentheses following each group indicate number of participants.

Autism Traits

The correlations between the demographic variables, AQ scores and repetitive behaviours are presented in Table 4. Results showed that gender correlated with overall cloze probability and non-modal cloze probability, whereas age correlated with modal cloze probability. The positive gender correlations indicate that females have higher cloze probability responses. Autism traits, measured by the AQ total scores did not correlate with any of the dependent variables. The communication subscale of the AQ and repetitive behaviours showed several significant correlations, specifically communication was significantly related to overall cloze probability, and repetitive behaviours correlated with all three dependent variables. The patterns across all ASD measures indicated negative relationships for overall and non-modal cloze probabilities (i.e., higher ASD traits corresponded with lower/worse prediction), and positive relationships for modal cloze probability (i.e., higher ASD traits corresponded with higher/better prediction). These trends demonstrate that individuals with higher ASD traits showed better prediction (or a higher likelihood) of producing modal responses. However, in cases in which the modal response was not produced, higher ASD traits were associated with worse prediction. In short, in situations where the modal prediction did not run through, high ASD trait individuals produced more lower cloze probability responses. We interpret these trends (across the dependent variables) as showing that tendency to produce lower non-modal responses was stronger than the tendency to produce higher modal responses, as shown by the negative relationship across the full set of critical items (i.e., overall cloze probabilities). Note that our interpretation of these trends is independent of statistical significance, as exactly half of the examined correlations were not significant.

Table 4
Results of Kendall's Tau correlations, p-values in parentheses following each correlation.

	Overall CP	Modal CP	Non-Modal CP
Age	.02(.76)	-.14(.04)*	.01(.88)
Gender	.28(<.001)*	-.03(.75)	.17(.04)
AQ total	-.13(.06)	.07(.30)	-.14(.04)
Symptom Domains			
AQ - Communication	-.16(.03)*	.06(.40)	-.14(.06)
ARBQ - Repetitive	-.21(.003)*	.19(.006)*	-.18(.01)*

Note. *indicates significant result following False Discovery Rate correction (Riffenburgh, 2012). Gender was coded 0 = male and 1 = female. Other/un-reported gender were omitted from analysis. CP = cloze probability, AQ = Autism Quotient, ARBQ = Adult Repetitive Behaviours Questionnaire.

The ASD group did not differ from the control group in this study based on age, but they did significantly differ in gender. In order to follow up on the significant findings with respect to ASD traits, we ran an initial set of three regressions, which included total AQ score, age, and gender as predictors. The results of those regressions are shown in the Table 5, regressions 1 – 3. Whilst statistically non-significant, there were *almost* significant effects of AQ scores on both overall cloze probability and modal cloze probability. There was a significant effect of AQ scores on non-modal cloze probability. Importantly, these findings held even when age and gender were included in the regression models. The pattern of regression coefficients showed a positive effect on modal cloze probability and negative effects on overall cloze probability and non-modal cloze probability, similar to the bi-variate correlations.

In a second set of regressions (see Table 5, regressions 4 – 6), we examined the AQ – communication subscale and the ARBQ questionnaire (note that we did not include AQ total scores in this analysis due to a high correlation between it and AQ – communication.) The reason for the second set of analyses was to determine whether prediction differences were related to the two main DSM diagnostic criteria of ASD, an issue initially raised in the Introduction. Results showed that AQ – communication was not related to any of the dependent variables, once included in a multiple regression, and that repetitive behaviours was significantly related to only modal responses. Based on these findings, we conclude that linguistic prediction is more strongly related to the restricted interests/repetitive behaviour symptom cluster, although more research is needed to definitively make this conclusion.

Table 5

Multiple regression results and coefficient.

Variable	*B*	*SE (B)*	*β*	*t*-value (*p*-value)	CILB	CIUB
1. *Overall High* $F(3,93) = 3.60$, $p < .05$, $R^2 = .10$						
Age	.000	.001	-.084	-.854 (.395)	-.000	.001
Gender	.035	.013	.279	2.81 (.006)	.010	.061
AQ Total	-.001	.001	-.193	-1.94 (.056)	-.002	.000
2. *High Modal* $F(3,93) = 3.91$, $p < .05$, $R^2 = .11$						
Age	-.001	.000	-.272	-2.78 (.007)	-.001	.000
Gender	-.003	.007	-.039	-.391 (.697)	-.017	.011
AQ Total	.001	.000	.192	1.94 (.055)	.000	.001
3. *High Non-Modal* $F(3,92) = 3.04$, $p < .05$, $R^2 = .09$						
Age	.000	.000	.024	.245 (.807)	.000	.001
Gender	.012	.006	.224	2.22 (.029)	.001	.023
AQ Total	-.001	.000	-.239	-2.37 (.020)	-.001	.000
4. *Overall High* $F(4,92) = 3.67$, $p < .05$, $R^2 = .13$						
Age	-.001	.001	-.122	-1.23 (.227)	-.002	.000
Gender	.034	.013	.267	2.58 (.011)	.008	.060
AQ - Communication	-.004	.003	-.174	-1.19 (.235)	-.009	.002
ARBQ - Repetitive	-.001	.001	-.094	-.633 (.528)	-.003	.002
5. *High Modal* $F(4,92) = 3.71$, $p < .05$, $R^2 = .14$						
Age	-.001	.000	-.210	-2.09 (.039)	-.001	.000
Gender	.003	.007	.042	.412 (.681)	-.011	.017
AQ - Communication	-.001	.002	-.119	-.823 (.413)	-.005	.002
ARBQ - Repetitive	.001	.001	.334	2.28 (.025)	.000	.003
5. *High Non-Modal* $F(4,91) = 2.59$, $p < .05$, $R^2 = .10$						
Age	-.000	.000	-.031	-.306 (.760)	-.001	.000
Gender	.010	.006	.175	1.66 (.100)	-.002	.021
AQ - Communication	-.001	.001	-.065	-.442 (.659)	-.003	.002
ARBQ - Repetitive	-.001	.001	-.216	-1.44 (.152)	-.002	.000

Note. SE = standard error, CILB = confidence interval lower bound, CIUB = confidence interval upper bound, AQ = Autism Quotient, ARBQ = Adult Repetitive Behaviours Questionnaire.

Discussion

The main **group** results with respect to prediction in this experiment were not significant. We did not observe significant group differences on any of three different cloze probability measures. In fact, the proportions were nearly identical for the two groups. This suggests that individuals with ASD do not experience impairment with linguistic prediction. However, when we analyzed ASD traits as a linear variable (i.e. using AQ total scores), there were two marginally significant results and one significant result.

The pattern of results showed that AQ total scores were marginally (negatively) related to overall cloze probability and significantly (negatively) related to non-modal cloze probability. This suggest that individuals with higher ASD traits showed lower overall cloze probability responses and lower mean cloze probability responses for non-modal responses. In contrast, the pattern reversed for modal cloze probability responses (i.e. higher ASD traits corresponded to higher cloze probability responses when the modal response was given). This reversed pattern was also only marginally significant. These positive/negative patterns suggest that high AQ individuals were more likely to produce modal responses compared to low AQ individuals, which is opposite of the hypothesis of this study. However, there were significant differences for non-modal responses, and this significant finding was stronger than the “reversed” pattern observed for modal responses. This is evidenced by the marginal/significant divergence, and also, by the fact that the overall cloze probabilities were negatively related to AQ scores. Again, that result showed only marginally significant differences. What this pattern of results suggests is that in situations in which the modal “prediction” is not activated (and therefore not produced) participants with high AQ scores were actually more likely to produce a significantly lower probability response, which is indicative of little-to-no prediction. In other words, when the key word/completion is not activated, participants with high ASD traits struggle much more than those with low ASD traits. The effect sizes of the AQ scores in the multiple regressions were small-to-medium. Ultimately, what these results suggest is that there is not strong evidence for impairments in linguistic prediction in ASD. When ASD traits were examined using a linear variable, which naturally has more predictive power potential, there are at the very best small-to-medium effects on linguistic prediction.

With respect to the relationship between prediction and individual symptom clusters, we observed that AQ "communication" scores were significantly correlated with overall cloze probability, and repetitive behaviours were significantly correlated with all three dependent variables. However, our second set of regression analyses, showed that only repetitive behaviours was significantly related to modal responses. Based on this finding, and the results of the correlations, it would seem that differences in linguistic prediction are more closely related to restricted interests/repetitive behaviours, as compared to social interactions and communication. We return to this issue in the General Discussion.

Experiment 2

One limitation of Experiment 1 was that it did not have an online measure of processing. Thus, in the second experiment, we conducted a lab-based study in which participants heard the sentence stems and had to produce (by speech rather than typing) the word that they thought best fit. We used the same items from Experiment 1. Thus, this study was essentially a replication of Experiment 1, except that it used the auditory modality, and it assessed, not only cloze probability, but also, the reaction times (voice onset time) for participants to begin speaking. Furthermore, based on Bavin et al. (2016), we hypothesised that autistic individuals would show significantly slower reaction times compared to controls (i.e., in the online measure). Based on the results from Experiment 1, we did not expect to find significant differences in cloze probabilities (i.e., in the offline measure). In this experiment, we also assessed vocabulary, as a key measure of linguistic abilities. In order to compare results across experiments, we also conducted the same correlation and regression analyses, similar to Experiment 1.

Methods

Participants

Forty-one undergraduate students participated in this study. There were 19 with a formal diagnosis of ASD and 22 typically-developing individuals, which were tested as control participants (see Table 6). Both groups were recruited from the University of East Anglia. The control participants were recruited via the SONA research participation system. The ASD group were recruited through advertisements that were placed around the UEA campus (Appendix C) and on online forums for individuals in the UEA Neurodivergent Society. All autistic participants verified that they had diagnostic assessments for autism in the past. All were native speakers of English with normal or corrected-to-normal vision. Participants were compensated for their time either with participation credits or with a £7 Amazon voucher. The study was approved by the School of Psychology Research Ethics Committee at the University of East Anglia (UK). Informed consent was obtained from all participants before carrying out the study and all were debriefed at the end of the study.

Materials

Autism-Spectrum Quotient (Baron-Cohen et al., 2001; Appendix A)

Same as Experiment 1. Descriptive statistics for total AQ score, as well as subscale scores, across both the ASD group and the control group can be seen in Table 6.

Peabody Picture Vocabulary Test - 4 (PPVT-4)

The PPVT-4 (Dunn & Dunn, 2007) is a tool to assesses receptive vocabulary. The researcher aurally presented a target word and participants were asked to choose the image which best illustrated the meaning between four options. The reliability range for Form A (the one used in this study) is reported to be from .89 to .97.

Cloze Probability Task

The audio files were recorded by a female native speaker of British English using Audacity software. Each of the 100 sentences was first recorded with an anomalous word (with a voiceless plosive consonant) in sentence final position (e.g. *The hunter shot a large peak*). This ensured no coarticulation effects between the final and penultimate words in the sentence. The final word was then digitally removed to create the stimuli for the experiment.

Table 6

Means and inferential tests for demographic variables and AQ scores.

	ASD(19)	Control(22)	Significance (Cohen's D)
Variable	Mean(SD)	Mean(SD)	
Demographics			
Age	20.0 (1.83)	19.91 (2.52)	$t(39) = -.13$, $p = .98(.04)$
Gender (% male)	47.4	22.7	$t(36) = 1.89$, $p = .07(.62)$
Autism Quotient			
AQ Social Skills	6.47 (1.83)	2.41 (1.79)	$t(39) = 7.23$, $p < .001(2.28)$
AQ Attention Switching	8.89 (1.20)	5.32 (2.06)	$t(39) = 6.66$, $p < .001(2.09)$
AQ Attention Details	7.05 (2.12)	5.73 (2.55)	$t(39) = 1.79$, $p = .08(.56)$
AQ Communication	7.84 (1.98)	3.05 (2.40)	$t(39) = 6.91$, $p < .001(2.17)$
AQ Imagination	5.16 (2.22)	2.23 (1.60)	$t(39) = 4.90$, $p < .001(1.53)$
AQ TOTAL	35.42 (6.97)	18.73 (6.16)	$t(39) = 8.14$, $p < .001(2.56)$

Note. Two participants with ASD reported non-binary gender, and one control reported “other” gender. These participants were not included in the gender analysis. ASD = Autism Spectrum Disorder, SD = standard deviation, AQ = Autism Quotient.

Design and Procedure

There was a single independent variable (group: control vs. ASD), which was between subjects. We assessed the mean cloze probability of the responses provided for each of the 50 high constraint sentences. We then coded the responses into modal and non-modal, and computed means for both categories. Cloze probabilities were one of dependent variables of the study, and were calculated in the same way as Experiment 1. The second dependent variable was the reaction time (RT), which was defined as the time from the end of the last word in the recorded sentence to the voice onset time of participants' response (i.e., from the end of the recording to when the participant began speaking). Reaction times, likewise were consider for all critical items, and then for modal and non-modal responses separately.

Before the start, participants were given an information sheet outlining the study. The researcher answered any questions. All participants then gave written informed consent. Participants first filled out some demographic questions and then the AQ (Baron-Cohen et al., 2001; Appendix A). They then did the PPVT. These tasks took approximately 20 minutes.

For the prediction task, participants were instructed to read the instructions, which indicated that they would hear a sentence, in which the final word was missing, and their task was to complete it as naturally as possible. There were three practice trials and 100 experimental trials. If they could not think of a word, participants could respond "I don't know". I don't know responses were excluded from all analyses. Participants pressed the space bar after each response, and the prediction task took approximately 15 minutes. All participants were given an information sheet and consent form. After providing consent, participants completed the various questionnaires and the experimental task, and they were debriefed following the study.

Results

Data Analysis Plan and Data Preparation

The data analysis plan had three main components. First, because there is a reasonably strong linear relationship between the cloze probability of words produced and reaction time (Staub et al., 2015), we assessed the correlation between the cloze probability and the reaction time. This allowed us to compare results from the current study to prior studies examining cloze probabilities and reaction times. The second component was to compare the groups (ASD vs. control) on mean cloze probabilities and mean reaction times, using independent samples *t*-tests. The main prediction was that the groups would not differ on cloze probability (replication of Experiment 1), but they would be different on mean reaction time (ASD > control). Given the relationship of cloze probability and reaction time, we followed up the reaction time *t*-test analyses with one-way ANCOVAs, in which group was a fixed effect and cloze probability was a covariate. These follow-up analyses allowed us to examine whether there were significant group effects on reaction time, whilst removing variance due to the cloze probability of the words produced. If the group effect remains significant, then it suggests that reaction time differences were not due to differences in the cloze probability of the word produced (i.e., at issue here is whether group exerts an effect beyond the typical cloze-RT relationship).

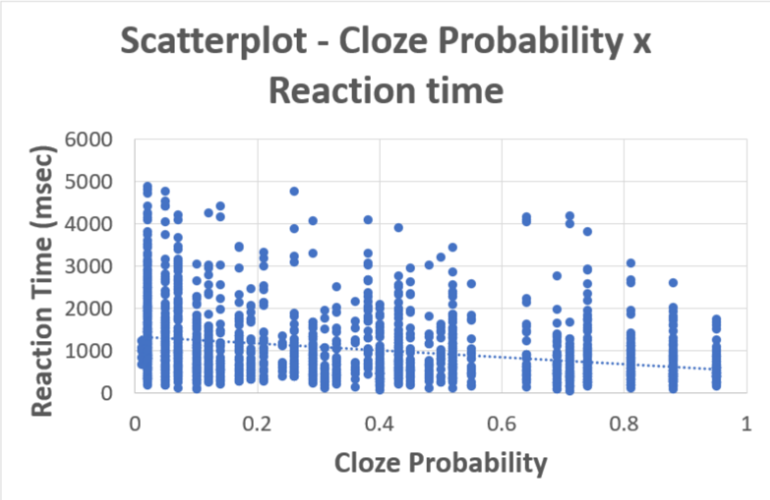
Prior to the inferential analyses, the data were checked for outliers and to ensure that the data were normally distributed (i.e. that skew was less than two times the standard error). The reaction time data was skewed and so we applied a logarithm transformation, which was then used in the inferential statistical analyses. In addition, there were two reaction time outliers (2.8 SDs and 3.1 SDs from the mean). Both data points occurred in a control participant, and the outlying values were replaced with the mean of that condition. Missing data (due to inaudible responses, or "I don't know" responses) constituted approximately 4% of the data. There were 18 trials in which a participant responded "I don't know", of these 15 were produced by a control participant and 3 were produced by a participant in the ASD group.

Cloze Probability – Reaction Time Relationship

The correlation between cloze probability and reaction time was $r(2037) = -.31$, $p < .001$ (see Figure 1). This is similar to what has been reported in prior studies (e.g., Engelhardt et al., 2023; Staub et al., 2015).

Figure 1

Scatterplot showing the relationship between cloze probabilities and reaction time.



Independent samples t-tests

We began the analysis by assessing group differences in cloze probability and reaction times on the full set of critical items. We also calculated the mean reaction times and cloze probabilities for the modal and non-modal responses produced. Results from these analyses are provided in Table 7.

We observed almost identical results for the cloze probabilities, as compared to Experiment 1. The only differences were for controls on the modal and non-modal responses, with a mean difference of .02 in both cases. Essentially, this experiment achieved a virtually perfect replication of offline results as Experiment 1. The results for reaction times showed two significant differences. The ASD participants had significantly slower reaction times for overall cloze probabilities and for modal responses. The significant differences were 221 ms and 230 ms, respectively. The non-significant reaction time difference (non-modal) was 166 ms. This shows that participants with ASD were slower to issue their responses for all three analyses, two of which achieved statistical significance.

When cloze probability was included as a covariate in a one-way ANOVA (group as IV, and reaction time as DV), the main effect of group on overall cloze probability remained significant (p = .05). Similarly, when cloze probability was included in the model for modal cloze probability, the main effect of group was also significant (p = .034). This shows that the reaction time effects held even when the reaction time × cloze probability relationship was accounted for.

Table 7

Results of independent samples t-tests for cloze probability and reaction time. Effect size (Cohen's D) in parentheses following each p-value.

	ASD(19)	Control(22)	Significance (Cohen's D)[1]
	Mean(SD)	Mean(SD)	
Overall Cloze	.36 (.04)	.37 (.04)	$t(39) = -1.03, p = .16$ (-.32)
Reaction Time	1144 (478)	923 (206)	$t(39) = 1.71, p = .05$ (.54)
Modal	.60 (.03)	.61 (.02)	$t(39) = -1.32, p = .10$ (-.41)
Reaction Time	957 (439)	727 (155)	$t(39) = 2.06, p = .02$ (.65)
Non-Modal	.10 (.02)	.09 (.02)	$t(39) = .66, p = .26$ (.21)
Reaction Time	1353 (547)	1187 (352)	$t(39) = .88, p = .19$ (.28)

Note. [1]Significance is reported at the one-tailed level. ASD = Autism Spectrum Disorder, SD = standard deviation. Number of participants in each group indicated in parentheses.

Autism Traits

For the demographic variables on cloze probabilities, there was only one significant correlation between age and non-modal cloze probability (see Table 8), which shows that older participants produced lower probability responses (i.e. less prediction). For demographic variables on reaction times, there were no significant correlations (all *p's* > .24). However, this study had a substantially smaller sample as compared to Experiment 1. Despite the power difference between studies, we again report the correlations between AQ total scores and AQ communication subscale, and the cloze probabilities (see Table 8). The reason for including these is for comparison to the results of Experiment 1. There is a fairly high degree of similarity between the two studies, expect for the results of modal cloze probability. Recall that in Experiment 1, the pattern of results was such that there were consistent negative correlations between AQ total and overall cloze probability and non-modal cloze probability, and a generally consistent pattern of positive correlations between AQ total and modal cloze probability. In contrast, the patterns in Experiment 2 showed consistently negative correlations for the modal cloze probability. Thus, in this experiment, higher ASD traits showed across-the-board weakness in prediction. It is important to note that the correlations for Experiment 2 were not significant, but there is a clear difference in numerical trends, specifically concerning positive/negative results.

Three further points are worth mentioning about the results. First, the AQ communication subscale showed more than twice as strong a correlation with overall cloze probability as compared to AQ total, and a stronger correlation than Experiment 1. When communication was included in a regression model with age and gender, it was a significant predictor of cloze probability $\beta = -.44$, $p < .01$, and age and gender were not (both *p's* > .10). Thus, in this experiment, AQ communication was more related to cloze probability, as compared to results in Experiment 1. The second point is that the reaction times did not significantly correlate with AQ total (all *p's* > .17), although this result comes with the caveat that the sample size, in Experiment 2, is likely too small for a proper examination of correlational data with respect to statistical significance. Third, our groups were matched in terms of vocabulary (an issue which we noted as a limitation in prior research). The mean for the ASD group was 41.37 (SD = 7.73) and the mean for the control group was 40.09 (8.95). The difference was not significant $t(39) = .49$, $p = .32$. Results showed that vocabulary correlated significantly with non-modal cloze (see Table 8). In contrast, there were no significant correlations between vocabulary and reaction times, and they were consistently negative (i.e., from -.06 to -.10).

Table 8
Results of Kendall's Tau correlations, p-values in parentheses following each correlation.

	Overall CP	Modal CP	Non-Modal CP
Age	-.11(.34)	-.05(.66)	-.27(.02)*
Gender	-.14(.29)	.06(.67)	-.12(.36)
AQ total	-.12(.27)	-.12(.27)	-.07(.55)
PPVT	.19(.08)	-.19(.08)	.37(<.001)*
AQ Sub-Scale			
Communication	-.27(.02)	-.10(.36)	-.14(.20)

Note. *indicates significant result following False Discovery Rate correction (Riffenbugh, 2012). Gender was coded 0 = male and 1 = female. Other/un-reported gender were omitted from analysis. CP = cloze probability, AQ = Autism Quotient, PPVT = Peabody Picture Vocabulary Test.

Discussion

To summarize the main findings, the mean cloze probabilities were virtually identical in Experiment 1 and Experiment 2. However, we observed two significant effects with respect to reaction times, which were consistent with our hypothesis that individuals with ASD would be slower, indicating worse linguistic prediction. The effect sizes for the significant results were medium, and the effect size for the non-significant result was small. In other words, in the online sentence-completion measure, the reaction times for selecting relevant and appropriate completions within each group were significantly different, and thus, it took ASD individuals longer to produce equivalent cloze probability responses.

The results of the AQ correlational data were in many ways similar to the results of Experiment 1, and in other ways distinct. It is interesting to note that the communication subscale of the AQ produced the largest correlation (in Experiment 2) and it was for overall cloze probability. The key difference across the two experiments was the results for the modal responses which were largely positive in Experiment 1 and largely negative in Experiment 2. We discuss these results further in the General Discussion.

General Discussion

The current study sought to investigate whether there is evidence for linguistic prediction deficits in ASD (Chambon et al., 2017; Gomot & Wicker, 2012; Sinha et al., 2014). In an attempt to understand how the phenotypes of autism and its correlates can be explained, researchers have suggested that autistic individuals have difficulty predicting the dynamic world, and therefore, manifestations of the disorder are a reflection of this clinically-significant domain-general inability (Król & Król, 2019; Millin et al., 2018; Palumbo et al., 2015).

