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Language Profiles Of Thai Children With Autism: Lexical, Grammatical, And Pragmatic Factors

Nattanun Chanchaochai
University of Pennsylvania

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Abstract

This dissertation is a linguistically-motivated investigation into different areas of language in children with autism spectrum disorders (ASD), compared to typically developing (TD) children. Fine distinctions between linguistic units were used in designing tasks on language production and comprehension in seven experiments. The focus of each chapter of this dissertation was on three main hypotheses respectively, namely (1) the Abstract Representation Difficulty Hypothesis that children with ASD (perhaps limited to the subgroup with co-morbid language impairments) have difficulties activating abstract lexical representations as effectively as TD children, due to their hyperattention to phonetic details of speech, (2) the Pragmatic over Grammatical Deficit Hypothesis that pragmatics is particularly difficult for all the ASD children, while morphological and semantic aspects of language are relatively intact, and (3) the Cognitive Factor Hypothesis that cognitive factors such as nonverbal intelligence quotient (NVIQ) and nonverbal working memory play a greater role in the ASD than the TD performance on linguistic tasks.

Chapter 2 investigates the morpho-phonological and semantic aspects of the lexical processing of Thai compound and simplex words. Results suggest that morphological facilitation effects can be obtained independently of phonological and semantic relatedness in the processing of Thai compounds. While children with ASD with lower task performance display hyper-attention to the acoustic differences between primes and targets, children with ASD in the higher performance group have enhanced morphological effects, compared to their TD peers, and the effects appear to be independent of the presence of phonological effects and enhanced semantic effects. The lack of phonological effects in the first set of experiments was explored further in the later experiments. Children with ASD were found to be slower in processing natural-sounding surface phonological forms, suggesting that a deeper processing of neutralized forms than full forms. The similar performance on the next task with the integration of visual information suggests that the slower processing may result from their slower lexical semantic processing. The Abstract Representation Difficulty Hypothesis, thus, holds for a subgroup of children with ASD, while other children with ASD display intact phonological representation, enhanced morphological processing compared to TD controls, and intact but slower lexical processing.

Chapter 3 explores the Pragmatic over Grammatical Deficits Hypothesis. Using fine distinctions within the personal reference terms, consistently replicated results suggest that while grammatical person phi-features are intact in children with ASD's representation of pronouns, these children are less sensitive to deictic information in their interpretation of pronouns and tend to avoid using the first-person pronoun, with high deictic level, when they have freedom to choose personal names to refer to themselves. Children with ASD also performed more poorly on the comprehension of unmarked pronouns which requires implicated presupposition, suggesting that even with minimal comparisons among the pronouns, lexically-encoded core grammatical features and pragmatic ones are distinguished in children's language processing. Chapter 3 also adds to the literature on lexical presuppositions, scalar implicature, and implicated presuppositions that not only adolescents, but also children with ASD are age-appropriate in deriving scalar implicatures and that not all kinds of pragmatic inferences are equally challenging for children with ASD. The most indicative difference between the children with ASD and the TD group lies in the children with ASD's heavier reliance on literal, logical meaning when other semantically- and pragmatically-inferred meanings are violated.

Chapter 4 partly contributes to the Cognitive Factor Hypothesis, suggesting a possibility that cognitive factors, as opposed to developmental factors, correlates more with children with ASD's performance on linguistic tasks. Additionally, children in both groups displayed correlations in their performance across all of the experiment in the dissertation. Individual language profiles were compiled with the results from the previous chapters. Two subgroups of children with ASD were identified through k-means cluster analysis. The children with ASD in Cluster 1 have globally better performance across experiments than children with ASD in Cluster 2, supporting that ASD children may be able to be classified into subgroups based on their performance on linguistic tasks alone. Even with globally better linguistic task performance, the children with ASD in Cluster 1 still appear to be less sensitive to social-deictic information, confirming that certain types of pragmatics are indeed more challenging than the others.

In sum, this dissertation advances our understanding on morphological, semantic, and pragmatic abilities of children with autism through carefully-designed linguistically-motivated experiments.

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LANGUAGE PROFILES OF THAI CHILDREN WITH AUTISM:

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Nattanun Chanchaochai

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Supervisor of Dissertation

____

Florian Schwarz, Associate Professor of Linguistics

Graduate Group Chairperson

____

Eugene Buckley, Associate Professor of Linguistics

Dissertation Committee:

David Embick, Professor of Linguistics

Kathryn Schuler, Assistant Professor of Linguistics

To the curiosity of my 8-year-old self...