The current study specifically aimed to determine whether these prediction issues could be extended to a psycholinguistic paradigm using a cloze probability task (i.e., are deficits in prediction also observed in linguistic prediction). Results, across both experiments, showed that there were no significant differences between groups on the cloze probability of the words produced. This was not in line with our main predictions, perhaps suggesting that deficits in prediction that have been observed in other studies are not domain-general. However, autistic traits, measured by the AQ (Baron-Cohen et al., 2001), did have a significant effect on non-modal cloze probabilities and marginal effects on overall cloze probabilities and modal probabilities in Experiment 1. The effect on modal probabilities showed that individuals with high AQ scores produced *higher* cloze probability responses (i.e. the reversed pattern of our prediction). The marginal effect of AQ scores on overall probabilities, and the significant effect of AQ scores on non-modal probabilities suggests that, in cases where the modal response is not produced, individuals with higher autistic traits produce significantly lower cloze probability responses. Thus, the evidence was mixed: worse prediction in non-modal responses but the opposite for modal responses.

The assumption of the cloze task (and particularly for high-constraint items) is that one or two possible continuations are strongly activated, perhaps three or four for less constraining items (Staub et al., 2015). The finding of differences with non-modal items suggests that in cases where the most probable word is not produced, then the prediction essentially falls apart, and participants produce, in response, a much lower probability word. Whatever the cause of the tendency to produce less probable non-modal responses, it is greater than the tendency to produce a higher rate of modal responses (i.e., more predictable responses). That is, the non-modal effect is numerically greater/stronger than the reversed modal effect, as can be seen in the (negative) overall cloze probabilities. Note that this conclusion is based on the patterns of positive/negative results across dependent variables, and we fully acknowledge that one of the results only achieved a marginally significant difference. The effect sizes of AQ scores on cloze probabilities in Experiment 1 were small-to-medium.

In Experiment 2, we fully replicated the non-significant group effect of cloze probability. However, consistent with predictions, we observed that autistic participants had slower reaction times, which averaged across all items, showed an approximately 200ms mean delay in voice onset time, which is consistent with a greater inefficiency in linguistic prediction in ASD. Effect sizes for the significant reaction time differences were medium. Another key difference between studies was that AQ communication was significantly related to overall cloze probabilities in Experiment 2 but not in Experiment 1. We concluded based on the second set of regression analyses in Experiment 1, that prediction differences associated with ASD traits were more likely due to the restricted interests/repetitive behaviours symptom domain, rather than social interaction and communication. We did not assess repetitive behaviours in Experiment 2, and so, we were unable to run the analogous tests in Experiment 2. However, the difference between experiments with respect to AQ communication warrants further investigation. To summarise the findings across both studies, we observed some evidence for weaker (and/or less efficient) linguistic prediction in ASD and in higher ASD traits (Huettig et al., 2023; Prescott et al., 2022). Furthermore, analyses consistently demonstrated that the significant effects were not due to age or gender differences, and in Experiment 2, our groups were matched on vocabulary (cf. Zhao et al., in press).

To summarize, our study shows a mixed and relatively complex picture about the linguistic prediction issues as they related to ASD traits. The findings for the group comparisons were more straightforward. Returning to the issues raised in the Introduction, and the beneficial aspects of prediction on (general) language comprehension abilities, we speculate that deficits and/or inefficiencies in linguistic prediction would necessarily make language comprehension more difficult. However, the issue of individual differences in prediction is an issue that has not yet been explored in the psycholinguistic literature. Instead, psycholinguists have, for the past 10-15 years, focused on what gets predicted (level of representation issues – semantic vs. phonological) and when (examining ERP measures and eye tracking). We hope that this study and other examining clinical populations bleeds into psycholinguistic literature to highlight individual differences in prediction and what may be the larger impacts of reduced linguistic prediction on other language processes.

Autism Diagnosis vs Broad Autism Traits

One question arising from these results is how possessing a high level of autistic traits (perhaps possessing the Broad Autism Phenotype) may result in predictive abilities that are in line with hypotheses through the lens of the theory of predictive impairment in autism (PIA). We raise this issue given the differences between the group analysis and the AQ scores in Experiment 1. We also note that the correlations with repetitive behaviours patterned similarly to AQ scores but were actually larger. Thus, it would seem that the repetitive behaviour aspect of ASD, may be most strongly linked with weakness in predictive abilities. Although, more work is needed to confirm this result. Some researchers argue that there may be some merit to the theory of prediction account not being apparent across all observed phenotypes of ASD. Cannon et al. (2021) suggested that attempting to unify diverse aspects of ASD risks diminishing the complexity of the disorder. They suggest that the theory of prediction account would instead do better to explain some correlates and traits of ASD, but should not be used as one unifying theory to encompass the whole disorder. Therefore, it is possible that the trends in the current study regarding linguistic prediction are an example of how correlations to autistic traits (i.e., the broad autism phenotype) are somewhat independent to a unifying and comprehensive account of prediction. Further research could extend this idea by identifying individuals with the broad autism phenotype with familial relations to autistic individuals, to determine where the cut-off is for the "window of predictability" observed in the current study.

Limitations and Future Directions

The current study had several limitations. The first one is that we did not administer the repetitive behaviours questionnaire in Experiment 2. Given the strength of the correlations observed in Experiment 1, it would have been good to corroborate those findings. Second, there were gender imbalances across groups in both studies. The groups in Experiment 1 were significantly different and just missed significance in Experiment 2. Third, the sample in Experiment 2 was quite limited and this prevented thorough conclusions for the correlational data. Finally, there were some age effects on prediction (in Experiment 1), and unfortunately, there were some age differences in our online study.

One obvious future experiment would be to put participants under time pressure to respond within a certain timeframe. Our prediction for that experiment is that we should observe significant differences between groups in cloze probability (i.e., if we eliminated the reaction time differences between groups, the result would be less effective prediction in ASD and hence lower cloze probability responses).

Conclusions

The current study sought to investigate whether atypicalities in predictive abilities in ASD were present in across domains, namely in linguistic prediction. There are three main conclusions from this study. First, there were small-to-medium effects of linguistic prediction. Small effects were observed in the offline measure in Experiment 1 on autism traits (AQ scores) and medium effects in the online measure (reaction times) in Experiment 2. Second, across both experiments, we observed the strongest correlations between cloze probability and the communication subscale of the AQ. Third, the differences we observed in terms of linguistic prediction align with domain-general assumptions of weakness in prediction, although clearly more work is needed to definitely support this conclusion. Given these results, we believe that the main impact of inefficiency in linguistic prediction relates to language comprehension more generally, and the fact that it would make language comprehension more difficult overall.

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APPENDIX A

The Autism-Spectrum Quotient

Please circle your answer to indicate how much you agree with the following statements.

1. I prefer to do things with others rather than on my own.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

2. I prefer to do things the same way over and over again.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

3. If I try to imagine something, I find it very easy to create a picture in my mind.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

4. I frequently get so strongly absorbed in one thing that I lose sight of other things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

5. I often notice small sounds when others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

6. I usually notice car number plates or similar strings of information.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

8. When I'm reading a story, I can easily imagine what the characters might look like.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

9. I am fascinated by dates.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

10. In a social group, I can easily keep track of several different people's conversations.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

11. I find social situations easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

12. I tend to notice details that others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

13. I would rather go to a library than a party.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

14. I find making up stories easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

15. I find myself drawn more strongly to people than to things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

16. I tend to have very strong interests, which I get upset about if I can't pursue.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

17. I enjoy social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

18. When I talk, it isn't always easy for others to get a word in edgeways.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

19. I am fascinated by numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

20. When I'm reading a story, I find it difficult to work out the characters' intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

21. I don't particularly enjoy reading fiction.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

22. I find it hard to make new friends.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

23. I notice patterns in things all the time.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

24. I would rather go to the theatre than a museum.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

25. It does not upset me if my daily routine is disturbed.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

26. I frequently find that I don't know how to keep a conversation going.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

27. I find it easy to "read between the lines" when someone is talking to me.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

28. I usually concentrate more on the whole picture, rather than the small details.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

29. I am not very good at remembering phone numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

30. I don't usually notice small changes in a situation, or a person's appearance.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

31. I know how to tell if someone listening to me is getting bored.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

32. I find it easy to do more than one thing at once.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

33. When I talk on the phone, I'm not sure when it's my turn to speak.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

34. I enjoy doing things spontaneously.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

35. I am often the last to understand the point of a joke.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

36. I find it easy to work out what someone is thinking or feeling just by looking at their face.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

37. If there is an interruption, I can switch back to what I was doing very quickly.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

38. I am good at social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

39. People often tell me that I keep going on and on about the same thing.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

40. When I was young, I used to enjoy playing games involving pretending with other children.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

41. I like to collect information about categories of things (e.g. types of car, types of bird,

types of train, types of plant, etc.).
Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

42. I find it difficult to imagine what it would be like to be someone else.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

43. I like to plan any activities I participate in carefully.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

44. I enjoy social occasions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

45. I find it difficult to work out people's intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

46. New situations make me anxious.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

47. I enjoy meeting new people.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

48. I am a good diplomat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

49. I am not very good at remembering people's date of birth.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

50. I find it very easy to play games with children that involve pretending.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

APPENDIX B

The Adult Repetitive Behaviours Questionnaire

Section 1

Do you

Like to arrange items in rows or patterns?

Repetitively fiddle with items? (e.g. spin, twiddle, bang, tap, twist, or flick anything repeatedly?)

Spin yourself around and around?

Rock backwards and forwards, or side to side, either when sitting or when standing?

Pace or move around repetitively (e.g. walk to and fro across a room, or around the same path in the garden?)

Never or Rarely

One or more times daily

15 or more times daily

Section 2

Do you

Make repetitive hand and/or finger movements? (e.g. flap, wave, or flick your hands or fingers repetitively?)

Have a fascination with specific objects (e.g. trains, road signs, or other things?)

Like to look at objects from particular or unusual angles?

Have a special interest in the smell of people or objects?

Have a special interest in the feel of different surfaces?

Have any special objects you like to carry around?

Collect or hoard items of any sort?

Never or Rarely

Mild or occasional

Marked or notable

Section 3

Do you

Insist on things at home remaining the same? (e.g. furniture staying in the same place, things being kept in certain places, or arranged in certain ways?)

Get upset about minor changes to objects (e.g. flecks of dirt on your clothes, minor scratches on objects?)

Insist that aspects of daily routine must remain the same?

Insist on doing things in a certain way or re-doing things until they “just right”?

Never or rarely

Mild or occasional (does not affect others)

Marked or notable (Occasional affects others)

Section 4

Do you

Play the same music, game or video, or read the same book repeatedly?

Insist on wearing the same clothes or refuse to wear new clothes?

Insist on eating the same foods, or a very small range of foods, at every meal?

Never or rarely

Mild or occasional (not entirely resistant to change or new things)

Marked or notable (will tolerate changes when necessary)

Section 5

What sort of activity will you choose if you are left to occupy yourself?

A range of different and flexible self-chosen activities

Some varied and flexible interests but commonly choose the same activities

Almost always choose from a restricted range of repetitive activities

APPENDIX C

Study Advert

APPENDIX D – SENTENCE STIMULI

1. There is something grand about the [n, 6]
2. In the distance they heard the [n, 6]
3. Their money was divided by the [n, 6]
4. She couldn't imagine anyone less [adj, 5]
5. There was nothing wrong with the [n, 6]
6. His ability to work was [adj, 5]
7. The ruby was so big it looked like a [n, 9]
8. I don't know why he didn't take his [n, 8]
9. They went to the rear of the long [n, 8]
10. He wondered if the storm would be [adj, 7]
11. They went to see the famous [n, 6]
12. Few had the nerve to take the needed [n, 8]
13. Joan showed her friend a new card [n, 7]
14. The police had never seen a man so [adj, 8]
15. Did you want to go to the [n, 7]
16. The Browns had never visited that [n, 6]
17. The final score of the game was [adj,v, 7]
18. The judge warned about the dangers of [n, 7]
19. The difficult concept was beyond his [n, 6]
20. The actor was praised for being very [adj, 7]
21. She dropped a glass and woke up her [n, 8]
22. Wally wanted to buy a beer, but he was too [adj, 10]
23. The kind old man asked us to [v, 7]
24. Rita slowly walked down the shaky [n, 6]

25. Ample food was provided for the [n, 6]

26. He was soothed by the gentle [n, 6]

27. I thought the sermon was very [adj, 6]

28. In the morning Jake took out the [n, 7]

29. The sun went down before he could [v, 7]

30. Larry chose not to join the [n, 6]

31. Even infants can be taught to [v, 6]

32. We used to have people round every [n, 7]

33. They rested under a tree in the [n, 7]

34. Hank reached into his pocket to get the [n, 8]

35. The surface of the water was nice and [adj, 8]

36. Don found that he had no spare [n, 7]

37. Ray fell down and hurt his [n, 7]

38. The paper was too thick to [v, 6]

39. The airplane went into a [n, 5]

40. Suzy liked to play with her toy [n, 7]

41. The cigar burned a hole in the [n, 7]

42. No one wanted to accuse him of [n,v, 7]

43. The elderly sometimes lose their [n, 5]

44. The hunter shot and killed a large [n, 7]

45. The sandwich wasn't very good without a slice of [n, 9]

46. Most students prefer to work during the [n, 7]

47. The wooded lake made a pretty [n, 6]

48. Few nations are now ruled by a [n, 7]

49. She cleaned the dirt from her [n, 6]

50. His ring fell into a hole in the [n, 8]

51. Rushing out he forgot to take his [n, 7]

52. The car stalled because the engine failed to [v, 8]

53. You can buy anything for a [n, 6]

54. A direct attack failed, so they changed the [n, 8]

55. The senator was startled by a sudden pain in his [n, 10]

56. The earth is shaped like a [n, 6]

57. His boss refused to give him a [n, 7]

58. After speaking Alan left the noisy [n, 6]

59. The person who caught the thieves deserves our [n, 8]

60. Before jogging, it's a good idea to [v, 7]

61. Sharon dried the bowls with a [n, 6]

62. Helen reached up to dust the [n, 6]

63. The birds in the garden ate every last [n, 8]

64. His view was blocked by the music [n, 7]

65. Plants will not grow in dry [n, 6]

66. James poured himself a glass of [n, 6]

67. He disliked having to commute to the [n, 7]

68. John wisely chose to pay the [n, 6]

69. He drove the nail into the [n, 6]

70. The sail got loose, so they tightened the [n, 8]

71. Being stood up made Paul [adj, 5]

72. Some of the ashes dropped on the [n, 7]

73. Her dress was made of very fine [n, 7]

74. Jim had learned the special passage by (n1, 7]

76. The lorry that Bill drove crashed into the [n, 8]

77. The long test left the class [adj, 6]

78. George must keep his pet on a [n, 7]

79. Most sharks attack very close to the [n, 7]

80. The child was born with a rare [n, 7]

81. Even their friends were left in the [n1, 7]

82. He was miles off the main [n, 6]

83. Harriet sang while my brother played the [n, 7]

84. My uncle gave my mother a big [n, 7]

85. Don't believe everything you [v, 4]

86. The academic year began in the [n, 6]

87. The children held their hands and formed a [n, 8]

88. The bill was due at the end of the [n, 9]

89. Carl felt sorry, but it was not his [n, 8]

90. Pam did not have any clothes to [v, 7]

91. Yesterday they canoed down the [n, 5]

92. He had to fill his car with [n, 7]

93. Karen awoke after a bad [n, 5]

94. Susan boiled the egg in (n,adv, 5]

95. Shuffle the cards before you [v, 5]

96. The paint turned out to be the wrong [n, 8]

97. The pigs wallowed in the [n, 5]

98. The pizza was too hot to [v, 6]

99. John swept the floor with a [n, 6]

100. When the power went out, the house became [adj, 8]

101. She tied up her hair with a yellow [n, 8]

104. The exit was marked by a large

CHAPTER 5 – SENTENCE COMPREHENSION

Abstract

The aim of this study was to investigate passive-implausible sentence comprehension in autistic individuals. We conducted two studies: the first ($N = 46$) sought to explore comprehension accuracy and reaction times in a picture-sentence verification task looking at syntactic structure (active and passive) and semantic plausibility (plausible and implausible). We found lower overall comprehension accuracy for autistic individuals, but no significant differences in reaction times. However, in the most difficult passive-implausible condition, autistic individuals performed better than in the two medium-difficult conditions, and there was no significant difference in accuracy to the controls. We conducted a second experiment ($N = 86$) focusing on correlations of performance with symptoms of ASD measured by the Autism-Quotient. Whilst we hypothesised that attention-to-detail may be a significant predictor of performance on the task, we instead found correlations predominantly in the attention-switching subscale and communication subscale. We offer explanations for these results and discussed limitations.

Keywords: Autism Spectrum Disorders, passive, active, semantics, plausible, implausible, sentence comprehension

Picture-Sentence Verification in Autism Spectrum Disorder: Comprehension of Passive and Implausible Sentences

In psycholinguistics, a heavily researched area is the comprehension and processing of syntactically complex sentences. In active sentences, the subject of the sentence is doing the action of the verb in the sentence, accentuating the actor and appearing more concise (Fitria & Muliasari, 2022). Thus, active sentences possess the canonical subject-verb-object word order in English, such as "*the boy threw the ball*". Comparatively, in passive sentences, the subject of the sentence is moved to the position of the object, appearing less direct and clear (Fitria & Muliasari, 2022). Passive sentences possess the non-canonical word order object-verb-subject, such as "*the ball was thrown by the boy*". Research on active and passive sentences commonly show misinterpretations for passive sentences relative to active sentences (Olson & Filby, 1972; Ferreira & Stacey, 2000), and have been shown to differentially activate certain brain regions associated with sentence processing (Mack, Meltzer-Asscher, Barbieri & Thomson, 2013; Feng et al., 2015). Theories as to why passive equivalents of active sentences are harder to comprehend are prominent in psycholinguistics. Generally speaking, people tend to ascribe the agent of action to the first noun in a sentence (Ferreira, 2003) due to the frequency of active sentences that appear in spoken and written language (approximately 99% and 95%, respectively, Dick & Elman, 2001). Therefore, delays and misinterpretations can occur when the stimulus is incongruent to the expectation of the syntactic structure of the sentence.

Interestingly, comprehension for both active and passive sentences is much poorer overall when sentences are inconsistent with real-world semantic knowledge. This has been shown in research investigating the comprehension of active and passive sentences which are varied in semantic plausibility. For example, "*the dog bit the man*" is an active-plausible sentence because in real life, it would be reasonable to assume that a dog may bite a man. The passive-plausible equivalent of this sentence is "*the man was bitten by the dog*". However, research has shown that when the thematic roles are reversed in these types of sentences, such as "*the man bit the dog*" (active-implausible) and "*the dog was bitten by the man*" (passive-implausible), comprehension tends to become much more difficult. Ferreira (2003) investigated the comprehension of sentences read aloud in active and passive voice, which were either semantically plausible or implausible, by asking participants who the agent of action in the sentence was. Ferreira (2003) found that, like other research on syntactic structures, misinterpretations for passive sentences were more common than for active sentences. Furthermore, most misinterpretations occurred when participants heard passive-implausible sentences. Ferreira (2003) suggested that, for semantically implausible sentences, typical people tend to go along with the interpretation of the sentence which aligns with their real-world knowledge. Therefore, whilst they may have heard "*the dog was bitten by the man*", it would be unlikely that they would have experienced that in the real-world, and they incorrectly assumed that the sentence was "*the man was bitten by the dog*". Stella and Engelhardt (2022) also investigated the effects of semantic plausibility on the comprehension of active and passive sentences. For typical participants, comprehension accuracy was overall lower for passive sentences than for active sentences. Within both active and passive sentence structures, comprehension accuracy for semantically implausible sentences was lower than for semantically plausible sentences. However, sentences in the active-implausible category were still more accurately interpreted than passive-plausible sentences, suggesting that the effect of syntactic structure was stronger than the effect of semantic plausibility. When looking at the reaction times of the participants, Stella and Engelhardt (2022) found that there was a main effect of semantic plausibility, but not a main effect of syntactic structure, suggesting that participants do not spend longer reading passive sentences, despite showing significant comprehension inaccuracy with these sentence types. This is contradictory to other psycholinguistic research suggesting that passives are not harder to interpret, they just take longer to remember (Paolazzi, Grillo, Alexiadou & Santi, 2019).

Autism Spectrum Disorder (ASD)

The comprehension of active and passive sentences has been researched in many clinical subgroups encompassing specific learning difficulties, such as dyslexia (Stella & Engelhardt, 2022), and language disorders, such as aphasia (Meyer, Mack & Thompson, 2012; Shin & Sung, 2020). It has also been investigated in autistic individuals. ASD is characterised by communicative difficulties but is not a language disorder. The communicative difficulties faced by autistic individuals can be primarily attributed to atypical skills in the socio-pragmatic elements of language, rather than impairments with the development and subsequent use of functional language skills. However, it is important to note that there is still a significant subgroup of autistic individuals who are either non-verbal or only minimally verbal (Norrelgen et al., 2015). Investigating active and passive sentence processing in autistic individuals is interesting due to the ambiguity surrounding ASD and language abilities, and the fact that autistic individuals comprise a highly heterogenous language group.

Passives in Autism Spectrum Disorder

There is a body of research exploring the comprehension of passive sentences in autistic individuals. The comprehension of passive sentences is generally more difficult than active sentences for neurotypical individuals, so it is unclear how autistic individuals will perform in these types of tasks considering that some autistic individuals show atypical structural language skills with regards to morphosyntax (LeGrand, Weil, Lord & Luyster, 2021). Durrleman, Delage and Tuller (2017) found that the comprehension of passives in autistic children was delayed, but not deviant, from typically-developing children. More significant delays were experienced by those who had more general impairments with morphosyntax (Durrleman et al., 2017), suggesting that issues with interpreting these types of sentence structures could be attributed to a broader impairment in structural language skills. Other research has suggested that the comprehension of passives in autistic individuals is intact (Pijnacker, Hagoort, Buitelaar, Teunisse & Geurts, 2009). Manenti, Tuller, Houy-Durand, Bonnet-Brilhault & Prévost (2023) explored the comprehension of non-reversible and reversible passive sentences in autistic individuals and found that autistic individuals were sensitive to complex syntactic structures only when accompanied with a poorer language ability. Ambridge, Bidgood and Thomas (2021) also investigated reversible passive sentence comprehension in autistic children and an IQ-matched typically-developing control group, finding that autistic children showed significantly more reversal errors (i.e. incorrectly reversing the thematic roles in the sentence). They concluded that the semantic elements of syntax are poorer in autistic children compared to those who are typically-developing, but that the structural elements are relatively intact. Jones, Dooley and Ambridge (2021) replicated the findings from Ambridge et al. (2021) in a new sample of high-functioning autistic children, concluding that thematic role assignment was indeed impaired in ASD.