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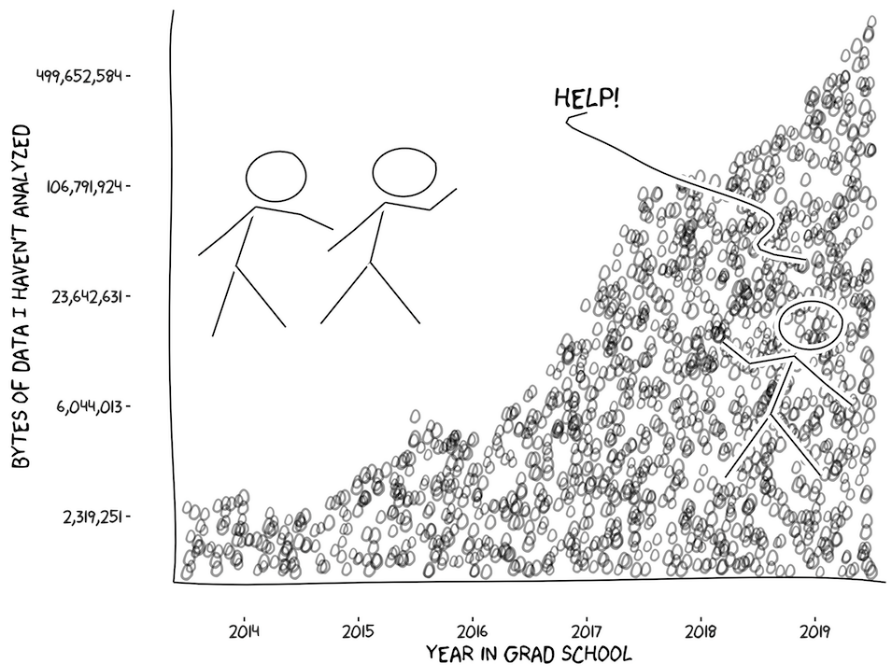

Figure 1: Aletheia Cui (left) and Emily Romanello (right) are helping me (buried under data points) get less overwhelmed. Figure courtesy of Aletheia.

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ABSTRACT

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Supervisor: Florian Schwarz

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ASD in Cluster 1 have globally better performance across experiments than children with ASD in Cluster 2, supporting that ASD children may be able to be classified into subgroups based on their performance on linguistic tasks alone. Even with globally better linguistic task performance, the children with ASD in Cluster 1 still appear to be less sensitive to social-deictic information, confirming that certain types of pragmatics are indeed more challenging than the others.

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Chapter 1

Introduction

This dissertation studies different aspects of the relationship between language and autism in order to explore the heterogeneous nature of the autistic population in the domain of linguistics. It employs a range of experimental methods to investigate the effects of lexical, grammatical, and pragmatic factors on the children's performance in linguistic tasks. In addition to the linguistic factors, this dissertation also studies the correlations between the task performance and cognitive and developmental factors, including chronological age, nonverbal intelligence quotient (NVIQ), and nonverbal working memory. The first aim of these studies is to probe any group effects of children with autism spectrum disorders (ASD), as compared to typically-developing children (TD). Such a comparison is aimed to reveal the areas of language that children with autism especially struggle with as a group. The next aim is to explore individual performance across tasks to create each child's language profile. The study on the individual differences is important because, despite being united by the same core characteristics, children on the autism spectrum have been increasingly recognized as being diverse and heterogeneous. Their heterogeneity exists in various dimensions ranging from symptom configurations (severity levels in behavioral deficits or accompanying deficits) to genetic variants (Georgiades et al., 2013; Lenroot and Yeung, 2013, a.o.). The heterogeneity of ASD in the linguistic domain is especially big. Some children with ASD never acquire language, and the ones who do can vary from having different degrees of language impairments (ALI: Autism - language impaired) to having normal or above average linguistic abilities (ALN: Autism - language normal) (Boucher, 2012; Tager-Flusberg, 2004).

While pragmatic and discourse deficits are perceived to be central to the characteristics of language in autism, evidence for impairment on other levels of language is inconclusive. The non-pragmatic aspects of language and autism are often unknown or unclear, most of the existing research about language and autism is also restricted to English and a few other languages. Research on less-studied languages is thus necessary to test the extent to which our current knowledge on this topic is influenced by certain properties of the English language, rather than the properties of ASD itself.

I expand the research area of language and autism to Thai-speaking children. Thai is a language well-suited for this topic since grammatical and pragmatic aspects can be simultaneously explored in various ways. Properties of Thai such as lexical tones, vowel length distinctions, compounding, a highly complex personal reference system, and deictic-center shifting were employed in designing carefully-planned experiments.