Passive-Implausible Sentences in Autism Spectrum Disorder

Few studies have reported the effect of biased-reversible passive sentences on autistic individuals. Biased-reversible sentences are the sentences described by Ferreira (2003) mentioned previously, such as "*the dog was bitten by the man*", where real-world semantic knowledge causes an expectation bias of the thematic roles of the stimulus, and where both nouns in the sentence are animate. Animate passives have been investigated in the research mentioned previously, namely by Manenti et al. (2023), Ambridge et al. (2021) and Jones et al. (2021). However, comprehension of these types of passives in these studies could not be facilitated by real-world knowledge. When the thematic roles were reversed in these studies, they were still plausible, for example "*the woman was contacted by the photographer*". The biased-reversible types of passives used by Ferreira (2003), therefore, provide a unique opportunity to assess the application of semantic knowledge to the interpretation of passive sentences. Tager-Flusberg (1981) tested the effects of biased-reversible active and passive sentences on children with and without ASD and found that autistic childrem showed less comprehension accuracy for all sentence types overall, and were similarly affected as typically-developing children by non-canonical word order. That is, they were less accurate with interpreting passive sentences compared with active sentences, but there were no group differences observed. However, Tager-Flusberg (1981) found that autistic children were less affected by "improbable" passive sentences than the typically-developing children. If we refer to the studies by Ferreira (2003) and Stella and Engelhardt (2022), where typically-developing adults had significantly worse comprehension accuracy in the passive-implausible condition, it would be reasonable to derive from the results of Tager-Flusberg (1981) that autistic individuals may show smaller within-group differences and thus be less affected by semantic implausibility.

There are some explanations as to why autistic individuals may have been less affected by semantic implausibility than typically-developing individuals in the study by Tager-Flusberg (1981). Firstly, autistic individuals have increased attention-to-detail compared with neurotypical individuals. Therefore, in tasks where directing attention to the smaller elements of the stimulus are key to the accuracy of its interpretation, autistic individuals may perform better. This may not occur for typically-developing individuals who have a tendency to engage in "good enough" comprehension (Ferreira & Patson, 2007), generating superficial and inaccurate interpretations of the stimulus. Autistic individuals, on the contrary, have a detailed-focused cognitive style (Happé & Frith, 2006). However, having a detail-focused cognitive style (Happé & Frith, 2006) would suggest that autistic individuals should have better overall comprehension accuracy, but this was not the case. However, we can still use this theory to understand why they were less affected by semantic implausibility. Passive-implausible sentence types require more cognitive effort to interpret – not only do they possess non-canonical word order, but they go against biases already made about the stimulus based on real-world knowledge. Therefore, it could be possible that because the cognitive demand of these types of sentences was higher, they elicited more effort to interpret. Therefore, the autistic children utilised their detail-focused cognitive style to interpret them. This means that whilst they still performed worse overall than the typically-developing children, they were less affected by the "most difficult" sentence condition. With this in mind, it could be possible that autistic individuals are less affected by semantic implausibility in terms of comprehension accuracy, but they may take longer to interpret them. Unfortunately, this was not a variable that was measured in the study by Tager-Flusberg (1981).

Another reason why autistic individuals may have been less affected by semantic implausibility in the study by Tager-Flusberg (1981) is the idea put forward by researchers in this domain that for these individuals, "form is easy, meaning is hard" (Naigles, 2002; Ambridge et al., 2021). The former part of this theory would suggest that more complex syntactic structures, like passives, are spared in individuals with ASD, which has been refuted by Tager-Flusberg (1981) but supported by other research (Durrlemam et al., 2017; Pijnacker et al., 2009). The latter part of this theory, that "meaning is hard", may explain why a difficulty in utilising semantics may actually cause autistic individuals to be less affected by the semantically implausible stimuli in these conditions. Previous research has found that in these types of sentence comprehension tasks, sentences that are in the passive-implausible condition are the most difficult to interpret (Ferreira, 2003; Stella & Engelhardt, 2022). This is because typically-developing individuals assign meanings to the nouns in a sentence which align with real-world semantic knowledge (Ferreira, 2003). Because autistic individuals are atypical in their application of semantics, this may explain why they were less affected by semantic implausibility than typically-developing individuals, as they did not use semantic knowledge to interpret the sentence. Autistic individuals are less able to situate a bottom-up input in the context of the real world, essentially making plausibility redundant. This is intrinsically related to Theory of Mind account of ASD (Frith, 1994) and also the theory of Weak Central Coherence (Happé, 2005). This is a good example of how typical autistic "weaknesses" may actually be strengths when the demands of the task make them so, offering a new viewpoint on these types of abilities through a neurodiversity lens.

The Current Study

The current study aimed to investigate passive-implausible sentence comprehension in autistic individuals. Firstly, we wanted to investigate whether the original claim by Tager-Flusberg (1981) can be supported: that autistic individuals have more difficulty than typically-developing individuals with the comprehension of passive sentences. Or, whether there is support for other research suggesting that passive sentence comprehension in ASD remains intact (Durrlemam et al., 2017; Pijnacker et al., 2009). Secondly, we wanted to see whether autistic individuals are less affected by semantic implausibility than typically-developing individuals. Unlike Tager-Flusberg (1981), our study aims to explore this effect in adults, not children. We believe that there is value in this approach because it is common for autistic children to experience language delay and other atypical language markers (O'Shea, Holmes & Engelhardt, 2023). However, a lot of language problems experienced by those with ASD are mitigated by support during childhood, and most progress at a comparable rate to typically-developing children by the time they reach adolescence (Brignell et al., 2018). Often, differences observed between autistic children and typically-developing children in language tasks can be confounded by this fact. We therefore wanted to explore these variables among adults, with the prerequisite that participants who attend the same university, as to minimise the effects of differing intellectual abilities. We also acknowledge that Tager-Flusberg (1981) did not measure reaction times, and therefore we aimed to measure both comprehension accuracy and reaction time in the current study. Finally, we wanted to determine whether comprehension for passive-implausible sentences is correlated with subscales of the AQ, to explore whether there are any specific ASD symptomology that are related to performance on these types of tasks. We specifically wanted to explore whether attention-to-detail was correlated with performance, as we believe this may explain some of the results of previous sentence comprehension tasks.

Experiment 1

Methods

Participants

Forty-six participants took part in this study. Sixteen had a diagnosis of Autism Spectrum Disorder (ASD) and 30 served as (typically-developing) control participants. All participants were native speakers of British English. Further demographic information and Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001) are presented in Table 1. Groups were matched on age, but not gender.

Participants were recruited in two ways. Firstly, they were recruited via the SONA psychology research participation system at UEA, and secondly, they were recruited though Facebook forums for UEA students and through the Autism Society page (Appendix A). There was no incentive given to take part in the study other than to help the programme of research, but individuals that signed up via SONA were rewarded 1 research credit. Participants were given the researchers contact details in the advertisement so that they could ask any questions before taking part. The link provided in the advertisement took the participants directly to Gorilla, where the study was completed. All data collected was fully anonymous.

Table 1

Means and standard deviations for demographic variables and the AQ questionnaire.

	Controls (*N* = 30)	ASD (*N* = 16)	*t-value*
Variable	Mean (SD)	Mean (SD)	
Age (years)	23.77 (6.22)	25.31 (7.86)	*t*(44) = .47
Gender (% male)	43.3	68.8	*t*(42) = 2.26*
AQ1 - SS	3.83 (1.98)	5.81 (1.94)	*t*(44) = 3.25**
AQ2 - AS	5.60 (2.28)	8.75 (1.57)	*t*(44) = 4.92***
AQ3 - AD	5.37 (2.39)	7.25 (1.88)	*t*(44) = 2.73**
AQ4 - COM	3.23 (2.31)	7.00 (2.22)	*t*(44) = 5.33***
AQ5 - IMG	3.03 (2.13)	4.75 (2.29)	*t*(44) = 2.53*
AQ Total	21.10 (7.58)	33.56 (7.11)	*t*(44) = 5.43***

Note. *$p < .05$, **$p < .01$, ***$p < .001$

Materials

Autism-Spectrum Quotient (AQ; Appendix B)

The AQ is a self-report measure of autistic traits, consisting of 50 items assessing ASD symptomology in five areas (Baron-Cohen et al., 2001). Answers are given on a four-point Likert scale with the options 'Definitely Agree', 'Slightly Agree', 'Slightly Disagree' and 'Definitely Disagree'. 'Scores on the AQ are summed and can range from 0 to 50, with a higher score indicating that the individual possesses a higher level of autistic traits. For the purpose of the current study, subscales were also summed. Descriptive statistics for total AQ score as well as subscale scores across both the ASD group and the control group can be seen in Table 1. Cronbach's alpha of the AQ for the current study is α = 0.90, demonstrating high internal consistency.

Sentence Comprehension

The critical stimuli consisted of 32 sentences that were obtained from prior studies assessing the comprehension of passives (Ferreira, 2003; Stella & Engelhardt, 2019). The nouns and verbs were specifically selected to permit a "plausibility" manipulation (see examples 1-4 below). For each item, all four versions were created (i.e. active and passive, and plausible and implausible). From the 128 critical sentences, we created four lists of items, which were rotated in a Latin Square Design.

- The dog bit the man (Active, Plausible)
- The man was bitten by the dog (Passive, Plausible)
- The man bit the dog (Active, Implausible)
- The man was bitten by the dog (Passive, Implausible)

For each sentence, two pictures were created that either matched or mismatched the sentence content. Thus, there were 64 pictures created for the critical sentences. Pictures were obtained from either Google Images or Clipart, and were edited (as necessary) for the purposes of the study. The pictures for examples 1-4 are shown in Figure 1. Thirty-two filler sentences were also created, half of which had a picture which matched the sentence content, and half of which did not match. The same filler items were used in all 4 lists.

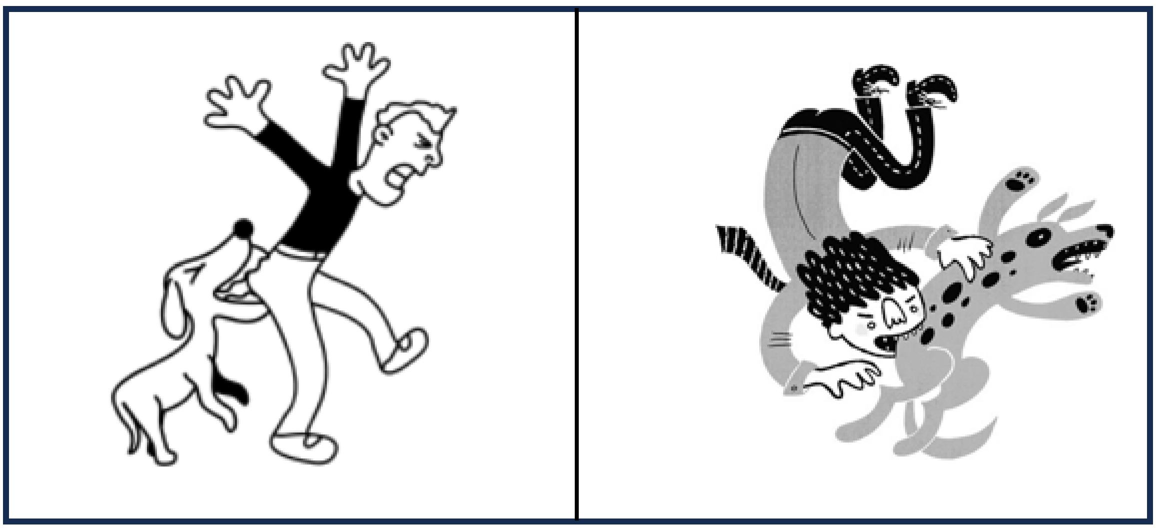

Figure 1. Example pictures for examples 1-4. Left panel shows the "plausible" picture and the right panel shows the "implausible" picture.

Design and Procedure

A 2 × 2 × 2 (Structure × Plausibility × Group) mixed design was used. Structure and Plausibility were within subject and Group was between subjects. There were two dependent measures: Comprehension, which was measured by number of correct responses, and reaction time, which was measure in milliseconds between the presentation of the picture to the participant's response.

Participants were contacted and requested to follow the link, where they were randomly assigned to one of the four lists of the experiment. Participants first saw an information page detailing the experiment and programme of research. They were then presented with a consent page, which required participants to tick a box if they consented to participate in the study. Participants first filled out the demographic questionnaire, followed by the AQ (Baron-Cohen et al., 2001; Appendix B). Participants were provided with instructions and then completed the sentence comprehension task. For each trial, participants saw the sentence, such as "*The dog bit the man*". They had unlimited time to read the sentence and were instructed to press 'Next'. They then saw a picture that either matched or mismatched the sentence. Their task was to decide whether it matched the previous sentence by selecting 'Match' or 'Mismatch'. Their reaction time was recorded from when the picture was presented to when they clicked the 'Match or 'Mismatch' button. Their responses were also recorded for accuracy. Each participant completed a total of 64 trials: 32 critical trials and 32 filler trials. The whole study took approximately 30 minutes in total to complete. At the end of the experiment, the participants were provided with a debrief.

Results

Prior to the analysis the data was checked for outliers. For comprehension, there were none. For reaction times, there were four outliers (RTs > 3 SDs). These were trimmed with rank order preserved. Prior to the statistical analyses, RTs were transformed (because the distributions were skewed) using the logarithm transformation. Following transformation the RTs were no longer skewed.

Comprehension

There was a significant main effect of plausibility $F(1,44) = 5.59$, $p < .05$, $\eta^2 = .11$. The plausible items had higher accuracy than the implausible items. The main effect of group was also significant $F(1,44) = 7.63$, $p < .01$, $\eta^2 = .15$. Individuals with ASD had lower comprehension than did the controls. There was a significant two-way interaction between structure and plausibility $F(1,44) = 12.22$, $p = .001$, $\eta^2 = .22$ and a significant three-way interaction $F(1,44) = 11.41$, $p < .01$, $\eta^2 = .21$ (see Figure 2).

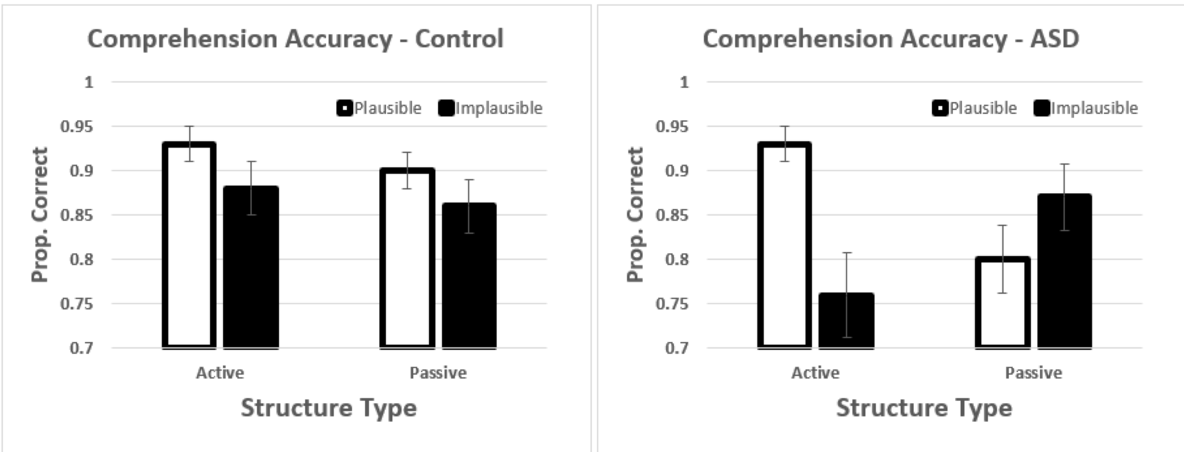

Figure 2. Mean comprehension accuracy. Left panel shows results for control participants, and the right panel shows results for participants with ASD. Error bars show the standard error of the mean.

To follow up the significant 3-way interaction, we considered each group separately. Participants with ASD showed a significant two-way interaction between structure and plausibility $F(1,15) = 18.44$, $p < .001$, $\eta^2 = .55$. Results of paired comparisons showed significant differences between active-plausible and active-implausible $t(15) = 3.48$, $p = .003$, active-plausible and the passive-plausible $t(15) = 3.04$, $p = .004$, and active-implausible and passive-implausible $t(15) = -2.33$, $p = .03$. However, the passive-plausible and passive-implausible comparison was not significant $t(15) = -1.29$, $p = .22$. Thus, the interaction is primarily driven by the differences with the active sentences, and specifically, the low comprehension accuracy with active-implausible sentences.

Control participants, in contrast, showed only a significant main effect of plausibility $F(1,29) = 4.13$, $p = .05$, $\eta^2 = .13$. The plausible conditions showed greater accuracy than did the implausible conditions. Finally, we conducted independent samples *t*-tests comparing the groups on the four within-subjects conditions. Results of those *t*-tests revealed two significant differences. Controls had significantly greater accuracy on the active-implausible sentences $t(44) = -2.65$, $p = .01$ and the passive-plausible sentences $t(44) = -2.61$, $p = .01$. This suggests that individuals with ASD had difficulty with the two medium difficulty conditions. They did not experience comprehension differences in the easiest condition (active-plausible) and the most difficult condition (passive-implausible).

Reaction Time

Results showed only a significant main effect of plausibility $F(1,44) = 5.62$, $p < .05$, $\eta^2 = .11$. The implausible items had higher reaction times compared to the plausible items. The main effect of plausibility would seem to be largely driven by the participants with ASD, as they showed longer RTs for the implausible items. However, the interaction between plausibility and group was not significant ($p = .12$).

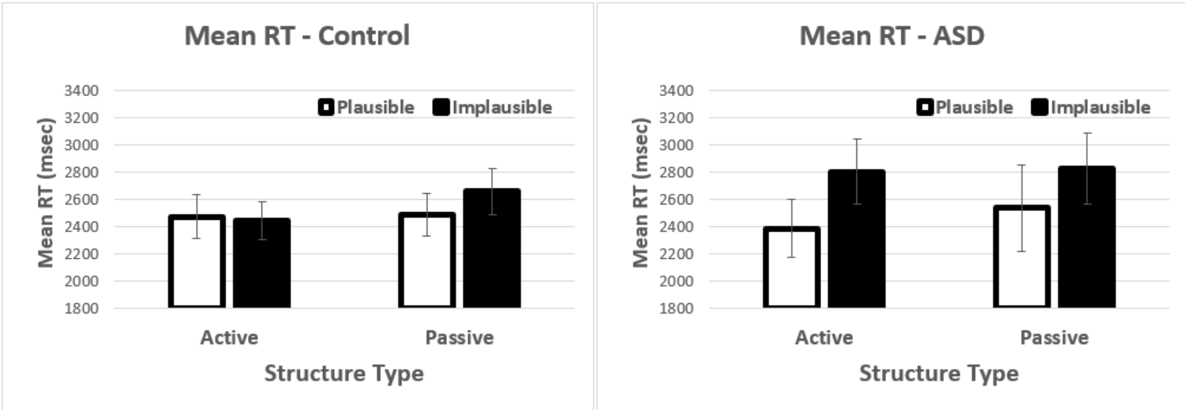

Figure 3. Mean reaction times. Left panel shows results for control participants, and the right panel shows results for participants with ASD. Error bars show the standard error of the mean.

Additional Analyses

We examined the correlations between RT and comprehension. There were not significant correlations for active-plausible, passive-plausible, and passive-implausible (all *r*'s > .38). There was a significant correlation in the active-implausible condition $r = -.46$, $p < .001$. Lower comprehension scores were associated with higher reaction times, and thus, participants who made fewer correct choices were generally longer in making the responses.

Recall that in this experiment, our groups were matched on age but not on gender. As a second set of additional analyses, we examined the correlations between these demographic variables, and comprehension and RT (see Table 2). Age showed several significant correlations with comprehension and RT, and gender did not show any significant correlations. We conducted two follow up ANCOVAs (one for age and one for gender) to ensure that the significant main effect of group and the 3-way interaction held even with differences in age and gender controlled (see Table 2). Results showed that the significant 3-way interaction replicated in both analyses, and the main effect of group was significant on comprehension and marginal on RT. Thus, it is clear that age and gender do not have substantial impacts on the ASD findings in this study.

Table 2

Mixed ANCOVA analysis covarying demographic variables

Age		
Group	$F(1,43) = 6.91, p = .01$	$\eta^2 = .14$
Structure × Plausibility × Group	$F(1,43) = 10.66, p = .002$	$\eta^2 = .20$
Gender		
Group	$F(1,43) = 3.71, p = .06$	$\eta^2 = .08$
Structure × Plausibility × Group	$F(1,43) = 12.45, p = .001$	$\eta^2 = .23$

Discussion

The results of this study showed that autistic individuals had worse comprehension overall (i.e. a main effect of group), a concurrence with the results from the Tager-Flusberg (1981) study, and a significant 3-way interaction, which was largely due to the autistic individuals performing more poorly in the active-implausible condition and the passive-plausible condition. In contrast, the groups were not different in the active-plausible and passive-implausible conditions. This is an unexpected pattern of results, given that the passive-implausible condition is the most difficult, and yet, the groups were not different. Thus, autistic individuals showed significant differences in the conditions that were “easier”, rather than more difficult. One theoretical explanation for this pattern involves the concept of “good enough” processing (Ferreira & Patson, 2007), which would suggest that autistic individuals are also likely to develop good enough representations. However, that explanation would not account for the divergence in performance between the “easier” conditions and the more difficult (passive-implausible) condition. An alternative explanation involves the concept of error detection. It is widely known that the anterior cingulate cortex acts as a conflict detector and can result in changes in behavioural responses (Braem, King, Korb, Krebs, Notebaert & Egner, 2017). By this explanation, we assume that autistic individuals are worse at detecting conflict (i.e. between the sentence content and real-world knowledge), specifically in those situations in which the conflict is minimal. And thus, there is a sensitivity threshold in which error detection becomes engaged and has a beneficial effect on comprehension responses. However, at this juncture, this explanation is speculative and there may be other equaling compelling explanations. It is also not entirely clear how an error detection explanation would fit alongside assumptions of the "good enough" theory of comprehension.

We did not observe significant group differences in reaction time, only a main effect of plausibility, such that implausible trials had longer RT than did plausible trials. Finally, we ensured that our group effects were robust when age and gender were controlled.

Experiment 2

The purpose of this experiment was to assess how ASD symptomology related to comprehension and reaction time. In order to do so, we recruited an additional forty participants, which were all undergraduate students. This gave us a sufficient sample size for examining correlations and the statistical power to run regression analyses, with AQ scores as predictor variables. Our initial hypothesis was that the attention-to-detail subscale would be the most related to sentence comprehension (Ruzich et al., 2015). Part of the motivating rationale for the study was based on autistic strengths, and that perhaps greater traits of attention-to-detail would be positively related to the ability to comprehend sentences with atypical syntactic structure and/or atypical content with respect to real world knowledge.

Methods

Participants

Eighty-six participants took part in this study. Sixteen had a diagnosis of Autism Spectrum Disorder (ASD) and 70 served as (typically-developing) control participants. The additional 40 participants were recruited via the SONA psychology research participation system at UEA and they were rewarded 1 credit.

Materials

Same as Experiment 1.

Design and Procedure

This used a correlational design to investigate whether AQ scores were significant predictors of comprehension and reaction time. We conduced eight backwards multiple regressions (four for comprehension and four for reaction time). The procedure was the same as Experiment 1.

Results

Prior to the analysis the data was checked for outliers. For comprehension, there were none. For reaction times, there was one outlier (RTs > 3 SDs), in the additional data collected for Experiment 2. This datapoint was trimmed with rank order preserved. Prior to the statistical analyses, RTs were transformed (because the distributions were skewed) using the logarithm transformation. Following transformation the RTs were no longer skewed. The descriptive statistics and correlations are presented in Table 3 and Table 4, respectively.

Comprehension

To assess AQ scores as predictors of comprehension, we conducted four backward multiple regressions using the four within subjects conditions from the sentence comprehension task (active-plausible, active-implausible, passive-plausible, and passive-implausible) as dependent variables. The results of those analyses are presented in Table 5. Attention-switching, attention to detail, and imagination were significant predictors of comprehension in the active-plausible condition. Communication was a significant predictor of active-implausible sentence comprehension, and finally, attention-switching was significantly related to passive-plausible sentence comprehension. There were no significant predictors of passive-implausible items.

Table 3

Descriptive statistics for the Autism Quotient and the Dependent Variables for Sentence Comprehension (N = 86).

Measure	Mean	SD	Min	Max	Skew	Kurtosis
Autism Quotient						
Sensation Seeking	4.50	.21	1.0	8.0	.12	-1.01
Attention Switching	5.90	.25	1.0	10.0	-.26	-.57
Attention to Detail	5.24	.26	0.0	10.0	-.36	-.44
Communication	5.40	.30	0.0	10.0	.27	-.81
Imagination	3.31	.24	0.0	9.0	.57	-.33
Total AQ	24.37	.95	6.0	45.0	.24	-.59
Comprehension						
Active Plausible	.92	.01	.50	1.0	-1.51	3.24
Active Implausible	.81	.02	.38	1.0	-1.29	1.23
Passive Plausible	.87	.01	.50	1.0	-.85	.21
Passive Implausible	.82	.02	.25	1.0	-1.04	1.08
Reaction Time						
Active Plausible[a]	7.69	.35	6.98	8.47	.26	-.32
Active Implausible[a]	7.68	.33	6.81	8.70	.50	1.00
Passive Plausible[a]	7.74	.32	6.92	8.70	.30	1.12
Passive Implausible[a]	7.72	.34	6.78	8.76	.30	1.02

Note. [a]logarithm transformation.

Table 4

Bivariate correlations between demographic variables, AQ scores, comprehension, and reaction time (N = 86).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age	-	-.13	-.29**	.08	.03	.02	.11	-.04	.05	-.06	-.30**	.14	.17	.22*	.47**	.11	.27*
2. Gender		-	-.24*	.33**	.21$^{\#}$	-.04	.17	.10	.20$^{\#}$	-.04	.11	.00	-.06	.02	-.06	-.06	-.13
3. ASD diagnosis			-	-.32**	-.49**	-.30**	-.46**	-.31**	-.50**	-.07	.26*	.23*	-.14	-.04	-.24*	.00	-.10
4. AQ 1 - SS				-	.49**	.24*	.72**	.40**	.74**	.04	-.19$^{\#}$	-.02	-.01	.15	.23*	.14	.16
5. AQ 2 - AS					-	.30**	.59**	.49**	.76**	.14	-.12	-.28**	.15	.10	.19$^{\#}$	.16	.17
6. AQ 3 - AD						-	.36*	.44**	.63**	.18	-.16	-.18	-.05	.00	.02	.03	.14
7. AQ 4 - CM							-	.54**	.87**	.03	-.32*	-.20$^{\#}$	.02	.13	.29**	.19$^{\#}$	.17
8. AQ 5 - IM								-	.76**	-.13	-.15	-.14	-.05	.01	.05	.06	.01
9. AQ Total									-	.07	-.25*	-.22*	.02	.10	.21$^{\#}$	.16	.18
10. Comp - ACTPLA										-	.23*	.16	.16	-.07	.00	.05	.13
11. Comp - ACTIMP											-	.16	.19$^{\#}$	.08	-.19$^{\#}$	.06	.14
12. Comp - PASPLA												-	.15	.22*	.12	.10	.08
13. Comp - PASIMP													-	.21$^{\#}$	.29**	.23*	.18
14. RT – ACTPLA[a]														-	.68**	.63**	.73**
15. RT - ACTIMP[a]															-	.58**	.71**
16. RT - PASPLA[a]																-	.71**
17. RT - PASIMP[a]																	-

Note. $^{\#}p < .08$, $^{*}p < .05$, $^{**}p < .01$. [a]Logarithm transformation. ASD diagnosis coded 0 = female and 1 = male.

Table 5

Regression coefficients for retained predictor variables by sentence type.

Variable	*B*	*SE (B)*	*β*	*t*-value
Active-Plausible $F(3,82) = 4.20$, $p = .008$, $R^2 = .13$				
AQ2 Attention Switching	.011	.005	.24	2.06*
AQ3 Attention to Detail	.011	.005	.27	2.36*
AQ5 Imagination	-.0171	.006	-.37	-2.94**
Active-Implausible $F(1,84) = 9.28$, $p = .003$, $R^2 = .089$				
AQ4 Communication	-.019	.006	-.32	-3.05**
Passive-Plausible $F(1,84) = 7.15$, $p = .009$, $R^2 = .078$				
AQ2 Attention Switching	-.016	.006	-.28	-2.67**

Note. ***$p < .001$, **$p < .01$, *$p < .05$, $^{\#}p < .10$

Reaction Time

Results showed only two significant effects. Communication was a significant predictor for both active-implausible and passive-plausible reaction times (Table 6). There were no significant predictors of active-plausible and passive-implausible sentences.

Table 6

Regression coefficients for retained predictor variables by sentence type.

Variable	*B*	*SE (B)*	*β*	*t*-value
Active-Implausible $F(1,84) = 7.84$, $p = .006$, $R^2 = .085$				
AQ4 Communication	.035	.013	.29	2.80**
Passive-Plausible $F(1,84) = 3.28$, $p = .074$, $R^2 = .038$				
AQ4 Communication	.022	.012	.19	$1.81^{\#}$

Note. ***$p < .001$, **$p < .01$, *$p < .05$, $^{\#}p < .10$

Discussion

This experiment produced several significant correlations between AQ scores and comprehension. Communication was significantly related to active-implausible sentence comprehension and attention-switching was related to passive-plausible sentence comprehension. Moreover, these two relationships were the only significant predictors, when tested in a multiple regression. The pattern for both was negative, suggesting that higher AQ scores were associated with lower comprehension. These are the two conditions that showed significant Group differences in Experiment 1. The standardized regression coefficients suggest medium-to-large effect sizes. For the active-plausible condition, three variables were retained. They were attention-switching, attention-to-detail, and imagination. Interestingly, none of these variables showed significant bi-variate correlations with the active-plausible sentences. However, when included in the multiple regression all three were significant. It is important to note that this condition did not show significant group differences in Experiment 1, and the direction of the relationship was mixed. Attention-switching and attention-to-detail were both positive and imagination was negative. In this case, it seems that the variables accounted for additive variance in the DV, rather than overlapping variance. The negative pattern with imagination is similar to the results presented above (i.e. higher ASD symptomology was associated with lower comprehension). The other two significant predictors were reversed (i.e. that higher ASD symptomology was associated with better comprehension). The effect of attention-to-detail is consistent with our initial predictions for this experiment. However, it is important to bear in mind that the active-plausible condition did not show significant group differences and overall is the easiest of the four within-subject conditions. The expectation was that attention-to-detail would be important, particularly for the passive and implausible sentences. Thus, even though we obtained a significant attention-to-detail result, it did not occur in the expected condition of the sentence comprehension task.

Results for reaction time showed only two significant effects. Communication was a significant predictor of active-implausible sentences and passive-plausible sentences. The direction of the effect was for individuals with higher communication scores (higher ASD traits) to have longer reaction times.

General Discussion

This study aimed to explore passive-implausible sentence comprehension in autistic individuals. Firstly, we wanted to investigate whether passive sentence comprehension was atypical in ASD, as there were mixed results from previous studies of this kind (Tager-Flusberg, 1981; Pijnacker et al., 2009). We failed to replicate findings from other studies, observing no main effect of syntactic structure on comprehension accuracy for neither the ASD nor the control group, which was particularly unexpected.

Secondly, we wanted to determine how autistic individuals are affected by semantic implausibility. There was a significant main effect of plausibility across all participants. Our results further showed that comprehension accuracy for the ASD participants was significantly lower in the active-implausible condition than the active-plausible condition. We can summarise that for active sentences, plausibility is a factor that determines correct interpretation. The direction of this effect was neither expected nor unexpected. However, there were no significant differences in terms of comprehension accuracy between the passive-plausible and passive-implausible conditions for the ASD participants. On the contrary, the control group showed significantly lower comprehension accuracy for implausible conditions across both sentence types, actives and passives. Interestingly, this means that for the condition that is generally most difficult for people to interpret, those with autism showed no significant differences, and actually performed better in this condition (if we consider means) than both the active-implausible and passive-plausible conditions. Like the Tager-Flusberg (1981) study, we can infer that autistic individuals are less affected by semantic implausibility in terms of comprehension accuracy, but that this is not consistent across both types of syntactic structure, being only the case for passives.

Looking at reaction times, there was a significant main effect of plausibility across all participants, and no other significant results. The autistic participants seemed to take the longest in the passive-implausible condition, but this was not significant when compared with other conditions or to the control group. If we consider our previous speculation, that autistic individuals may not perform the lowest in the most difficult condition (passive-implausible) like typically-developing individuals do, because their detail-focused cognitive style might make it so that they contemplate the most cognitively demanding condition *more,* there is some evidence that this may have been the case in the current study.

We therefore analysed sentence comprehension against the AQ to determine whether the attention-to-detail subscale, a synonymous concept to the detail-focused cognitive style that is characteristic of ASD (Happé & Frith, 2006), can be predictive of performance in this task. We found that attention-to-detail was only a significant predictor of comprehension accuracy in the easiest condition (active-plausible). If we take each condition separately, attention-switching was a significant predictor of all plausible sentences, both in the active and passive conditions. Attention-switching is intrinsically related to cognitive flexibility (Polderman et al., 2013), which has been shown to affect active and passive sentence comprehension (He & Bi, 2020). Therefore, if we consider that attention-switching, as measured by the AQ, may be a significant correlate of cognitive flexibility, the results from our study suggest that the ability to be able to "flip" sentences round to comprehend ambiguous syntactic structure may have been utilised across groups. However, this was only the case for sentences that were plausible, as attention-switching was not a significant predictor of comprehension accuracy in the implausible conditions (active-implausible and passive-implausible). We were intrigued to see if there were any predictors of comprehension accuracy in the passive-implausible condition, considering the interesting ANOVA result for ASD participants, however we found no significant predictors of either measure of performance in this condition. Therefore, it is obvious that the unexpected performance of ASD participants in the passive-implausible condition was not necessarily driven by a factor measured in the current study. Furthermore, communication was a significant predictor of comprehension accuracy in the active-implausible condition, suggesting that poorer communication tends to results in a lower performance for these types of sentences. Communication was also a significant predictor of reaction times in the active-implausible and the passive-plausible conditions, suggests that poorer communication is a factor that contributes to longer reaction times in those conditions. These results do not tell the clearest story on the relationship between communication and performance on these tasks. However, we can note that the active-implausible and passive-plausible conditions are the two medium-difficulty conditions, and perhaps require a certain level of communicative skill to interpret. This means that there are other factors to consider with performance in the easiest condition (active-plausible) and the most difficult condition (passive-implausible).

Limitations

We acknowledge that there are a few limitations of this study. Firstly, the smaller sample size for the ASD group. Ideally, we would have liked to obtain more autistic participants so that there was at least as many autistic participants as the controls. Generally, it is harder to make comparisons between autistic participants and the control group due to differences in age and gender. However, as we showed for this study (Table 2), age and gender did not have an impact on the findings in the ASD group. This is important considering that we had 43.3% of males in the control group and 68.8% of males in the ASD group. It is widely known that male presentation of autism is much different to female presentation, so generally creating gender-matched groups is ideal.

We also address that it would have perhaps been useful to measure the participants' reading times for the sentences, not just the reaction time at the point they were asked about comprehension. For the study, participants had unlimited time to read the sentence, which may have impacted results. This means that they could essentially spend however long they liked rehearsing the sentence. Therefore, this may be why the results of the study did not align with what we expected, most notably in the control group. Measuring reading times for the sentences may have given us an insight into the cognitive processes that were underlying comprehension, and whether accuracy was immediate or took time. This would have been particularly interesting for the ASD group.

Conclusions

To conclude this study, we suggest that passive-implausible sentence comprehension in ASD is something that warrants further exploration. Whilst this specific task elicited worse accuracy for autistic individuals, it is clear that they do not show the typical trend that is usually seen in this type of sentence comprehension, such as being less affected by plausibility than typically-developing individuals. The reasons for these results are speculatory, but we believe that it may be related to atypical semantic knowledge application. Studying language abilities in autism is challenging because of the large variation of language abilities across the spectrum. However, we think it is particularly valuable to test adults with high-functioning autism to tease apart more subtle differences in sentence comprehension.

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APPENDIX A

Study Advert

Hello UEA students!

I am looking to recruit individuals with Autism for an online study looking at matched and mismatched pictures and sentences.

The study will take no longer than 15/20 minutes - you will first complete a couple of questionnaires followed by the picture/sentence task (full instructions provided).

If you are interested or know anyone who might be interested, please use the link which will take you directly to the study! It is recommended that you complete the study on a PC or laptop.

If you have any questions or you would like some further information, please email me on a.oshea@uea.ac.uk.

Thank you!

https://eur01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fresearch.sc%2Fparticipant%2Flogin%2Fdynamic%2FBCC42697-DB44-4A87-A046-CD63976F1307&data=05%7C02%7CA.OShea%40uea.ac.uk%7C80019ebcea3342481c1b08dd41587841%7Cc65f8795ba3d43518a070865e5d8f090%7C0%7C0%7C638738570413403622%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C&sdata=GEirMRKu2g0YRAUjHoAQ3cnsrP3I2QdiBp3qyIN7ios%3D&reserved=0

APPENDIX B

The Autism-Spectrum Quotient

Please circle your answer to indicate how much you agree with the following statements.

1. I prefer to do things with others rather than on my own.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

2. I prefer to do things the same way over and over again.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

3. If I try to imagine something, I find it very easy to create a picture in my mind.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

4. I frequently get so strongly absorbed in one thing that I lose sight of other things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

5. I often notice small sounds when others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

6. I usually notice car number plates or similar strings of information.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

8. When I'm reading a story, I can easily imagine what the characters might look like.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

9. I am fascinated by dates.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

10. In a social group, I can easily keep track of several different people's conversations.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

11. I find social situations easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

12. I tend to notice details that others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

13. I would rather go to a library than a party.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

14. I find making up stories easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

15. I find myself drawn more strongly to people than to things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

16. I tend to have very strong interests, which I get upset about if I can’t pursue.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

17. I enjoy social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

18. When I talk, it isn’t always easy for others to get a word in edgeways.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

19. I am fascinated by numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

20. When I’m reading a story, I find it difficult to work out the characters’ intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

21. I don’t particularly enjoy reading fiction.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

22. I find it hard to make new friends.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

23. I notice patterns in things all the time.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

24. I would rather go to the theatre than a museum.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

25. It does not upset me if my daily routine is disturbed.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

26. I frequently find that I don’t know how to keep a conversation going.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

27. I find it easy to “read between the lines” when someone is talking to me.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

28. I usually concentrate more on the whole picture, rather than the small details.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

29. I am not very good at remembering phone numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

30. I don't usually notice small changes in a situation, or a person's appearance.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

31. I know how to tell if someone listening to me is getting bored.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

32. I find it easy to do more than one thing at once.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

33. When I talk on the phone, I'm not sure when it's my turn to speak.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

34. I enjoy doing things spontaneously.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

35. I am often the last to understand the point of a joke.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

36. I find it easy to work out what someone is thinking or feeling just by looking at their face.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

37. If there is an interruption, I can switch back to what I was doing very quickly.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

38. I am good at social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

39. People often tell me that I keep going on and on about the same thing.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

40. When I was young, I used to enjoy playing games involving pretending with other children.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

41. I like to collect information about categories of things (e.g. types of car, types of bird,

types of train, types of plant, etc.).
Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

42. I find it difficult to imagine what it would be like to be someone else.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

43. I like to plan any activities I participate in carefully.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

44. I enjoy social occasions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

45. I find it difficult to work out people's intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

46. New situations make me anxious.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

47. I enjoy meeting new people.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

48. I am a good diplomat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

49. I am not very good at remembering people's date of birth.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

50. I find it very easy to play games with children that involve pretending.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

APPENDIX C – STIMULI

ACTIVE-PLAUSIBLE SENTENCES

The dog bit the man
The cat chased the mouse
The waiter served the customer
The mother fed the baby
The girl washed the puppy
The bird ate the worm
The ghost scared the boy
The owner fed the cat
The fox chased the rabbit
The monster scared the girl
The cop caught the robber
The dog licked the child
The bee stung the boy
The shark chased the fish
The chick followed the mother
The frog ate the fly
The hunter shot the deer
The doctor treated the patient
The prince slayed the dragon
The judge sentenced the prisoner
The boy fed the rabbit
The child chased the pigeon
The lion hunted the deer
The wasp stung the boy
The girl bought the hamster
The customer paid the server
The child rode the pony
The woman groomed the horse

PASSIVE-PLAUSIBLE SENTENCES

The man was bitten by the dog
The mouse was chased by the cat
The customer was served by the waiter
The baby was fed by the mother
The puppy was washed by the girl
The worm was eaten by the bird
The boy was scared by the ghost
The cat was fed by the owner

The rabbit was chased by the fox
The girl was scared by the monster
The robber was caught by the cop
The child was licked by the dog
The boy was stung by the bee
The fish was chased by the shark
The mother was followed by the chick
The fly was eaten by the frog
The deer was shot by the hunter
The patient was treated by the doctor
The dragon was slain by the prince
The prisoner was sentenced by the judge
The rabbit was fed by the boy
The pigeon was chased by the child
The deer was hunted by the lion
The boy was stung by the wasp
The hamster was bought by the girl
The server was paid by the customer
The pony was ridden by the child
The horse was groomed by the woman
The fish was caught by the man
The girl was frightened by the clown
The student was taught by the teacher
The dog was walked by the man
The puppy was washed by the girl
The worm was eaten by the bird
The boy was scared by the ghost
The cat was fed by the owner
The rabbit was chased by the fox
The girl was scared by the monster
The robber was caught by the cop
The child was licked by the dog
The boy was stung by the bee
The fish was chased by the shark
The mother was followed by the chick
The fly was eaten by the frog
The deer was shot by the hunter
The patient was treated by the doctor
The dragon was slain by the prince
The prisoner was sentenced by the judge
The rabbit was fed by the boy
The pigeon was chased by the child
The deer was hunted by the lion

The boy was stung by the wasp
The hamster was bought by the girl
The server was paid by the customer
The pony was ridden by the child
The horse was groomed by the woman
The fish was caught by the man
The girl was frightened by the clown
The student was taught by the teacher
The dog was walked by the man

ACTIVE-IMPLAUSIBLE

The man bit the dog
The mouse chased the cat
The customer served the waiter
The baby fed the mother
The puppy washed the girl
The worm ate the bird
The boy scared the ghost
The cat fed the owner
The rabbit chased the fox
The girl scared the monster
The robber caught the cop
The child licked the dog
The boy stung the bee
The fish chased the shark
The mother followed the chick
The fly ate the frog
The deer shot the hunter
The patient treated the doctor
The dragon slayed the prince
The prisoner sentenced the judge
The rabbit fed the boy
The pigeon chased the child
The deer hunted the lion
The boy stung the wasp
The hamster bought the girl
The server paid the customer
The pony rode the child
The horse groomed the woman
The fish caught the man
The girl frightened the clown
The student taught the teacher

The dog walked the man
The puppy washed the girl
The worm ate the bird
The boy scared the ghost
The cat fed the owner
The rabbit chased the fox
The girl scared the monster
The robber caught the cop
The child licked the dog
The boy stung the bee
The fish chased the shark
The mother followed the chick
The fly ate the frog
The deer shot the hunter
The patient treated the doctor
The dragon slayed the prince
The prisoner sentenced the judge
The rabbit fed the boy
The pigeon chased the child
The deer hunted the lion
The boy stung the wasp
The hamster bought the girl
The server paid the customer
The pony rode the child
The horse groomed the woman
The fish caught the man
The girl frightened the clown
The student taught the teacher
The dog walked the man

PASSIVE-IMPLAUSIBLE

The dog was bitten by the man
The cat was chased by the mouse
The waiter was served by the customer
The mother was fed by the baby
The girl was washed by the puppy
The bird was eaten by the worm
The ghost was scared by the boy
The owner was fed by the cat
The fox was chased by the rabbit
The monster was scared by the girl
The cop was caught by the robber

The dog was licked by the child

The bee was stung by the boy

The shark was chased by the fish

The chick was followed by the mother

The frog was eaten by the fly

The hunter was shot by the deer

The doctor was treated by the patient

The prince was slain by the dragon

The judge was sentenced by the prisoner

The boy was fed by the rabbit

The child was chased by the pigeon

The lion was hunted by the deer

The wasp was stung by the boy

The girl was bought by the hamster

The customer was paid by the server

The child was ridden by the pony

The woman was groomed by the horse

The man was caught by the fish

The clown was frightened by the girl

The teacher was taught by the student

The man was walked by the dog

The girl was washed by the puppy

The bird was eaten by the worm

The ghost was scared by the boy

The owner was fed by the cat

The fox was chased by the rabbit

The monster was scared by the girl

The cop was caught by the robber

The dog was licked by the child

The bee was stung by the boy

The shark was chased by the fish

The chick was followed by the mother

The frog was eaten by the fly

The hunter was shot by the deer

The doctor was treated by the patient

The prince was slain by the dragon

The judge was sentenced by the prisoner

The boy was fed by the rabbit

The child was chased by the pigeon

The lion was hunted by the deer

The wasp was stung by the boy

The girl was bought by the hamster

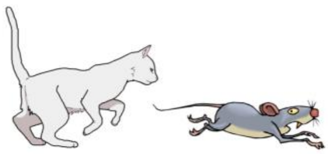
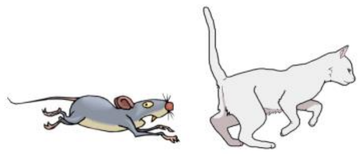
The customer was paid by the server

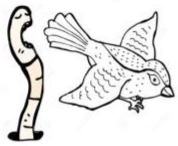
The child was ridden by the pony
The woman was groomed by the horse
The man was caught by the fish
The clown was frightened by the girl
The teacher was taught by the student
The man was walked by the dog

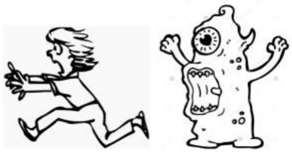
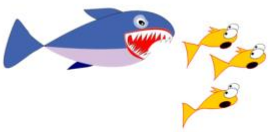
FILLERS

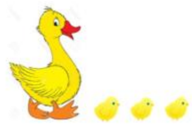
The children built a sandcastle
The cat played with the ball of yarn
The man rode the bike
The woman carried the shopping
The girl did her makeup
The dog chased the ball
The hamster ran on the wheel
The man brushed his teeth
The children played with a ball
The boy tried to catch a butterfly
The mum folded the laundry
The man played the guitar
The woman held the baby
The woman knocked on the door
The girl sat on the sofa
The man sat on the chair
The children played with a yellow ball
The child played the piano
The girl played the saxophone
The dog chased the rabbit
The cat ate the mouse
The man ate the pizza
The man went running
The girl washed her hair
The cat chased the bird
The baby watched the TV
The dog ate the cheese
The green monster scared the girl
The rabbit chased the ball
The cat looked out the window
The child hid under the blanket
The man dug a hole

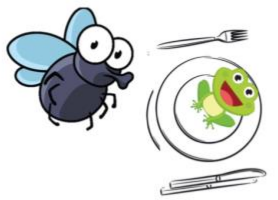
ACCOMPANYING PICTURES FOR SENTENCE STIMULI

PLAUSIBLE	IMPLAUSIBLE
	
	
	
	





PET STORE	PET STORE
	
	
	
	

	
	
	
FILLER PICTURES	
	

CHAPTER 6 – METAPHOR COMPREHENSION

Abstract

The aim of this study was to investigate novel metaphor comprehension in autistic adults. Previous literature is conflicting with regards to an impairment in particular type of figurative language. Participants in the study completed a visual world paradigm eye-tracking task, which involved selecting an interpretation of an auditorily presented sentence (i.e. a picture-sentence matching task), where images corresponded to literal and metaphorical interpretations. Thus, the study also investigated online processing. Forty adults participated in the study (18 with ASD and 22 typically-developing controls). Each participant completed an ADOS semi-structured interview, as well as the AQ questionnaire and had their vocabulary assessed. Results showed that autistic participants comprehended metaphorical utterances with the same accuracy as controls. However, they had significantly slower reaction times, and specifically, were approximately 800ms slower. Analysis of eye movements revealed that autistic participants showed significantly longer fixation times on both the target and distractor image, the latter of which suggests difficulty overcoming the literal interpretation. Consistent with some prior studies, we show that autistic adults are not impaired in novel metaphor comprehension, but they were clearly less efficient. Verbal abilities did not significantly relate to performance. Finally, our online measure (eye tracking) provided us with insights into the nature of the ASD inefficiency (i.e. a literality bias).