This chapter explains crucial terminology used in the dissertation. It provides some background on language and autism, including the language impairment subtype of autism and the domains of language deficits in autism. Terminological issues and some major theories in the language and autism literature are also discussed and clarified in this chapter. With each chapter covering various topics of study, additional relevant terminology will be defined in the subsequent chapters. Towards the end of this chapter, the scope and aim of this dissertation, along with an overview of the data collections and chapters in this dissertation, are presented.

1.1 Terminology

Grammar In this dissertation, ***grammar*** refers to a system of rules that speakers of a particular language instinctively follow and have internalized (e.g., the sound sequence [rkitf] as a word and "Love dogs I" as a sentence are not grammatical in English). Such a system contains a set of rules that provide different levels of structures or combinatory relations for elements of language. It is crucial to emphasize that grammar is not restricted to the word or sentence levels, as some studies in the language and autism literature emphasize. Instead, levels of language structures range from sound (phonology), word (morphology), phrase and sentence (syntax), and meaning and structure composition (semantics).

Lexicon In this dissertation, the lexicon refers to the total set of word-level representations, assuming a general, non-technical definition of 'word'. The lexicon provides the building blocks that go into the grammatical structure at the sentence level. What counts as 'word' and how complex words are represented in the lexicon are partially investigated in this dissertation's experimentas. These broad questions remain to be answered more thoroughly through future cross-linguistic studies.

Pragmatics Even though the exact same sentence is produced twice, the meaning it conveys is not necessarily constant (take for example, a declarative statement versus a sarcastic remark). Pragmatics accounts for the variation in meaning from the context of language use. It distinguishes between *sentences* and *utterances* in real conversations and interactions. Effective communication not only requires speakers to master the grammar of a particular language and have a sufficient mental lexicon, but also for them to be able to draw conclusions from seemingly ambiguous, irrelevant, inappropriate, or even untrue utterances.

1.2 Autism and autism spectrum disorders

Until 2013, autism was diagnosed through the exhibition of at least six of the twelve symptoms from all three core clinical features: impaired social interaction, impaired language and communication, and repetitive and stereotyped patterns of behaviors (American Psychiatric Association, 2000). The diagnosis with this *triad of impairments* has fallen into disuse as the latest Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V; American Psychiatric Association, 2013) updated the diagnostic criteria to include only a *dyad of impairments*: social communication impairments and restricted, repetitive patterns of behaviors and interests. Social deficits and communication deficits, which were previously separate categories, are now combined, due to their frequent co-occurrence. The scope of language and communication deficits has been reduced to conversational reciprocity and integrated verbal and nonverbal communication, instead of generally weighing a delay or a total lack of spoken language development as in the previous DSM-IV-TR (DSM-IV with a "text revision"; American Psychiatric Association, 2000). Moreover, restricted patterns of behaviors and interests now include hyper- or hyporeactivity to sensory input or unusual sensory interest. The criteria in DSM-V has become stricter than before, requiring five out of seven symptoms from the two categories. In order to be diagnosed using the new criteria, every item under social communication deficits and two out of four items under the restricted, repetitive behavior category have to be present. These stricter criteria result in lower ASD prevalence where the DSM-V case definition is used compared to the DSM-IV-TR case definition (Baio et al., 2018; Gibbs et al., 2012; Volkmar and Reichow, 2013, a.o.).

In addition to the adjustments to the core clinical features, the DSM-V also changed the label of the disorder to '*autism spectrum disorder*' to acknowledge the heterogeneity among the autistic population. Instead of having four previously distinct disorders: autistic disorder, Aspergers disorder, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified, the current standard views all of them as being on the spectrum of one single disorder, with different levels severity of the core symptoms. This dissertation, therefore, uses the term autism and autism spectrum disorder interchangeably.

Autism is a developmental disorder, meaning that it occurs early in life. Signs of autism such as abnormal eye contact, the lack of joint attention, and failure to respond to own name are manifested in early child development. The onset of concern by most parents of children with autism is reported to be around 18 months of age (Howlin and Moore, 1997; Howlin and Asgharian, 1999; Mundy and Markus, 1997; Wetherby et al., 2013), but it is not until an average of 6 months later that they seek professional help (Howlin and Moore, 1997;

Howlin and Asgharian, 1999).

The most recent study from the Centers for Disease Control and Prevention (CDC)'s Autism and Developmental Disabilities Monitoring (ADDM) Network (Baio et al., 2018) surveyed 8-year-old children in 11 ADDM Network communities in the United States (Arizona, Arkansas, Colorado, Georgia, Maryland, Minnesota, Missouri, New Jersey, North Carolina, Tennessee, and Wisconsin). The survey found a rise in the ASD prevalence estimates from 1 in 69 children (Christensen et al., 2016) to 1 in 59. The ASD prevalence estimates were four times higher for boys than for girls. This report also showed that only 42% of children with ASD received a comprehensive evaluation by 36 months of age, even though by that time, 85% of the children were already documented to have developmental issues.