Keywords: Autism Spectrum Disorders, metaphor processing, language ability, pragmatics, social communication

Online Metaphor Comprehension in Adults with Autism Spectrum Disorders: An Eye Tracking study

Metaphor comprehension is commonly considered challenging for autistic individuals. The latest edition of the Diagnostic and Statistical Manual of the American Psychiatric Association (DSM-5; 2013) includes difficulties in understanding non-literal and ambiguous language meanings, such as metaphors, as key criteria for diagnosing autism spectrum disorder (ASD). However, recent findings cast doubt on the notion that autistic individuals encounter metaphor processing difficulties, beyond those attributed to broader language impairments (Brock et al., 2008; Gernsbacher & Pripas-Kapit, 2012; Norbury, 2005).

The finding that metaphors are not understood (or only partially understood) by autistic individuals was first proposed in seminal work by Happé (1993), who linked difficulties in understanding figurative language to weaknesses in Theory of Mind (ToM), frequently found in ASD (Baron-Cohen et al., 2001). ToM, defined as the ability to attribute mental states to oneself and others (Frank, 2018), is essential for interpreting beliefs, intentions, thoughts, and emotions, thereby directly influencing communicative pragmatics. However, the precise role of ToM in metaphor comprehension remains a subject of much debate (Bosco et al., 2018; Gernsbacher & Pripas-Kapit, 2012). Happé (1993) proposed that metaphors, unlike similes, necessitate the recipient to discern the speaker's intention as the meaning conveyed is non-literal. To test this hypothesis, Happé employed a sentence completion task including synonyms, similes, and metaphors, differentiating participants based on impairments in first-order, second-order, or both orders of ToM. First-order ToM pertains to inferring another individual's mental states, whereas second-order ToM involves deducing another individual's mental states concerning a third party (Duval et al., 2011). The group with impairments in both orders of ToM exhibited lower scores (only) in the metaphorical condition, while the other two groups did not manifest significant differences from each other.

Several subsequent research studies contributed to the idea that autistic individuals have issues with figurative language comprehension (e.g., Dennis et al., 2001; Kaland et al., 2002; MacKay & Shaw, 2004). Lower accuracy in metaphor tasks was confirmed by recent meta-analyses (Kalandadze et al., 2019; Morsanyi et al., 2020), which found a medium-to-large group difference (Hedges' g was respectively 0.63 and 0.76). However, both meta-analyses caution against drawing firm conclusions from these results because of the heterogeneity of the studies examined. The main reasons for this variability are (i) participants' individual differences in linguistic abilities, and (ii) the format of the tasks used to assess metaphor comprehension.

Interestingly, a number of research studies found that group differences are no longer significant when the ASD and control groups were matched on verbal ability (e.g., Brock et al., 2008; Gernsbacher & Pripas-Kapit, 2012; Geurts et al., 2020; Kalandadze et al., 2018; Norbury, 2005). Metaphors require individuals to perceive similarities between two terms typically regarded as distinct, often involving features that are not the most salient in either term (Giora et al., 2012). Therefore, a comprehender must possess enough world knowledge and sufficiently broad semantic representations to grasp the intended comparison (Norbury, 2004). Morsanyi et al. (2020) observed a notable impact of verbal intelligence, where distinctions in metaphor processing between ASD and control groups were reduced or absent among participants with higher verbal skills. Notably, approximately 60% of the variance in effect sizes across studies could be attributed to variance in participants' verbal abilities.

Norbury (2005) was among the first to highlight the significance of language skills in metaphor processing in ASD. Contrary to the assumption that ToM deficits solely account for difficulties in understanding metaphorical language, Norbury observed that children with language impairments encounter challenges in comprehending metaphors, despite maintaining relatively intact ToM abilities (Highnam et al., 1999; Rinaldi, 2000; Leslie & Frith, 1988; Shields et al., 1996; Ziatas et al., 1998). In her investigation, Norbury found that only children with language impairment, with or without concurrent ASD features, displayed difficulties in metaphorical tasks. Moreover, possessing first-order ToM skills did not guarantee metaphor comprehension. Instead, Norbury highlighted semantic ability as a more robust predictor of performance on metaphor tasks. Consequently, she underscored the centrality of semantic knowledge, suggesting that ToM skills facilitate metaphor understanding by enriching contextual representations.

Language skills are extremely variable across the autism spectrum. While many autistic individuals develop language skills within the typical trajectory observed in typically-developing individuals (Friedman & Sterling, 2019; Kjelgaard & Tager-Flusberg, 2001), a substantial proportion, estimated to be between 25% and 30%, remain non-verbal or possess only minimal verbal abilities (Pickles et al., 2014; Tager-Flusberg & Kasari, 2013). Studies investigating metaphor comprehension predominantly involve people with average functional language skills. Contrary to the assumption that deficits in figurative language comprehension are universal among autistic individuals (Gernsbacher & Pripas-Kapit, 2012), some researchers suggest that these challenges may not be specific to ASD and could instead be linked to individual structural language abilities, including vocabulary and syntax (Norbury, 2004, 2005; Whyte et al., 2014). In another study, Norbury (2004) reported that autistic children and adolescents did not exhibit impairments in figurative language comprehension when their vocabulary and syntactic skills fell within the normal range. This finding was corroborated by a meta-analysis conducted by Kalandadze et al. (2018), which identified language ability as a significant contributor to the variability in figurative language comprehension across studies. Specifically, when comparing the performance of autistic individuals and typically-developing peers on core language assessments, the effect size was found to be small (Hedges' g = -0.06). Therefore, the overall challenges encountered in figurative language comprehension appear to be more directly associated with core language skills, rather than ToM.

There are also studies which found no significant difference between ASD and typically-developing individuals in the comprehension of metaphors (e.g., Chouinard & Cummine, 2016; Hermann et al., 2013; Kasirer & Mashal, 2016; Olofson et al., 2014). Hermann et al. (2013) and Chouinard & Cummine (2016) used the Metaphor Interference Effect (MIE) paradigm to investigate the initial stages of metaphor comprehension. This semantic-judgement task was useful to discern the time where a metaphorical meaning was generated from the time where unintended meanings were suppressed. In fact, the generation of metaphorical meaning may occur independently of understanding the metaphor in conversation, which requires subsequent steps of inhibiting the literal meaning and integrating the metaphorical utterance within discourse and social contexts. Their findings suggested that autistic indviduals correctly generate the metaphorical meaning, but potential difficulties arise in suppressing irrelevant literal features.

Issues related to the suppression of semantic components, which are not relevant for the computation of the appropriate meaning, can lead to slower processing, as indicated by Gold et al. (2010). Those authors observed longer response times and greater N400 amplitudes, despite similar accuracy rates between an autistic group and a group of typically-developing individuals. Morsanyi et al. (2020) considered reaction time results related to metaphor processing in their meta-analysis. Drawing from the findings of four studies that reported both accuracy and reaction times for metaphor processing (Chahboun et al., 2016; Gold et al., 2010; Gold & Faust, 2010; Morsanyi et al., 2021), they observed a general advantage for typically-developing individuals where the reaction time was lower (Hedges' g = 0.74). Thus, autistic individuals are not necessarily less accurate in metaphor comprehension, but the few online studies seem to suggest slower processing.

Another source of heterogeneity among studies investigating metaphor comprehension in ASD is the variety of tasks employed. In a meta-analysis, Kalandadze et al. (2019) observed that the method of assessing metaphor comprehension can yield varying outcomes. For example, tasks that necessitate individuals to explain the meaning of a metaphor may pose particular challenges for autistic individuals due to difficulties with expressive language (Kwok et al., 2015). Another meta-analysis (Morsanyi et al., 2020) corroborated this finding, emphasizing that studies that presented more substantial and consistent group disparities, typically used tasks demanding more complex responses. These tasks included verbalising metaphors depicted in images (Tzuriel & Groman, 2017), explaining a metaphorical meaning (Borkowska, 2015; de Villiers et al., 2011; Landa & Goldberg, 2005), or drawing inferences based on ambiguous metaphorical expressions (Minshew et al., 1995).

In summary, while autistic individuals often face more pronounced challenges in metaphor comprehension, attributing issues in figurative language as a hallmark of ASD remains a topic of contention. It is crucial to acknowledge that multiple factors, including language skills and task formats, may contribute to group disparities. Therefore, further research is needed to shed light on (1) whether differences exist and if they do, (2) what are the underlying causes of the differences.

Current Study

The current study focused on providing further evidence about how adults with ASD understand metaphors through the use of eye-tracking data, combined with response time and comprehension accuracy. As far as we know, there has never been an eye tacking study to explore metaphor comprehension in this population. There are eye tracking studies of metaphor comprehension, but those involved eye movements in reading (e.g. Ashby et al., 2018; Columbus et al., 2015; Ronderos et al., 2021; cf. Coulson et al., 2015). In addition, the majority of previous research on metaphor comprehension in ASD only included behavioral assessment, and only few report online measures (e.g. reaction time or neuroimaging). As suggested by Kalandadze et al. (2019), "more high-quality studies on metaphor comprehension in ASD are needed combining offline and online comprehension methods widely used in psycholinguistic research" (pg. 1447). Online tasks are able to measure implicit processing and to provide more fine-grained insights on how metaphors are understood by autistic people.

Additionally, there is little data on autistic adults in comparison to research conducted on children and adolescents, and the findings thus far appear to be inconclusive. In their examination of figurative language, Saban-Bezalel and Mashal (2018) determined that challenges in metaphor processing among autistic individuals are more evident during childhood and adolescence, but may not persist into adulthood, although this outcome is contingent upon the specific type of metaphor task and the manner in which responses are elicited. They analysed a study conducted by Kasirer and Mashal (2014), where autistic adults and controls underwent a metaphor comprehension multiple-choice test and no differences were found. By contrast, a review conducted by Vulchanova et al. (2015) concluded that disparities in metaphor processing persist among high-functioning autistic individuals due to challenges related to integrating information. The authors highlighted the significance of various cognitive and linguistic skills in metaphor comprehension, emphasizing that deficits in any of these areas can impede the processing of figurative language.

Since metaphor processing relies heavily on semantic skills, our study is aimed at providing further insights on how autistic adults understand metaphors by assessing vocabulary skills (one component of verbal ability) together with metaphor comprehension. Based on the existing literature, we hypothesise that no substantial differences in accuracy would emerge if the two groups do not differ on vocabulary skills, as Kalandadze et al. (2019) and Morsanyi et al. (2020) point out in their meta-analyses. Still, it is possible that slowness in computing the correct meaning would arise, as suggested in the few studies that took reaction times into consideration (e.g. Chahboun et al., 2016; Gold et al., 2010; Gold & Faust, 2010; Morsanyi et al., 2021).

Eye-tracking data, particularly the pattern of fixations to different visual representations, allowed us to clarify how the process of understanding a metaphor unfolds in autistic adults. Longer fixations on the picture representing the literal meaning (i.e., the distractor image, see Materials section, Figure 1) would indicate a possible "literality bias" already mentioned by some authors (see Rossetti, Brambilla, & Papagno, 2018) or, alternatively, the difficulty in rejecting irrelevant meaning that emerged in the studies that used the Metaphor Interference Effect in ASD (Chouinard & Cummine, 2016; Hermann et al., 2013). Accuracy data would allow us to discriminate between the two: lower accuracy due to a high number of literal interpretations is more likely to be attributed to the former, while higher accuracy to the latter.

Methods

Participants

Forty-one undergraduate students participated in this study. There were 18 with a formal diagnosis of ASD and 22 typically-developing adults were tested as control participants (see Table 1). Both groups were recruited from the University of East Anglia. Those in the control group were recruited from the SONA research participation system, and those in the ASD group were recruited from advertisements that were placed round campus and in online forums for the UEA Neurodivergent society (Appendix A). All participants with autism verified that they had diagnostic assessments for autism in the past. All were native speakers of English with normal or corrected-to-normal vision. Participants were compensated for their time either with participation credits or with a £7 amazon voucher. The study was approved by the School of Psychology Research Ethics Committee at the University of East Anglia (UK). Informed consent was obtained from all participants before carrying out the study and all were debriefed at the end of the study.

Table 1

Means for demographic variables, vocabulary, and ASD screening measures.

	ASD(18)	Control(22)	Significance
Variable	Mean(SD)	Mean(SD)	
Age	19.89 (1.81)	19.91 (2.52)	$t(38) = -.0.28, p = .98$
Gender (% male)	50.0	72.7	$t(36) = 2.08, p < .05$
AQ SS	6.50 (1.82)	2.41 (1.79)	$t(38) = 7.13, p < .001$
AQ AS	8.89 (1.23)	5.32 (2.06)	$t(38) = 6.47, p < .001$
AQ AD	7.00 (2.17)	5.73 (2.55)	$t(38) = 1.68, p = .10$
AQ COM	7.78 (2.02)	3.05 (2.40)	$t(38) = 6.66, p < .001$
AQ IMG	5.06 (2.24)	2.23 (1.60)	$t(38) = 4.66, p < .001$
AQ TOTAL	35.22 (7.12)	18.73 (6.16)	$t(38) = 7.86, p < .001$
PPVT	41.56 (7.91)	40.10 (8.95)	$t(38) = 0.54, p = .59$

Note. Two participants with ASD reported non-binary gender, and one control reported “other” gender. These participants were not included in any gender analysis.

Materials

All participants were tested individually before the eye-tracking task. The standardised procedures of administration for each test were followed as described in the test manuals.

Peabody Picture Vocabulary Test - 4 (PPVT-4)

The PPVT-4 (Dunn & Dunn, 2007) is a tool to assesses receptive vocabulary. The researcher aurally presented a target word and participants were asked to choose the image which best illustrated the meaning between four. The reliability range for Form A (the one used in this study) is reported to be from .89 to .97.

Autism-Spectrum Quotient (Appendix B)

The AQ is a self-report measure of autistic traits (Baron-Cohen et al, 2001), consisting of 50 items assessing ASD symptomology in five areas (social skills, attention switching, attention to detail, communication, and imagination). Answers are given on a four-point Likert scale with the options 'Definitely Agree', 'Slightly Agree', 'Slightly Disagree' and 'Definitely Disagree'. Scores on the AQ are summed and can range from 0 to 50, with a higher score indicating that the individual possesses a higher level of autistic traits. For the purpose of the current study, subscales of the AQ were also summed. Descriptive statistics for total AQ score as well as subscale scores across both the ASD group and the control group can be seen in Table 1.

Autism-Diagnostic Observation Schedule – 2 (ADOS-2)

The ADOS-2 (Lord et al., 2012) is a standardised measure of various behaviours associated with ASD symptomology, used in the diagnostic assessment for ASD. In the current study, semi-structured interviews were administered with questions that were procured from the talking activities in the ADOS-2 Module 4 assessment, which is specifically designed for use with verbally fluent adolescents and adults. Specific subjects were covered in accordance with the ADOS-2, namely 'current work or school', 'emotions', 'daily living', 'friends, relationships and marriage', and 'plans and hopes' (Appendix C).

Metaphor Comprehension Task

The metaphor comprehension task utilised a version of the Visual World Paradigm (VWP; Tanenhaus et al., 1995) and stimuli were a combination of a visual array consisting of three pictures and an auditorily presented sentence. Stimuli for this task were adapted from Pouscoulous and Tomasello (2020) and Di Paola et al. (2020). Novel metaphors were created to be suitable for adult participants. Twenty pairs of novel metaphors were constructed. They were in a syntactic structure in the form [The X with the Y], where the qualifier (Y) was figurative in the metaphor condition. All sentences were similar in length. Nouns used in the (X) and (Y) positions were frequent and concrete. To check for the words concreteness and frequency, we used ratings from Brysbaert et al., (2014) and van Heuven et al. (2014). For each trial, a target picture and two control pictures were sourced: (1) the target picture showed the target object referred to either metaphorically or literally (e.g., a cup with handles for *The cup with the ears/handles*), (2) the irrelevant picture illustrated the metaphor target without the relevant property (e.g., a cup without handles), and (3) the distractor was a literal competitor, showing both target and vehicle (e.g., a cup and a boy pointing at his ears) (see Figure 1).

We defined five key time points for each trial (see Figure 1, bottom panel). Based on the key time points, we analysed two critical time windows. The first time window (Region 1) was from the onset of NP1 to the onset of NP2 (time point 2 to time point 3). The second time window (Region 2) was from the onset of NP2 to when the participant made a button response (time point 3 to time point 5). Two additional windows were also considered and those results are presented in the Appendix (D and E). The first was from the onset of the trial to the onset of NP1, and the second was from the onset of NP2 to the ofset of NP2.

500ms	The	cup with the	ears	*2000 ms*
Blank	Det1	NP1+PP+Det2	NP2	Ending/Button Press

0. 1. 2. 3. 4. 5.

Figure 1. Top panel shows example visual array: the metaphorical utterance was "the cup with the ears" and the literal utterance was "the cup with the handles". Image (1) is the target picture, image (2) is the irrelevant picture, and image (3) is the distractor picture. Bottom panel shows the key time points for dividing the sentence into critical time periods. Det = Determiner. NP = Noun Phrase. PP = Prepositional Phrase.

Metaphors were normed on a 7-point Likert scale for their familiarity, aptness, and conventionality following the same procedure, as in Dulcinati et al. (2014). Target pictures were normed for their suitability to the sentence (i.e., *How suitable is this image to represent the sentence?*). A total of 120 native English speakers, recruited through Prolific (www.prolific.co), took part in the norming task and were paid for their time, with groups of 30 unique participants assigned to each survey. Three sentences were considered as outliers and removed from the study. Two sentences showed high familiarity or conventionality ratings (between 4 and 7 points). One showed a low picture suitability (less than 3 points). All sentences were considered apt metaphors (i.e., are perceived as providing an accurate description of the topic). One sentence was taken as a practice item. A total of 16 sentences rated as apt novel metaphors were included in the study together with their 16 literal corresponding expressions and 32 fillers. (Half of the fillers were idioms, and half were controls in which the sentence referred to only one picture.)

Apparatus

Eye movements were recorded with an SR Research Ltd. EyeLink 1000 eye-tracker, which records the position of the reader's eye every millisecond. Head movements were minimised with a chin rest. Eye movements were recorded from the right eye. Experiment Builder was used to program the experiment, and Data Viewer was used to extract the interest area reports for eye movements and message reports for button presses. The sentences were auditorily presented through a computer speaker.

Design and Procedure

The design was a 2 × 2 (Sentence Type × Group) mixed model, in which sentence type (literal and metaphorical) was within subject and group (ASD and typically-developing control) was between subject. Participants completed two practice trials, 32 experimental trials, and 36 fillers. Trials were presented in a random order for each participant. Critical trials were rotated in a Latin Square design, resulting in six lists of stimuli. Each critical utterance had a literal utterance counterpart, and images were rotated through the different possible positions in the arrays.

Before the start, details of the tasks were given to the participants. The researcher answered any questions, if required. All participants gave written informed consent. Participants were first asked to fill out a demographic questionnaire and the AQ (Baron-Cohen et al., 2001), followed by taking part in the PPVT-4 (Dunn & Dunn, 2007). The researcher then administered the ADOS-2 (Lord et al., 2012). These preliminary measures took approximately 20 minutes to complete.

Participants were then guided to the experimental task, where they were required to sit at the eye tracker and respond to on-screen instructions using the keyboard. At the beginning of each trial, a message appeared asking the participant to press a button when they were ready to continue. After the participant pressed the button, they were required to fixate a drift-correction dot, which appeared in the centre of the screen. The experimenter then initiated the trial. Participants heard the sentences, while simultaneously being presented with three pictures on the screen. There were two practice trials. If the participant was ready and had no more questions, they proceeded to the critical trials.

For each trial, the audio file started 500ms after the pictured appeared. There was a 2000 ms time window following the sentence in which participants needed to make their choice about which picture they thought best fit the sentence. They were asked to press '1' if they wanted to choose the left picture, '2' for the centre picture, and '3' for the picture on the right. The eye-tracking testing session for each participant lasted approximately 5 minutes. To avoid any bias, participants were not informed of the inclusion of figurative language among the sentences. During the debrief, the aim of the experiment was explained in detail and participants were compensated for their time before leaving. The whole study took approximately 30 minutes to complete.

Results

Outliers were defined by examining standardized scores and histogram plots. We use a threshold of 3.0 SDs from the mean. There were two datapoints exceeding this threshold for reaction times for one participant. We ran all analyses with this participant removed from the dataset, and the main effects and interactions fully replicated. Thus, we retained the outlier in the dataset. The results section is organized in the following order: comprehension accuracy, reaction time for all trials, reaction time for correct and incorrect trials, and eye movements. Eye movement analyses focused on two interest periods (see Figure 1). The eye movement dependent measure was summed fixation times (dwell time) on each picture in the array during critical interest periods. In the remainder of the paper, we use dwell time and fixations, interchangeably.

Comprehension Accuracy

For comprehension accuracy, results showed a significant main effect of sentence type $F(1,38) = 91.50$, $p < .001$, $\eta^2 = .71$, in which literal sentences had higher comprehension than did metaphor sentences (see Figure 2). The main effect of group $F(1,38) = 0.98$, $p = .33$, $\eta^2 = .03$ and the interaction $F(1,38) = 0.98$, $p = .33$, $\eta^2 = .03$ were not significant. We also conducted one sample t-tests on comprehension accuracy, see Appendix F.

Reaction Time – All Trials

Reaction times were computed from the onset of NP2 (time point 3) to when participants made the button press (see Figure 1). For reaction time, results for all trials showed significant main effects of sentence type $F(1,38) = 42.15$, $p < .001$, $\eta^2 = .53$, in which literal sentences were processed more quickly compared to metaphor sentences, and group $F(1,38) = 12.22$, $p = .001$, $\eta^2 = .24$, where the control group had shorter reaction times than did the ASD group (see Figure 2). The interaction was also significant $F(1,38) = 9.01$, $p < .01$, $\eta^2 = .19$. Paired comparisons showed significant differences between literal and metaphor sentences for both groups: ASD $t(17) = -4.96$, $p < .001$, Cohen's $D = -1.17$, and control $t(21) = -3.83$, $p < .001$, Cohen's $D = -.82$. The comparison of ASD vs. control showed significant differences for both metaphor trials $t(38) = 3.72$, $p < .001$, Cohen's $D = 1.18$ and literal trials $t(38) = 2.97$, $p < .01$, Cohen's $D = .95$. Thus, all paired comparisons were significant, but the interaction was based primarily on the elevated reaction times for metaphor trials in autistic individuals.

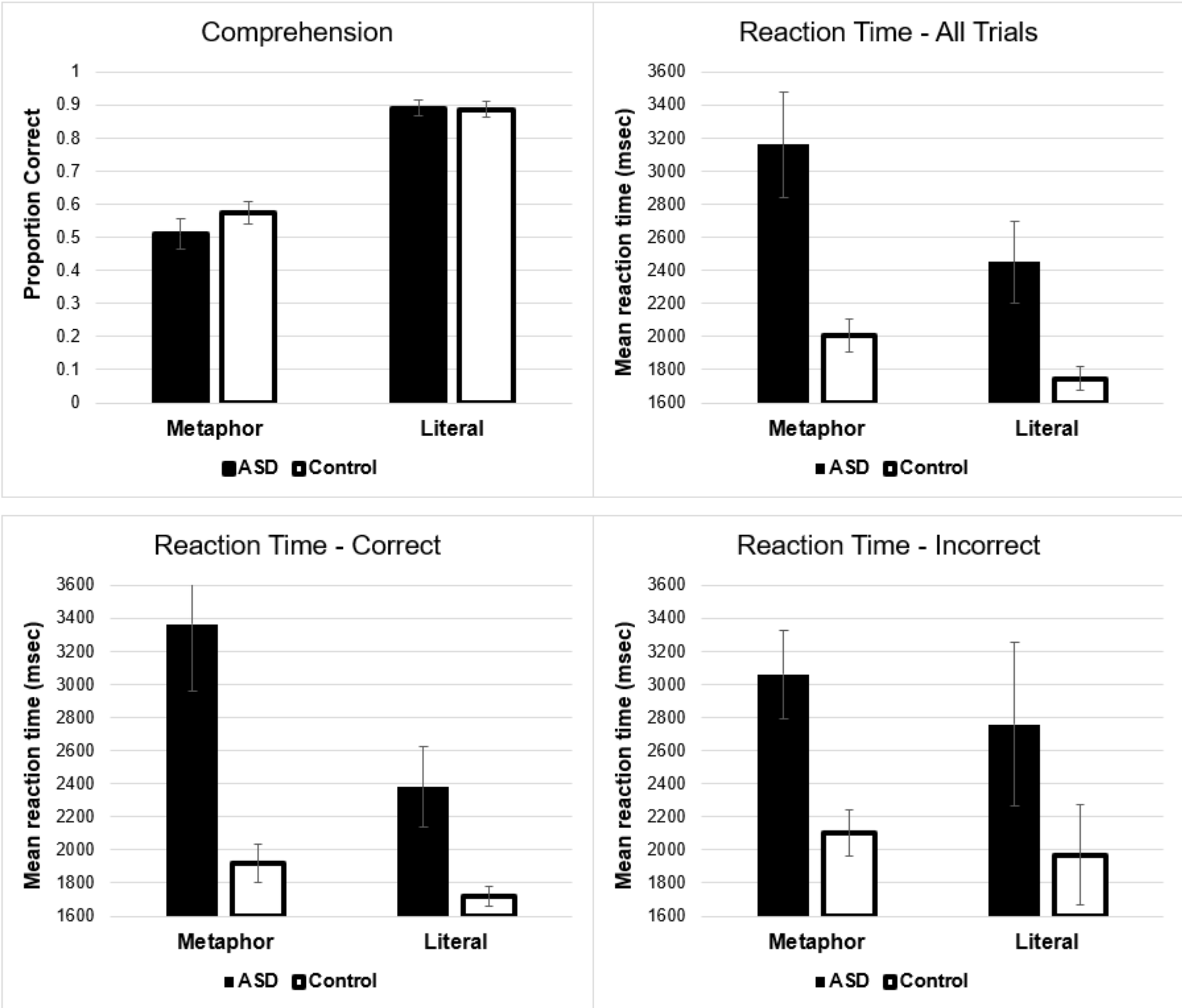


Figure 2. *Upper left panel shows mean comprehension accuracy. Upper right panel shows mean reaction time for all trials. Bottom left panel shows mean reaction time for correct trials. Lower right panel shows the reaction time for incorrect trials. Note that there were very few literal trials that were incorrect. Error bars show the standard error of the mean.*

Reaction Time – Correct Trials

Reaction times for correct trials confirmed significant main effects of sentence type $F(1,38) = 24.55$, $p < .001$, $\eta^2 = .39$ and group $F(1,38) = 12.68$, $p = .001$, $\eta^2 = .25$, and a significant interaction between variables $F(1,38) = 10.88$, $p < .01$, $\eta^2 = .22$ (see Figure 2). Note that Figure 2 also shows reaction times for incorrect trials. We did not analyse these trials statistically, but have included them for the purposes of comparison. Paired comparisons showed significant group differences for metaphor trials $t(38) = 3.73$, $p < .001$, Cohen's $D = 1.19$ and for literal trials $t(38) = 2.86$, $p < .01$, Cohen's $D = .91$. The comparison of metaphor and literal were significant for ASD $t(17) = -4.09$, $p < .001$, Cohen's $D = -.96$ and for controls $t(21) = -2.22$, $p < .05$, Cohen's $D = -.47$. Thus, again, the interaction was primarily driven by the elevated reaction times in metaphor trials in autistic individuals.

Metaphor Processing – Cost Analysis

There were significant differences for both literal and metaphorical trials in terms of reaction times between groups. As one final analysis of reaction time, we computed a difference score in which we subtracted the mean literal reaction time (correct trials) from the mean metaphor reaction time (correct trials). This difference score provides the metaphor processing costs, while taking into account literal (base-line) processing time. The difference score mean for ASD was 985 ms and for controls was 198 ms. This was a statistically significant difference $t(38) = 3.30$, $p < .01$, Cohen's $D = 1.05$. Thus, participants with ASD took approximately 800 ms longer to process novel metaphors compared to controls.

Eye Movements

For the eye movement analysis, we analysed group, sentence type, and picture type (target vs. distractor), which results in 2 × 2 × 2 mixed design. Picture type and sentence type were within subject and group was between subjects. Note that we did not include the irrelevant picture in statistical analyses, but did include it in the figures for comparison purposes. The main analyses focused on eye movements for correct trials. However, we also considered eye movement results for incorrect metaphor trials. (Incorrect responses were uncommon in literal trials.)

Region 1

In the first time window (onset of NP1 to onset of NP2), there was a significant main effect of picture type $F(1,38) = 11.97$, $p < .001$, $\eta^2 = .24$ (see upper panels, Figure 3). The distractor was viewed for longer compared to the target. There was also a significant interaction between picture type and group $F(1,38) = 10.54$, $p < .01$, $\eta^2 = .22$ (see lower right panel, Figure 3). Paired comparisons showed significant differences between ASD and controls for target fixations $t(38) = 3.61$, $p < .001$, Cohen's $D = 1.15$ but not for distractor fixations $t(38) = -1.67$, $p = .10$, Cohen's $D = -.53$. There was also a significant difference comparing target to distractor for controls $t(21) = -4.95$, $p < .001$, Cohen's $D = -1.06$, but not for the ASD group $t(17) = -0.15$, $p = .89$, Cohen's $D = -.03$.

Thus, the interaction was due to the fact that control participants spent more time fixating the distractor and less time fixating the target. In contrast, the ASD group showed equal fixation of the target and distractor, and significantly more target fixations, compared to the control group. None of the other main effects or interactions were significant. There were also no significant differences in metaphor incorrect trials (all *p's* > .15) (see lower left panel, Figure 3).

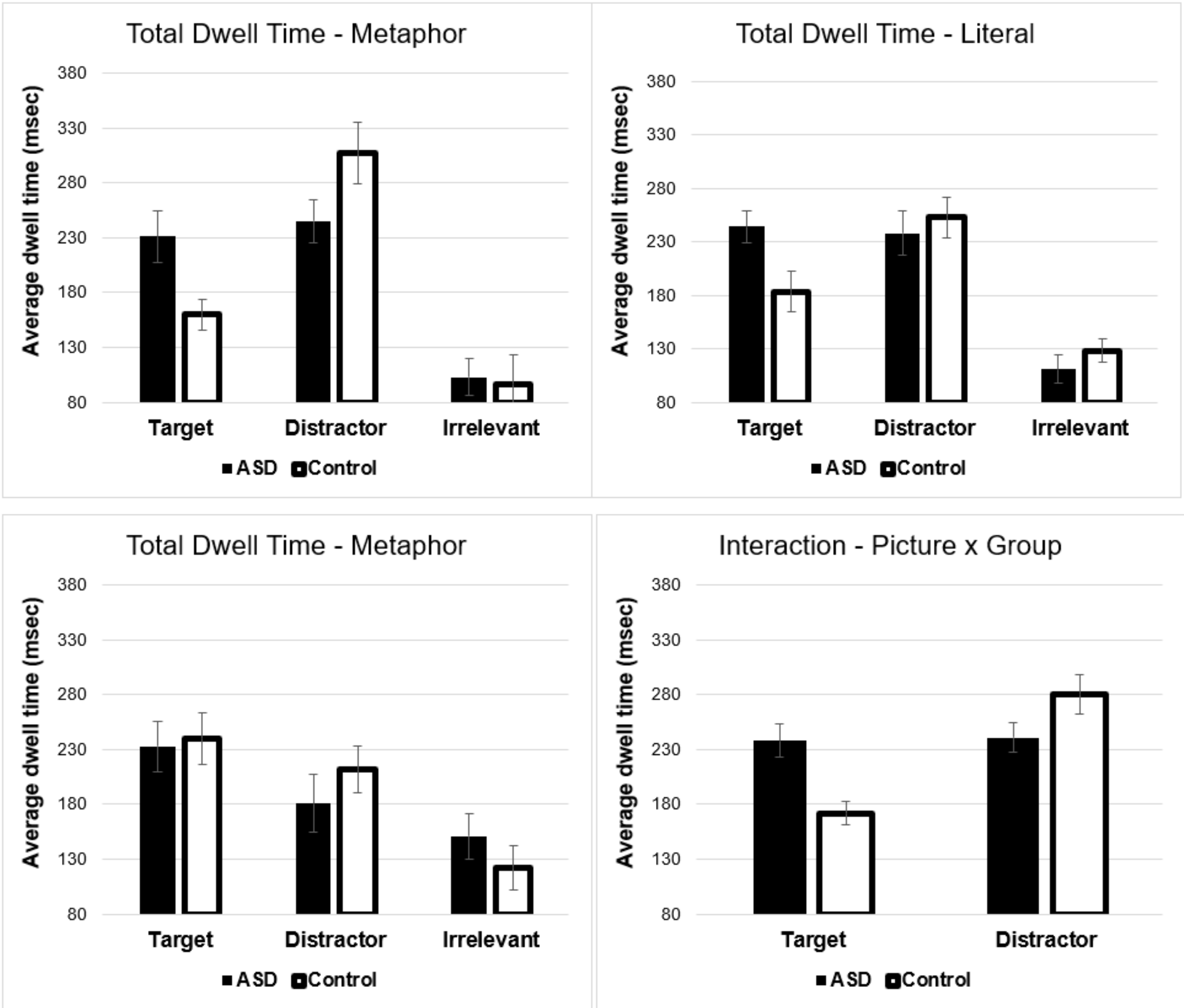


Figure 3. *Mean fixation times. Upper panels show mean dwell times for the correct trials (left metaphorical and right literal). Lower left panel shows the mean dwell times for metaphor incorrect trials. Lower right panel shows the means for the picture by group interaction. Error bars show the standard error of the mean.*

Region 2

In the second time window, results showed significant main effects of picture type $F(1,38) = 20.67$, $p < .001$, $\eta^2 = .35$, sentence type $F(1,38) = 24.47$, $p < .001$, $\eta^2 = .39$, and group $F(1,38) = 9.02$, $p < .01$, $\eta^2 = .19$ (see upper panels, Figure 4). Participants spent (1) more time viewing the target compared to the distractor, (2) more time fixating in metaphor trials compared to literal trials, and (3) participants with ASD had longer viewing times compared to controls. The latter main effect is consistent with the reaction time analyses.

There was one significant two-way interaction between sentence type and group *F*(1,38) = 6.03, $p < .05$, $\eta^2 = .14$ (see lower right panel, Figure 4). Significant paired comparisons were observed between ASD and controls for metaphor trials *t*(38) = 3.55, $p < .001$, Cohen's *D* = 1.13, and between metaphor and literal trials in participants with ASD *t*(17) = 5.15, $p < .001$, Cohen's *D* = 1.21. The other two paired comparisons were not significant (literal-ASD vs. literal-control: *t*(38) = 1.54, $p = .13$, Cohen's *D* = .49, and metaphor-control vs. literal-control: *t*(21) = 1.81, $p = .08$, Cohen's *D* = .39). The interaction between sentence type and group is driven by the fact that individuals with ASD spent longer viewing the target **and** distractor in metaphor trials. Analysis of metaphor incorrect trials showed only a significant main effect of picture type *F*(1,38) = 41.82, $p < .001$, $\eta^2 = .52$, which shows that the distractor was viewed longer than was the target (see lower left panel, Figure 4). The main effect of group and interactions were not significant.

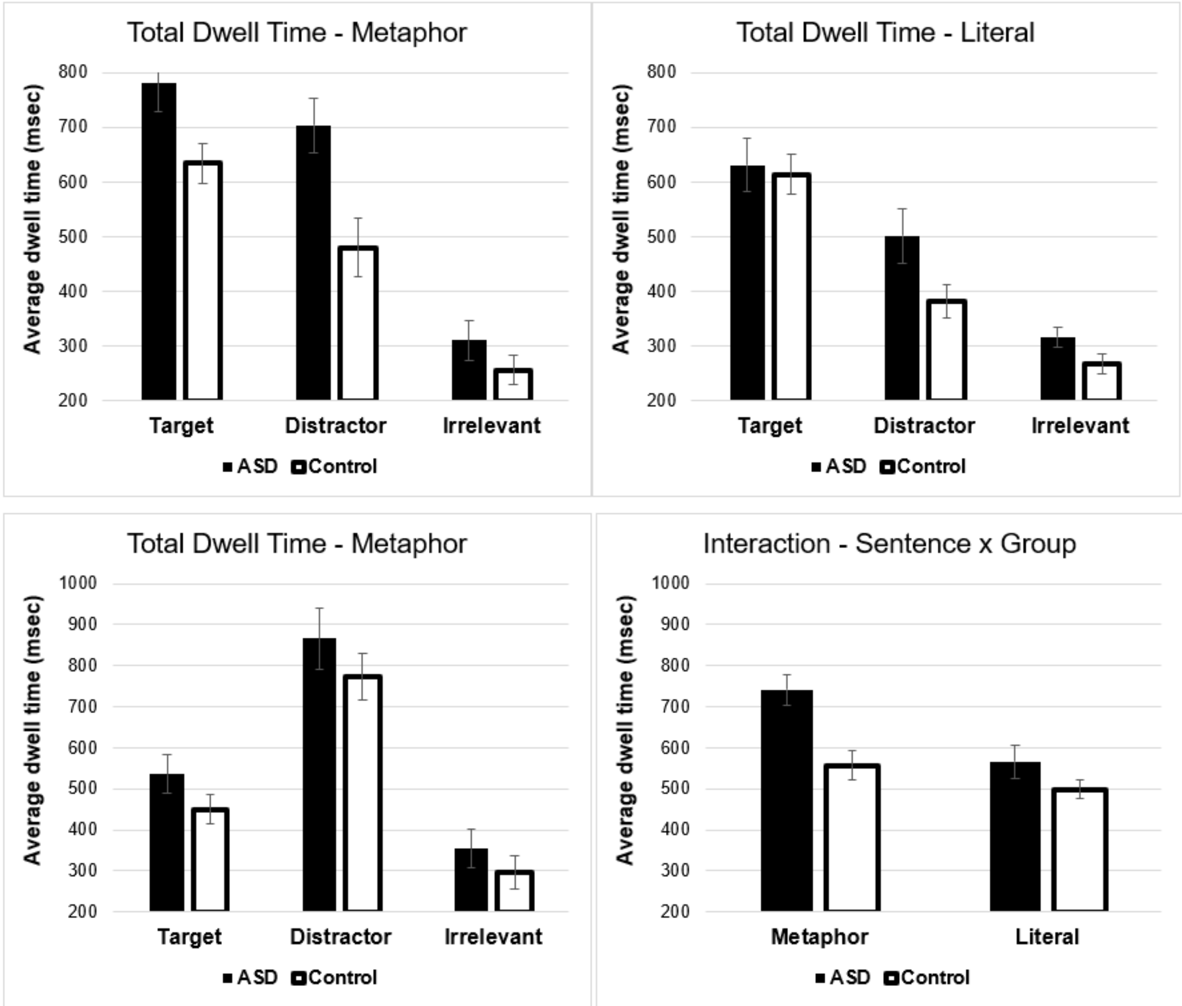


Figure 4. Mean fixation times. Upper panels show mean dwell times for the correct trials. Lower left panel shows the mean dwell times for metaphor incorrect trials. Lower right panel shows the means for the sentence type by group interaction. Error bars show the standard error of the mean.

Demographic and Vocabulary Analyses

The correlations between variables are presented in Table 2. Results showed that age significantly correlated with comprehension accuracy for metaphorical trials. Gender significantly correlated with dwell times to the distractor image on metaphor trials, and marginally correlated (1) with reaction times on metaphor trials and (2) dwell times to the target image on literal trials. In general, the pattern of correlations for the AQ scores largely mirrored the categorical group variable. Finally, vocabulary scores did not correlate with any of the key dependent measures.

We conducted several backwards regression analyses in order to investigate whether demographic variables (age and gender) and/or vocabulary contributed significant variance above and beyond the group variable (ASD vs. TD control). In particular, we focused on metaphor trials and examined comprehension, reaction times for correct trials, and dwell times for correct trials (see Table 3). The results of the regression analyses showed that age was a significant predictor of comprehension, suggesting that older participants were more likely to select the metaphorical interpretation on metaphor trials. Second, gender was not a significant predictor in any of the regression analyses. Thus, the correlations, which showed that gender marginally correlated with metaphor reaction time and significantly correlated with distractor dwell time, did not survive once group was included in the model.

To take the analysis of gender one-step further, we conducted partial correlations. The correlation between group and metaphor reaction time was -.52, and it was -.47 with gender partialled. Both of these correlations were significant ($p < .05$). Likewise, the correlation between group and metaphor distractor dwell time was -.44, and it was -.34 with gender partialled. Both of these were also significant ($p < .05$). For both partial correlations, there was some reduction in the correlation once gender variance was removed, but the remaining group effects were robust, and significant in both cases.

Table 2

Bivariate correlations between demographic variables, diagnostic group, vocabulary, and metaphor processing task.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	-	.24	.01	.07	.07	-.02	.36*	-.04	-.02	-.21	.07	-.01	-.10
2. Gender		-	-.33*	.24	.32#	.19	.06	.22	.31#	-.05	.33*	.30#	.11
3. Group (ASD/TD)			-	-.79**	-.08	-.04	.18	-.42**	-.52**	-.31#	-.44**	-.05	-.36*
4. AQ Total				-	.15	-.06	-.18	.47**	.52**	.29#	.32*	.10	.32*
5. Vocabulary					-	-.02	-.11	-.17	-.20	-.01	.05	.13	-.02
6. Comp. Literal						-	-.26	.32*	.25	-.01	.22	.59**	.34*
7. Comp. Metaphorical							-	-.02	-.11	-.25	-.17	-.13	-.04
8. RT Literal (correct)								-	.85**	.42**	.45**	.53**	.45**
9. RT Metaphorical (correct)									-	.25	.63**	.45**	.44**
10. DW Distractor Literal R2										-	.44**	.11	.15
11. DW Distractor Metaphor R2											-	.33*	.30#
12. DW Target Literal R2												-	.42**
13. DW Target Metaphor R2													-

Note. #$p < .10$, *$p < .05$, **$p < .01$.. ASD coded 0 = ASD and 1 = control, comp. = comprehension accuracy, RT = reaction time, DW = dwell time

There was one marginal effect of vocabulary on reaction time in metaphor trials. As predicted, higher vocabulary scores were associated with lower reaction time. However, in general, there were not significant correlations between vocabulary and the main dependent measures on metaphor trials. The fact that vocabulary was retained in the regression analysis suggests that it accounts for unique variance over and above that accounted for by group, but given, that it was only marginally significant, caution is warranted in interpreting it.

Table 3

Backwards regression results and coefficients for predictor variables.

Variable	*B*	*SE (B)*	*β*	*t*-value (*p*-value)
Metaphor Comprehension $F(1,35) = 4.84, p < .05, R^2 = .12$				
Age	.028	.013	.349	2.20 (.034)
Metaphor RT (correct) $F(2,34) = 8.41, p < .05, R^2 = .33$				
Group	-1587.76	407365	-.55	-3.90 (<.001)
Vocabulary	-43.06	24.96	-.24	-173 (.094)
Metaphor DW Target $F(1,35) = 5.62, p < .05, R^2 = .14$				
Group	-153.63	64.79	-.37	-2.37 (.023)
Metaphor DW Distractor $F(1,35) = 7.01, p < .05, R^2 = .17$				
Group	-211.20	79.76	-.41	-2.65 (.012)

Discussion

The purpose of this study was to investigate novel metaphor processing in ASD. We hypothesised that autistic individuals may not be significantly less likely than controls to choose the metaphorical meaning of critical utterances (e.g. Attwood, 1997; MacKay & Shaw, 2004; Rapin & Dunn, 2003; Tager-Flusberg, 2003), given that the evidence for impaired novel metaphor processing in ASD is mixed (Gold et al., 2010; cf. Giora et al., 2012; Hermann et al., 2013; Kasirer & Mishal, 2011, 2014, 2016). We did expect that reaction times for metaphorical trials, in which the metaphorical meaning was chosen would be significantly slower in ASD. A key rationale for this study concerned online processing and what the eye movements may reveal in a VWP study (Engelhardt et al., 2006; Tanenhaus et al., 1995). Specifically, we were interested in the extent to which autistic individuals viewed the images corresponding to the literal and metaphorical interpretations, and whether these fixations mirrored performance in the control group or were distinct. Specifically, eye movement should show the extent to which autistic individuals consider the target image in metaphor trials.

Consistent with our hypotheses, comprehension showed a non-significant difference between groups, indicating that autistic adults were not impaired in novel metaphor comprehension. That is, they interpreted the metaphor utterances, as metaphors, at the same rate as did the control participants (Giora et al., 2012; Hermann et al., 2013; Kasirer & Mishal, 2011). Also, consistent with our hypotheses, reaction time analyses showed that autistic participants took significantly longer to process metaphors. They were also slower on literal utterances. However, a base-line correction, which accounted for the additional processing time on literal trials, showed that it took autistic participants almost 800ms longer to process metaphor utterances as metaphors, compared to controls. The effect size (Cohen's D) for this particular analysis was 1.05, indicating a large effect size. Interestingly, Gold and Faust (2012) reported an almost identical reaction time difference between controls (1003ms) and ASD (1807ms), when metaphorical expressions were presented to the left visual field, consistent with those authors assertions that the right hemisphere has a greater role in novel metaphor processing, due to semantic processing. However, it is important to bear in mind that the task used in the Gold and Faust (2012) study was quite different to the one used here. The additional time required for processing novel metaphors has obvious effects on autistic individuals across a wide range of language comprehension situations (Olofsone et al., 2014), and likely poses a barrier to successful communication across a range of contexts, which

Gold and Faust (2012) refer to as “everyday soaked-in-metaphors in linguistic interactions” (pg. 62). In text comprehension, where the reader controls the rate of input, it would lead to substantially slower overall reading times. The problem of slow metaphor processing would be compounded in interactive dialogue, which typically proceeds at a rate of 3-4 words a second, with little-to-no time between turns. Thus, by the time a metaphor is fully comprehended, the conversation will, in many cases, have moved on.

Recall that the filler trials contained idioms, which are another type of figurative language but conventional. We also analysed the comprehension and reaction times for idiom trials and results showed that autistic participants had a mean of 2797ms for correct trials and controls had a mean of 1933ms (see Appendix G). Thus, the mean reaction time for idioms for autistic participants fell virtually in the middle between metaphor and literal trials, whereas for controls idiom reaction time was just slightly higher than the metaphor trials. Thus, controls reaction times were nearly the same for both types of figurative language. Importantly, the difference score between metaphor and idiom for ASD was 567ms and for controls was -16ms. This difference was statistically significant $t(38) = 2.14$, $p < .05$, Cohen’s $D = .68$, and again, shows that novel metaphor comprehension in ASD has a substantial processing cost implication compared to a distinct type of conventional figurative language (i.e. idioms). Whereas, controls did not show a difference between the two types of figurative language, and were in general substantially faster at processing both. Thus, the novel mapping between the target and vehicle seems to require significantly more time in autistic individuals.

For eye movements, we observed two key findings. The first was that autistic participants showed elevated target fixations in Region 2 (NP1), which at first glance should be a benefit to overall comprehension (i.e. give a head start on processing). However, after examining the fixations on incorrect trials, we instead interpret this finding as showing more uncertainty or slower visual information processing (Vulchanova et al., 2015), but at present, this conclusion is speculative. What we do know from our results is that there is a clear group difference in which autistic participants show approximately equal fixations to the target and distractor images during and shortly after NP1, whereas control participants show significantly more fixations to the distractor image and fewer fixations on the target.

The second key eye movement finding is that autistic participants showed elevated fixation times on both target and the distractor pictures in metaphor trials compared to controls. We interpret this group difference as a difficulty overcoming/suppressing the literal interpretation of metaphor utterances (Giora et al., 2012; Rubio-Fernandez, 2007). The effect size of the key paired comparison here was 1.13, indicating a large effect size. In cases where participants adopted a literal interpretation of a metaphorical sentence (i.e. incorrect metaphor trials), it was clear that participants almost solely focused on the distractor image and did not (or rarely) fixated the target image. Dwell times for incorrect trials showed a significant main effect of picture type (with a large effect size .52), and there was no difference between groups. Thus, both groups interpreted metaphor trials literally, at the same rate, and viewing behaviour did not differ between groups.

We included a section in the results, in which we consider two demographic variables and vocabulary scores. In an earlier study that focused on metaphor comprehension in dyslexia, we also did not find that vocabulary scores correlated with metaphor comprehension (r = -.13) or metaphor reaction time (r = -.04). The direction of the comprehension effect was not in the expected direction (i.e. higher vocabulary scores corresponded with worse comprehension). In the current study, we observed an almost identical correlation for comprehension (r = -.11), whereas the reaction time was much higher (r = -.20). Moreover, when vocabulary was included in a regression model with group (ASD vs. control), it was actually retained, suggesting that it had a significant impact on the R^2, despite being only marginally significant (p = .09). Again, the direction of the effect on reaction times was in the expected direction, with higher vocabulary scores being negatively related to reaction time. One final point worth mentioning is that the correlations between AQ scores and comprehension, reaction time, and eye movements showed very similar results, as compared to the ASD group variable. Thus, treating ASD traits as a continuous variable did not account for further variance in the main dependent measures as compared to analysing ASD status categorically. In general, linear variables have more power potential compared to categorical variables.

To summarize, elevated fixation times on the distractor (in metaphor trials) suggests a difficulty suppressing the literal interpretation. This bias is despite more time viewing the target in the earlier time window, which is similar to the viewing pattern in incorrect trials. Although it is not fully clear why an initial bias toward the target image in metaphor trials would lead to a greater tendency to interpret metaphorical utterances literally. Our speculation was that it was due to integration issues and/or slower visual processing, which is consistent with multi-modal integration arguments by Vulchanova et al. (2015). (Our task required integration of an auditory utterance with visual representations.) Our integration speculation is also consistent with an increased tendency to fixate the distractor image in literal trials for participants with ASD (see upper left panel, Figure 4). Importantly, in the literal condition, the distractor is an unrelated image, which clearly indicates some uncertainty on the part of participants with ASD. For incorrect trials, neither group considers the target image in the metaphor condition.

Limitations

The most important limitation of the study was the gender imbalance between groups (groups were matched on age and vocabulary). The ASD group was much more gender balanced compared to the controls, who were primarily female (~73%). Moreover, there were some gender differences in performance on the metaphor task, such that females were generally faster processors. We think this limitation is much less relevant given the results of the partial correlations and the regression analyses. When both group and gender were included in statistical models, ASD was a significant predictor and gender was not. We also considered dropping two or three females from the control group, which would have made the gender difference between groups not significant. However, this does not seem like good practice to us, and thus, we preferred to address the gender imbalance statistically. The results of those analyses confirm, that despite small-to-medium gender differences in reaction times, ASD status is much stronger and always survived analyses which took gender into account. A second limitation of the current study is that it did not include a Theory of Mind test, which may have also accounted for unique variance in the dependent measures.

Conclusions

This study has shown that autistic adults comprehend novel metaphors at the same rate as controls, but they were substantially slower in doing so. Based on the comprehension results, we might conclude that autistic individuals are **not** impaired at comprehending this particular type of figurative language, consistent with results from autistic adolescents (Kasirer & Mishal, 2016). But, what does the additional ~800ms of processing time tell us? If we conclude that they are not impaired, then we at least have to conclude that they are less efficient processing novel metaphors. Some researchers have linked processing time of metaphors with cognitive issues due to executive functioning (e.g. Chiappe & Chiappe, 2007; Dietrich, 2004; cf. Russell, 1997), but given our data, that inefficiency is unlikely due to verbal abilities. Furthermore, because we tracked eye movements, we are in a position to say that a good deal of the inefficiency is due to increased time spent fixating the distractor. The higher fixation time on the distractor clearly suggests some inability to switch or suppress the literal interpretation compared to typically-developing controls (Giora et al., 2012), who showed quite different patterns of viewing behaviour.

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APPENDIX A

Study Advert

APPENDIX B

The Autism-Spectrum Quotient

Please circle your answer to indicate how much you agree with the following statements.

1. I prefer to do things with others rather than on my own.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

2. I prefer to do things the same way over and over again.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

3. If I try to imagine something, I find it very easy to create a picture in my mind.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

4. I frequently get so strongly absorbed in one thing that I lose sight of other things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

5. I often notice small sounds when others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

6. I usually notice car number plates or similar strings of information.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

8. When I'm reading a story, I can easily imagine what the characters might look like.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

9. I am fascinated by dates.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

10. In a social group, I can easily keep track of several different people's conversations.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

11. I find social situations easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

12. I tend to notice details that others do not.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

13. I would rather go to a library than a party.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

14. I find making up stories easy.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

15. I find myself drawn more strongly to people than to things.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

16. I tend to have very strong interests, which I get upset about if I can't pursue.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

17. I enjoy social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

18. When I talk, it isn't always easy for others to get a word in edgeways.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

19. I am fascinated by numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

20. When I'm reading a story, I find it difficult to work out the characters' intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

21. I don't particularly enjoy reading fiction.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

22. I find it hard to make new friends.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

23. I notice patterns in things all the time.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

24. I would rather go to the theatre than a museum.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

25. It does not upset me if my daily routine is disturbed.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

26. I frequently find that I don't know how to keep a conversation going.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

27. I find it easy to "read between the lines" when someone is talking to me.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

28. I usually concentrate more on the whole picture, rather than the small details.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

29. I am not very good at remembering phone numbers.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

30. I don't usually notice small changes in a situation, or a person's appearance.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

31. I know how to tell if someone listening to me is getting bored.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

32. I find it easy to do more than one thing at once.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

33. When I talk on the phone, I'm not sure when it's my turn to speak.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

34. I enjoy doing things spontaneously.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

35. I am often the last to understand the point of a joke.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

36. I find it easy to work out what someone is thinking or feeling just by looking at their face.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

37. If there is an interruption, I can switch back to what I was doing very quickly.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

38. I am good at social chit-chat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

39. People often tell me that I keep going on and on about the same thing.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

40. When I was young, I used to enjoy playing games involving pretending with other children.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

41. I like to collect information about categories of things (e.g. types of car, types of bird,

types of train, types of plant, etc.).
Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

42. I find it difficult to imagine what it would be like to be someone else.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

43. I like to plan any activities I participate in carefully.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

44. I enjoy social occasions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

45. I find it difficult to work out people's intentions.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

46. New situations make me anxious.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

47. I enjoy meeting new people.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

48. I am a good diplomat.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

49. I am not very good at remembering people's date of birth.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

50. I find it very easy to play games with children that involve pretending.

Definitely Agree Slightly Agree Slightly Disagree Definitely Disagree

APPENDIX C

ADOS Questions

Can you tell me a bit about yourself?

Are you enjoying university?

What subject are you studying?

What modules do you like the most?

What ones do you not like?

Do you currently have a job?

Is there anything that makes you stressed?

Are you involved in any extra curricular activities?

What are your hobbies?

What are your friends like?

What do you like doing together?

Do you have a partner?

What do you like doing with them?

What kind of stuff do you do to make you happy?

What stuff maybe doesn't make you happy?

Can you tell me if there's anything that makes you frightened or anxious?

What are your plans for when you finish university?

What do you plan to do when you're older / leave university?

APPENDIX D

Initial Region Analysis

The initial region of analysis was the time from when the picture appeared to the onset of NP1. In this window, there was only a significant main effect of picture type $F(1,38) = 7.85$, $p < .01$, $\eta^2 = .17$ (see Figure A). The distractor had increased fixation time compared to the target. The other main effects and interactions were not significant.

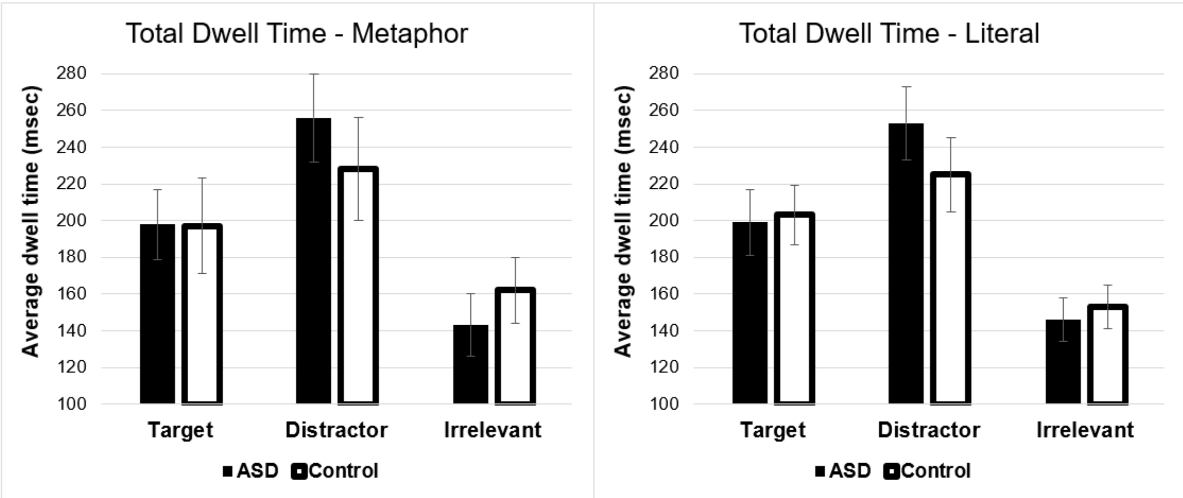


Figure A. Mean fixation times. Left panel shows mean dwell times for the metaphor trials, and the right panel shows the mean dwell times for literal trials. Error bars shows standard error of the mean.

APPENDIX E

NP2 Analysis

Figure B shows the fixation data from the onset of NP2 to the offset of NP2 (see also Figure 1). In this window, there was a significant main effect of picture type $F(1,38) = 4.20$, $p = .05$, $\eta^2 = .10$ The target had increased fixation time compared to the distractor. There was also an interaction between sentence type and picture type $F(1,38) = 7.45$, $p = .01$, $\eta^2 = .16$. This interaction is driven by the fact that there are more looks to the target and less looks to the distractor in literal trials $t(39) = -4.37$, $p < .001$, Cohen's $D = -.69$, whereas in the metaphor trials, fixations were more-or-less equally distributed between the target and distractor $t(39) = .58$, $p = .57$, Cohen's $D = .09$. In addition, there were more looks to the target in literal trials compared to metaphor trials $t(39) = 3.13$, $p < .05$, Cohen's $D = .50$, and fewer looks to the distractor in literal trials compared to metaphor trials $t(39) = -2.13$, $p < .05$, Cohen's $D = -.34$. The other main effects and interactions were not significant. Finally, we considered fixation times for incorrect metaphor trials (see Figure B). Results showed only a marginally significant main effect of picture $F(1,38) = 4.03$, $p = .052$, $\eta^2 = .10$. There were more fixations on the distractor compared to the target. The main effect of group and the interaction between picture and group were not significant.

APPENDIX F

One-Sample *T*-Test Results

We conducted one-sample *t*-tests to determine whether the comprehension means were significantly different than .50 (see upper left panel, Figure 2), which would indicate chance performance (omitting the irrelevant image). The literal conditions were significantly greater than .50 (ASD: $t(17) = 16.44$, $p < .001$, Cohen's D = 3.87; control: $t(21) = 16.70$, $p < .001$, Cohen's D = 3.56). The ASD group was not significantly different from chance for metaphor trials $t(17) = .20$, $p = .85$, Cohen's $D = .05$, and the control group was significantly greater than chance for metaphor trials $t(21) = 2.20$, $p < .05$, Cohen's $D = .47$.

APPENDIX G

Idiom Results

For comprehension, the ASD group was not significantly different controls $t(38) = -.24$, $p = .82$, Cohen's $D = -.08$ (see Figure D and E). Furthermore, neither group was significantly different from chance .50 (ASD: $t(17) = -.55$, $p = .59$, Cohen's $D = -.13$, and controls: $t(21) = .47$, $p = .93$, Cohen's $D = -.02$. For reaction times, the ASD group was significantly different from controls for both correct trials $t(38) = 3.44$, $p < .001$, Cohen's $D = 1.09$ and all trials $t(38) = 3.77$, $p < .001$, Cohen's $D = 1.20$.

Figure D. Example item for idiom trial. The corresponding utterance was *He kicked the bucket.*

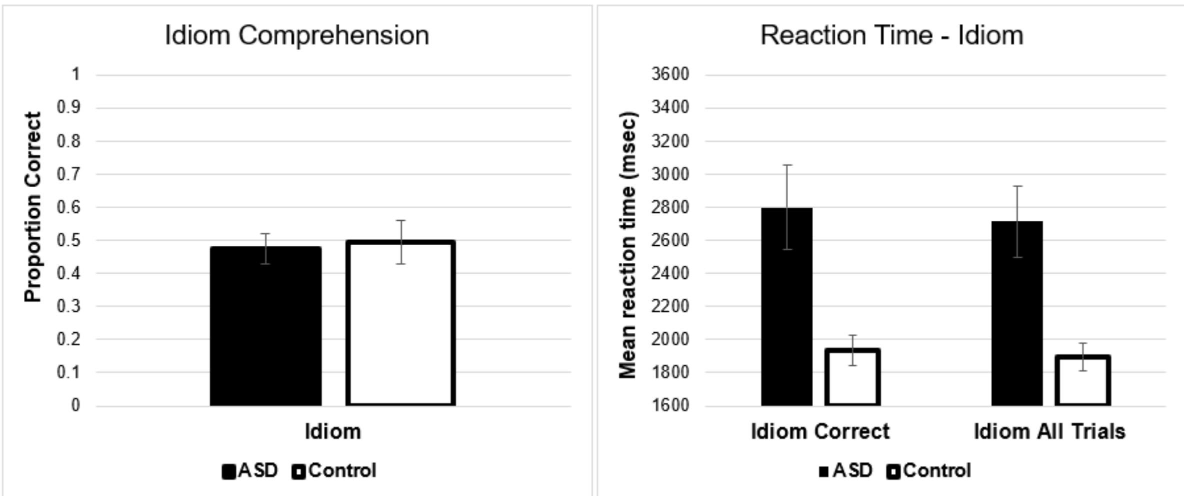


Figure E. Proportion correct and mean reaction times for idiom trials. Error bars show the standard error of the mean.

APPENDIX H - STIMULI

The cup with the antenna.
The cup with the straws.

The tree with the arms.
The tree with the branches.

The tower with the hat.
The tower with the cone.

The carrots with the hair.
The carrots with tops.

The car with the backpack.
The car with the box.

The desert with the rest area.
The desert with the oasis.

The apple with the guest.
The apple with the worm.

The sock with the peephole.
The sock with the hole.

The eyes with the curtains.
The eyes with the eyelids.

The cup with the ears.
The cup with the handles.

The bush with the pimples.
The bush with the berries.

The throat with the flames.
The throat with the pain.

The teeth with the window.
The teeth with the gap.

The coffee with the mountain.
The coffee with the cream.

The cake with the snow.
The cake with icing sugar.

Fillers

- Idioms
- Literal sentences (with ambiguous or not ambiguous pictures)

I have to hit the books.

He kicked the bucket at the age of 80.


You'll be the best, break a leg!



He's on thin ice with him.



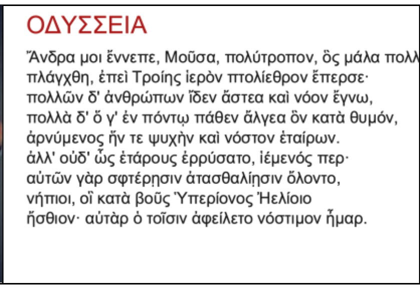
He has sticky fingers.



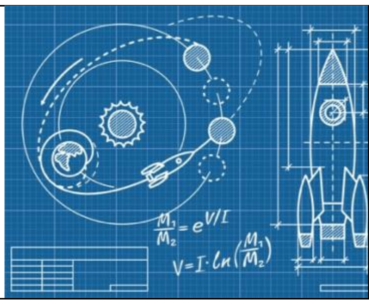
Blond hair runs in the family.



This document is Greek to me.

Just follow the recipe, it’s not rocket science.


She has immediately broken the ice.

I missed the boat on that deal.

Charlie is the teacher’s pet.

I’ve burnt a bridge with him.

Keep it under your hat.

Just bite the bullet and stop smoking.

John is a policeman.

Sarah is good at dancing.

The pear was juicy.



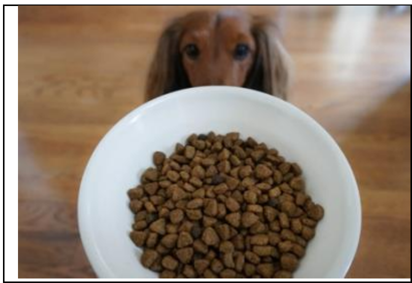
The shirt has long sleeves.



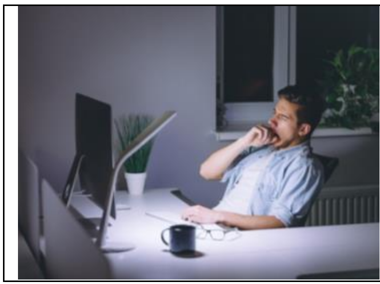
I usually finish work at 5 p.m.



Kibble is good for dogs.



I hate working overtime.



They are very close friends.



Broccoli are delicious.



Humanoid robots are nice.

Your child is very well behaved.

It was such an entertaining film.

My house is not cold.

The exam wasn't difficult at all.



CHAPTER 7 – CONCLUSION

Conclusion to Thesis

To conclude this thesis, we will revisit the research questions and discuss the relevance and implications of each chapter. We will also offer some insight into the navigation of sensitive ethical issues when doing autism research, as well as the limitations of our studies, concluding with opportunities for future directions.

Language Markers in Facilitating the Diagnosis of ASD

We separated the themes of this thesis into two "arms", or research questions. Our first research question focussed on whether we can use specific language markers to provide assistance in the diagnostic assessment of autism. The clinical importance of this is clear. The capacity of diagnostic services in England has been stretched. As of September 2024, there are 204,876 patients with an open referral in the NHS for suspected autism (NHS, 2024), and waiting times can often be up to a year, particularly in more deprived areas, highlighting the economic burden of this process. There is a significant need for the improvement of diagnostic processes and assessments, which will directly translate to outcomes when support can be offered more promptly to individuals with an official diagnosis (Ellie Wilson, 2013). McKenzie et al. (2015) measured experiences of individuals going through the process of receiving an autism diagnosis by observing three time points: wait to first appointment, assessment duration and total wait for diagnosis. Of all predictors measured, encompassing gender, ethnicity and socioeconomic status, the biggest predictor of assessment duration in children was the amount of information about autism that was available to the individual and their caregiver prior to the assessment. Furthermore, one of the biggest predictors of wait to first appointment was the risk of ASD score. Consequently, there is a universal understanding of the need for identifying "red flags" of autism in children (Allison, Auyeung & Baron-Cohen, 2012; McKenzie et al., 2015).

Awareness of the importance of this is what guided our rationale for Chapter 2, where we aimed to develop a screening measure for autism symptoms in children and adolescents, based on functional language milestones and early pragmatic communication. We acknowledged that there were clear gaps in this area, as current screening instruments are costly and time-consuming, and often require a trained professional to administer. This contributes to the lengthy process of receiving an ASD diagnosis for children, which is particularly problematic when age of diagnosis is negatively related to outcomes, and when early intervention is a significant predictor of later adjustment and social integration (Clark, Vinen, Barbaro & Dissanayake, 2018; Sandbank et al., 2020). Furthermore, we believed that education of these “red flags”, and a tool which allows for quick and easy identification of them, is crucial in relieving the pressure on diagnostic services, having clear economic implications. Thus, we developed the Language and Pragmatics Questionnaire (LAPQ). The initial test and validation of this questionnaire was established with 230 participants, and demonstrated not only that these specific symptoms are clear indicators of early autism, but that the LAPQ is a concise and practical instrument for use in a variety of contexts to assess language abilities and communication in ASD. We wanted this instrument to have important clinical value by supplementing current diagnostic assessments and tools. Given that McKenzie et al. (2015) identified that the most important predictor of the duration of this process was prior education about autism symptoms, we hope that this will be particularly appreciated by caregivers by mitigating the effect of lacking knowledge of when language issues may be 1) significantly problematic from a clinical point of view and 2) when they may be potential indicators of ASD. In turn, we hope that this will reduce waiting times once a referral has been made, establishing a prompter pathway to pinpoint where support and intervention may be required. We acknowledge that there are a number of limitations with our study. Firstly, that factor analysis is confined by the subjectivity in which the factors are interpreted. Therefore, it is possible that someone could interpret the loading factors as a measure strongly related to language abilities, but not language abilities themselves, which would ultimately question the validity of our tool. Furthermore, given that there was a proportion of variance that remained unexplained by the model, it would have been useful to test the divergent validity of the tool. For example, the items in the questionnaire could potentially be reflective of a more general learning disability in our participant group. To measure divergent validity of the tool against a measure of another learning impairment would have been useful in this respect. We also had a lot of missing age data from Study 2 which posed a problem when making comparable results to Study 1. Despite this, we concluded from our study of the LAPQ that it has great internal consistency, strong predictive validity, and good convergent validity. We strongly believe it to be a useful clinical tool for its intended purpose, allowing us to be satisfied that we have contributed an important insight to this research question. With regards to the limitations we discussed, we welcome any refinements of the questionnaire and/or other suggestions about the interpretation of the factor analysis.

Whilst language markers of autism have been relatively well-established in children, these symptoms tell a more complex story in adults. With support, functional language skills improve over time for autistic individuals, often reaching a comparable level to neurotypical individuals (Brignell et al., 2018). Therefore, identifiers of atypical pragmatic communication are a lot more subtle. The consequence of this is that these issues are harder to recognise for the autistic person and their loved ones, particularly when education is lacking, so the process of referring themselves for an autism diagnosis is often lengthier, causing considerable anxiety (Lewis, 2017; Crane et al., 2018). Lewis (2017) used a mixed methods approach to explore barriers to diagnosis for autistic adults. Lewis (2017) found that 87.6% of adults with a formal diagnosis of ASD said that a barrier to diagnosis for them was the inability to adequately describe their symptoms. The diagnostic criteria for ASD regarding pragmatic communication is quite vague, and it may not be clear for individuals referring themselves for a diagnosis or their loved ones what atypical pragmatic communication looks like when observing external behaviour. Furthermore, as there is a strong reliance on the autistic individual for self-referral as an adult, they may not acknowledge these symptoms as being atypical, particularly when the nature of socio-pragmatic communication itself may make it hard for an individual with autism to recognise that what they are experiencing is a clinically significant issue. Therefore, as part of our first research question, we aimed to identify some psycholinguistic trends in autistic individuals that may provide clinical value if they are utilised in diagnostic assessments. We identified that disfluencies are an area of research in ASD that has been relatively consistent, which informed our rationale for Chapter 3. Disfluencies are thought to be an observable measure of pragmatic communication skills (Clark & Wasow, 1998). We aimed to replicate previous findings concerning disfluencies, specifically with the rate of filled pauses, repetitions and repairs made during spontaneous speech samples. With these results, we sought to conduct a discriminant analysis where we could predict ASD group status based on disfluency rate, with the belief that this would provide strong support for the use of disfluencies as diagnostic markers of ASD. Education about these language symptoms would therefore be useful in the referral process, allowing individuals to be formally diagnosed and receive appropriate support. Furthermore, disfluencies could be utilised by clinicians in the diagnostic assessment of autism. Whilst there have been consistent trends concerning disfluencies in autistic populations, we failed to find any significant group differences between autistic participants and typically-developing control participants. However, we used um/uh ratio, repetitions and gender as predictors in a discriminant analysis anyway, as these variables showed the most promising results. The discriminant analysis showed that only 66.7% cases could be successfully predicted, which we believed was insufficient to argue for disfluency as a diagnostic marker. Therefore, we were unable to provide support for the diagnostic utilisation of disfluencies. We discussed in Chapter 3 that there are some limitations of our study, most notably the gender imbalance between our groups. We attempted to understand why our results did not align with previous research (e.g. Gorman et al., 2016; Lunsford, Heeman, Black & van Santen, 2010; Lake, Humphreys & Cardy, 2011; Shriberg et al., 2001) by re-examining these key studies. These studies had similar sample sizes to ours, analysed disfluencies from those classed as "high-functioning", and had a variety of spontaneous speech tasks similar to the one used in our study. The key difference with our study is that we had a higher number of females than males, whereas these studies had a higher number of males than females. Given that we found a significant effect of gender (i.e. males produced more disfluencies than females), it is possible that disfluency rates align more with the male autism phenotype than the female. However, we could not follow-up this speculation due to insufficient statistical power in our male sample. Additionally, it is possible that perhaps disfluencies are not consistent across all autistic individuals. We therefore questioned whether disfluencies are truly a measure of pragmatic communication (i.e. are listener-oriented), and proposed that they instead may be a product of poor speech planning, which may not have been the case for the high-functioning autistic individuals in our study. Furthermore, it is possible that there are significant group differences in the literature due to publication bias, but this is only a speculation.

Overall, we believe that we were able to acknowledge that we can utilise language symptoms in autistic individuals to aid in the process of formal diagnosis. The LAPQ is a useful clinical tool that can provide assistance with this, particularly in the screening process before a referral has been made. The clinical value of this is evident. Furthermore, since developing the tool, we have since received various correspondence from people across the world, to ask permission to have it translated into Greek, Indian and Chinese languages for research and clinical use. Since it is being recognised by others, we believe that our rationale was entirely justified, and hope for its continued use. However, as we were not able to provide evidence that disfluencies can be a valid marker of an ASD diagnosis, we believe that we should be hesitant when approaching disfluency research and trying to implicate them in clinical practice.

Exploration of Language Comprehension in ASD

Researchers are in agreement that autism is defined as a different way of processing the world (Happé & Frith, 2021; Chown & Leatherland, 2021). However, there is still speculation about the cognitive processes underlying the observed atypical behaviours in ASD. In the language comprehension domain, there are a variety of under-researched areas that, if utilised with both online and offline processing, may provide important insight into the phenotypes of autism. Our second research question sought to explore some of these domains utilising these methods in high-functioning adults with autism. Our reason for this is clear. High-functioning individuals tend to camouflage their symptoms, the purpose of which is to better "fit" into a neurotypical society. Subtle differences in language comprehension, however, are prominent. The importance of selecting high-functioning autistic individuals in research has been emphasised by Happé & Frith (2020), as their observable behavioural traits would not obviously indicate that autism was present to an untrained individual. However, through research such as this, we can gain valuable cognitive-level insight into how these individuals process the dynamic world.

The atypical socio-pragmatic communication phenotype of autism generally presents as the most problematic of the two. Communicative difficulties faced by autistic individuals are ultimately the biggest challenge leading to greater isolation and the subsequent poorer outcomes that we discussed in Chapter 1 (Magiati, Tay & Howlin, 2014; Cage, Di Monaco & Newell, 2018). We believed it would be valuable to explore whether there are cognitive processes underlying the challenges with socio-pragmatic communication which are the primary diagnostic criteria of ASD. The first area we identified as being a potential atypical area was linguistic prediction (Chapter 4). Linguistic prediction in psycholinguistics is the process of being able to predict a bottom-up linguistic input ahead of its presentation (Engelhardt, Yuen, Kenning & Filipovic, 2021). For example, being able to predict the word at the end of a sentence before it is said. The importance of linguistic prediction is evident in the idea that linguistic prediction aids the efficiency of communication (Huettig, 2015). If linguistic prediction is impaired, or atypical, generally communication becomes more challenging for the participant. There is a new, but prominent, theory in autism research called the theory of Predictive Impairment in Autism (PIA) (Sinha et al., 2014). The crux of this theory is that autistic individuals make significant prediction errors when they estimate the probable outcome of an event, as their brains do not code information the same way that neurotypical individuals do. As linguistic prediction is a process thought to benefit the ease of communication, we thought it would be interesting to investigate whether linguistic prediction is atypical in autistic individuals. We hoped that this would 1) offer support or contradict the PIA hypothesis, and 2) hope to understand more about processes underlying the communicative difficulties experienced by autistic individuals. We conducted two studies, both a pilot and a main, investigating linguistic prediction in ASD using a cloze probability task. In study 1, we found no differences in accuracy of prediction between our autistic group and the control group. However, we acknowledged that a limitation of this study design was that it did not measure how "efficient" the prediction process was, as participants' reaction time was not recorded. In Study 2, we aimed to rectify this by recording reaction times before a prediction was given. We found that autistic individuals were significantly slower, but again predicted to the same accuracy as our control group. Our results suggest that although we cannot corroborate evidence for a broad, domain-general predictive impairment in autism based on prediction errors, there is evidence that the prediction process for autistic individuals is atypical. Whilst we think this is important in providing insight into the processes that underlie the various phenotypes of autism, we acknowledge some limitations of cloze probability tasks that question the overall validity of our study. For example, cloze-probability tasks are often criticised for being artificial by focusing on exact-word predictions and not words that could still be semantically and contextually appropriate (Arkhipova, Lopopolo, Vasishth & Rabovsky, 2025), and therefore not representative of real-life predictive processes. Large language models are often considered a better alternative to cloze-probability tasks (Jacobs, Grobol & Tsang, 2024). What was surprising about our results is that repetitive behaviours were strongly linked to predictive abilities in our pilot study, suggesting that linguistic prediction can relate to both the repetitive behaviours and the social communication phenotypes. This provides some partial evidence for predictive processes contributing to the insistence on sameness behaviours in autistic individuals. Longer predictive processes generally attest to a greater cognitive load, so the demands of a dynamic changing world, as well as those of social communication, may be much more effortful for autistic individuals. We believe that this is valuable in understanding more about the autism phenotypes, and believe that more research is warranted in this area to determine how this can translate to greater support in society for autistic individuals.

Another domain of language comprehension we believed to be under-explored is the comprehension of active and passive sentences. In typical people, sentences with syntactic ambiguity (i.e. passives) are more difficult to comprehend, particularly when they are semantically implausible (Ferreira, 2003), because they rely on "good enough" comprehension. As a result, interpretations of these types of sentences are often shallow and inaccurate. However, as we discussed in Chapter 1, it is believed that autistic individuals have enhanced perceptual functioning, superior attention-to-detail and focus more on the "local" elements of a stimulus rather than the global elements (Mottron, Dawson, Soulières, Hubert & Burack, 2006), highlighting autistic strengths. We used this as our rationale for Chapter 5, predicting that autistic individuals will have greater comprehension accuracy with these types of sentences, and be less affected by semantic implausibility than typical individuals. However, we thought that this would be driven by increased reaction times, demonstrating more thorough processing. We found that individuals with ASD had overall worse comprehension accuracy, and reaction times were not a factor which contributed to this. We could not determine therefore, if there were cognitive processes affecting this result. However, they were less affected by the passive-implausible sentences than the typically-developing control participants. Whilst we thought it would be important to highlight autistic strengths here and did not find such a result, we note that the study design may have affected the results. The study was designed so that participants could have unlimited time to view the sentence, and then select whether they thought the following picture matched or mismatched. If we were to revisit this design, we would make it so that the viewing of the sentence was on a time-constraint, to make it more challenging and eliminate the potential for sentence rehearsals. Alternatively, we could have measured the viewing time of the sentence. This would have allowed us to analyse whether autistic individuals were quicker with reading the sentences, perhaps explaining their greater rate of inaccuracy across all sentence types. Furthermore, it is important to highlight that individuals show atypical language processing when it comes to reading sentences, and not just in spoken language. This supports the narrative in research that there are broader structural language issues in ASD, such as with morphosyntax, and not just with socio-pragmatic communication. This task was an online task that participants could complete at home without the presence of a researcher, eliminating any social demands of a task which can often affect performance in these types of studies, as well as being attentionally and motivationally challenging. However, we acknowledge that this could have been a disadvantage of the experiment due to not having the task completed in a controlled lab environment. This questions the exclusive nature of how language issues are clinically classified in ASD. As we have emphasised, functional language skills are not part of the ASD diagnostic criteria. However, given that there is clear evidence for atypical functional language skills in autistic individuals, it would be interesting to see whether screening these markers can allude to a greater risk of ASD, particularly in high-functioning adults, where the symptoms are more subtle and often camouflaged.

The final area of language comprehension that we identified as being under-researched was the comprehension of novel metaphors utilising a Visual World Paradigm (VWP, Tanenhaus, Spivey-knowlton, Eberhard & Sedivy, 1995). Metaphor comprehension in ASD has been widely studied. The processing of figurative language is said to be atypical in ASD, and may represent manifestations of the challenges with Theory of Mind (ToM) experienced by autistic individuals that were discussed in Chapter 1, although this has been debated. An atypical ability to comprehend figurative language would pose a significant issue in the ease of communicative pragmatics, as this would undeniably affect the interpretation of non-verbal conversational cues, which is one of the defining features of autism (Morsanyi, Stamenković & Holyoak, 2020; American Psychiatric Association, 2013). To our knowledge, no studies have previously utilised a VWP in autistic adults. We strongly believed in the benefit of measuring implicit processing of metaphors, in accordance with ideas put forward by other researchers (for example, Kalandadze, Norbury, Nærland & Næss, 2018; Baron-Cohen, 2002; Kleinman, Marciano & Ault, 2001), which we used as our basis for Chapter 6. Similar to our study on linguistic prediction (Chapter 4), we believed this to be valuable in understanding the cognitive processes behind some of the observed atypical social behaviours in autistic individuals. Our study on novel metaphor comprehension found no differences between autistic individuals and typically-developing control participants in their accuracy of interpreting novel metaphors. We address that this may be due to the ease of the task, which was originally designed to be used with children. However, when we looked at the online measures, it was clear that autistic individuals were less efficient at processing novel metaphors, showed by increased reaction times and significantly greater eye fixations on the distractor image. However, VWP tasks demand a combination of visual and linguistic processing, and autistic individuals classically find multi-modal integration challenging (Dcouto & Pradeepkandhasamy, 2024), which could be an alternative explanation of these results. Regardless, we think that this provides important insight into the implicit processing involved when faced with figurative stimuli, and strongly believe that this may underly some of the difficulties in socio-pragmatic communication faced by autistic individuals.

Overall, these studies suggest that there is implicit, atypical language comprehension in autistic individuals on a cognitive level. During the recruitment process, we exclusively selected high-functioning autistic individuals. Therefore, whilst we cannot extrapolate these findings to other autistic individuals who experience higher degrees of affectedness than others, we found support that even in those who function well and do not experience significant difficulties, there are still substantial language-related differences to those observed in a neurotypical population. What we would like to highlight the most from this research is that in majority of the language tasks we explored here, autistic participants perform to a comparable standard to typically-developing participants on behavioural measures. However, we found differences in the online measures of these tasks, perhaps driven by implicit challenges with these types of stimuli. We cannot conclude that this process is *consciously* more challenging for autistic individuals, but we can speculate that these delays in processing may underlie the atypical behaviours we see in ASD, particularly with regards to social interactions. Furthermore, this questions the use of almost exclusively behavioural measures in the diagnostic assessment of ASD, and perhaps this is a factor contributing to the fact that autism often goes undiagnosed, or can be missed in those who are high-functioning (van't Hof et al., 2021).

Ethical and Theoretical Considerations

We addressed in Chapter 1 that language is important when talking about ASD. Research has been largely deficit based, which contributes to the stigma around autism and the view of it as a "disability". We think that our research helps to challenge this view of autism, by providing evidence that there are often no observed behavioural differences in autistic individuals, but that we can celebrate that there are clear cognitive differences in the way that they perceive and process the world. Therefore, we have been apprehensive about using the word "impairment" throughout this thesis, and have preferred to refer to these differences as being "atypical". Words associated with less inclusive language have been used only when to emphasise when observations may pose a significant problem for autistic people.

Furthermore, the concept of autism has changed drastically in the past few years, moving from the once widely accepted 'medical model', where research has attempted to ascertain the biomarkers indicating the developmental trajectory of autism symptoms, to a more evolved perception of autism in line with neurodiversity. We believe that our research aligns with the neurodiversity stance, by showing that ASD is much more complex than simply being a disability or something that is debilitating for the individual. Instead, it is clear that even when unaccompanied by intellectual disability, autism constitutes a unique and distinct pattern of atypical cognitive processes with regards to language. With that in mind, early manifestations of language symptoms can cause some developmental concerns, which we have addressed in Chapter 2. We do not want to diminish the experience of individuals whose early language symptoms of ASD may have caused significant challenges for them, which is why we think it is important to approach these observations from a "symptom severity" clinical point of view (i.e. do they cause a challenge for the individual or not?).

Categorical vs Dimensional Approaches to Autism

Recently there has been discussion about whether we should take a categorical or dimensional approach to autism. That is, should we retain dichotomous boundaries separating "autism" from "non-autism", a categorical approach (Wittkopf et al., 2023). Or, are symptoms continuously distributed in the general population, so that an individual can be "a bit" or "a lot" autistic, a dimensional approach (Wittkopf et al., 2023). In our studies, we kept ASD group status as a categorical variable, determined by whether a participant confirmed formal diagnosis or not. However, we also measured a continuous variable of autistic traits, the Autism-Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001), in most of our studies. In the studies finding the most pronounced group differences, such as our study on metaphors in Chapter 6, we found similar results when we analysed our results using AQ scores, too. However, in other parts of our research, such as our pilot study of linguistic prediction, we only found significant differences with AQ scores and no group differences when using ASD diagnostic status as a variable. Therefore, we cannot confirm that categorical nor dimensional approaches fully capture the complexity of autism, and believe that perhaps hybrid model has the most benefit here, a claim supported by other researchers (Wittkopf et al., 2023).

General Limitations of Our Research

We acknowledge that there are two major limitations of our research, both concerned with demographic factors of the participants in our studies. Firstly, in the majority of our studies there seemed to be a gender imbalance between the ASD group and the control group, often reaching statistical significance. Researchers have emphasised the importance of mixed gender studies (Happé & Frith, 2020). Historically, autism studies were conducted predominantly on males, leading to diagnostic overshadowing in females. Phenotypic expression of autism can differ quite notably between genders, which we discussed in Chapter 1. We think it would be beneficial for future research in these language domains to create gender matched groups, to properly classify how atypical language abilities are presented in males and females. We think this would be particular insightful for disfluencies, which had a large effect of gender. However, we did control for gender in both Chapter 4 and Chapter 6.

Furthermore, we address that the autistic individuals in our studies were predominantly white British, and our participants did not constitute a diverse range of ethnic backgrounds. We addressed in Chapter 1 that there are racial and ethnic disparities in receiving an ASD diagnosis, posing a significant barrier to intervention and support (Durkin et al., 2017). We think that this is problematic, and more research should aim to investigate language abilities across other ethnicities and cultures. This would be particularly interesting given the very nature of language and social communication, giving insight into how other cultures may classify atypical language and pragmatics. We think that this warrants further investigation.

Another limitation of the research conducted in this thesis, is that for some chapters (namely the pilot study for Chapter 4 and Chapter 5) we were limited to online data collection due to the COVID pandemic. Therefore, we did not have control over certain extraneous factors, which may have affected our results. Particularly in Chapter 5, we think that it would be beneficial to assess active and passive sentence comprehension in a laboratory setting.

Finally, our studies relied purely on self-reported diagnosis of ASD. Whilst we did gain information about pathway to diagnosis for the participants in Chapters 3, 4 and 6, we did not ask for formal documentation to corroborate this. Considering that there is a high number of people who self-diagnose autism, we should have kept this is mind during the recruitment phases for each chapter. However, people often self-diagnose due to barriers to diagnosis, which we discussed in Chapter 1. Therefore, while we think it is beneficial to have evidence of formal diagnosis from a research perspective, this is not always possible and there is a large subset of autistic people who have not yet received an official diagnosis.

General Conclusion

We conclude that there is substantial variation in language abilities in autistic individuals. However, language remains to be an important factor in the ASD diagnosis, and autistic individuals exhibit a diverse cognitive and behavioural language profile. Based on our research questions, we consider that there are different levels of recognising ASD language symptoms.

The first arm of this thesis focussed on language characteristics as potential diagnostic markers of ASD, which we acknowledge as being a behavioural level of classifying language in ASD. This is because these language abilities are observable, easily measured and can be utilised in diagnostic assessments. There is a need for more robust measures of autism symptoms, identifying areas that cause significant challenges for autistic individuals. We believe that there is value in using the LAPQ as a screening tool for language-related problems in children and adolescents. Early language problems can often be indicative of more severe autism (Bent, Dissanayake & Barbaro, 2015), and are a clear identifier for intervention and support, given the effect that language problems can have on social integration (Magiati et al., 2014). Whilst we acknowledged that there are consistent trends in the literature concerning rate of disfluencies in autistic individuals, we could not find any significant group differences with any of our disfluency measures. Therefore, we do not believe in the clinical value of using disfluencies as diagnostic markers of ASD, but more research is warranted in this area.

The second arm of this thesis focussed on language comprehension in autism on a cognitive level. Whilst research concerning behavioural levels of autism symptoms are important from a diagnostic point of view, Happé & Frith (2021) acknowledge that they tell us little about the cognitive underpinnings of such observations. It is important for research to measure internal, implicit levels of traits, and not just outward social behaviour. Cognitive-level research is therefore valuable, particular for individuals who may camouflage symptoms, which can be the case for individuals identified as “high functioning”. We identified that there were clear cognitive differences in the way that autistic individuals process language, even if they perform to the same level of accuracy in language tasks as typically-developing control participants from a behavoural perspective. Happé & Frith (2020) acknowledge the importance of identifying “stratification” markers of autism, which can be achieved through research such as this. Furthermore, Happé & Frith (2021) emphasised the need for more cognitive tests of ASD symptoms, “to reliably identify autism in the clinic at the individual level” (p. 752), and suggest that this may be beneficial in uncovering areas of compensation and camouflage in autistic individuals.

In our research, we did not measure language abilities from a biological level. We believe that it would be interesting to see if there is genetic vulnerability to these language abilities, representing a language endophenotype in autism. This could be achieved by identifying relatives of autistic individuals, with the Broad Autism Phenotype (BAP), and assessing performance in these language tasks.

In conclusion, we retain the narrative that language is important in ASD. Language abilities are a gateway to social cognition, and research in this area provide us with a more fine-tuned understanding of the complexities of autism and insight into how autistic individuals experience such a dynamic world. Even in individuals who do not face considerable functional language problems, there are still distinct differences in the way that they process and understanding language. Research that acknowledges these areas paves the way for greater understanding of autism, meaning that language differences can be supported and accommodated for in wider societal contexts. Furthermore, it is important to reshape public perceptions of autism, and research is a stepping-stone for making that possible.

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