Comorbidity, i.e., the co-presence of other deficits, impairments, or symptoms, also varies from individual to individual. Accompanying medical conditions are, for instance, fragile X syndrome, tuberous sclerosis, epilepsy, and cerebral palsy. This suggests that autism has certain neurological and genetic bases (American Academy of Pediatrics, Committee on Children with Disabilities, 2001; Cook, 1998; Kielinen et al., 2004; Minshew et al., 1997, a.o.). Such comorbid disorders also contribute to their increased risk of seizures and intellectual disability. The data from 9 ADDM sites showed that over half of the children with ASD were either in the range of intellectual disability (31% with IQ <70) or in the borderline range (25% with IQ 71-85). The prevalence estimates of comorbidity in autism generally vary by medical and psychiatric condition.

1.3 Language and autism

The lack of nonverbal communication and delayed speech are common concerns for parents of children with autism during their children's toddler and preschool years. Language abilities in autism vary greatly from individual to individual. Whether an autistic child acquires some language by age five predicts the child's developmental outcome (Rutter, 1970; Venter et al., 1992). Around 14-20% of children with autism are non-verbal, i.e., they produce fewer than 5 words per day (Lord et al., 2004). Those who have acquired language also vary in language and communicative abilities.

This heterogeneity in the language of autistic individuals was brought to attention in the autism literature. Two main questions arise: (1) Can language deficits in ASD be explained in terms of comorbid specific language impairment (SLI)[1]? (2) What aspects of language are within the domain of language deficits in autism? These questions will be discussed in the following sections.

1.3.1 Language impairment in autism

The possibility that there can be a link between autism and Specific Language Impairment (SLI) has long been considered. Churchill (1972) hypothesized that severe developmental language deficits may be the cause of social withdrawals and other defining characteristics of autism. The claim became indefensible when Asperger's syndrome was introduced as a part of ASD since the absence of language impairment is what marks Asperger's syndrome. The interest in the relationship between SLI and autism was revived after the findings in the 1990s on a genetic link between vulnerability to autism and vulnerability to SLI (e.g., Bolton et al., 1994; Folstein et al., 1999; Fombonne et al., 1997; Piven and Palmer, 1997; Szatmari et al., 2000). Different results and hypotheses were proposed. One group of studies concluded that the language phenotypes, i.e., the defining characteristics, of the ALI subtype is the same as those of SLI, suggesting that the ALI subgroup has comorbid SLI (e.g., Kjelgaard and Tager-Flusberg, 2001; Roberts et al., 2004; Tager-Flusberg, 2006; Tager-Flusberg and Joseph, 2003). For instance, Kjelgaard and Tager-Flusberg (2001) divided

[1]SLI has been referred to with various names, including language disorder, developmental language disorder and developmental dysphasia. The diagnosis of SLI relies heavily on indirect negative evidence from other relevant conditions, including physical abnormality, general intelligence, ASD, etc. In other words, it is generally the term that is used for 'unexplained language problems' (Bishop, 2014). The diagnostic criteria for SLI is already an issue on its own as there are currently no standardized measures for the degree of language impairment nor agreement on the cut-off points (Ebbels, 2014; Reilly et al., 2014b). In recent debates, researchers also proposed that there should be a new diagnostic label for the condition (Reilly et al., 2014a). Some concerns with regards to dropping the term SLI are that the change of label make break the connection to past research (Ebbels, 2014). In my dissertation, I use the term SLI in order to link with previous literature. I am not claiming anything about the appropriateness of the term. A tremendous amount of future research is needed on SLI across languages.

children with ASD into three groups: (1) normal language (scoring >85%), (2) borderline language (70-84%; 1 *SD* below the mean), and (3) language-impaired (<70%; >2 *SD*s below the mean), based on their test results of Clinical Evaluation of Language Fundamentals (CELF; Wiig et al., 1992). This test assesses both receptive and expressive language skills, including tests on word classes, word structure, sentence structure, concepts and directions, semantic relationships, recalling sentences, formulated sentences, and sentence assembly. Both the borderline and language-impaired subgroups of ASD were found to have normal articulation but scored below the mean on vocabulary comprehension and production. Yet, their vocabulary is less impaired than other areas. Kjelgaard and Tager-Flusberg (2001) concluded that the language profiles of the language-impaired subgroups of ASD and those of SLI are alike, suggesting that the language deficits in SLI may not be specific to their own disorder, but can also be found in other disorders.

However, the other view in the literature (e.g., Boucher, 2012; Whitehouse et al., 2008; Williams et al., 2008) does not support the claim that the langauge impairment pattern found in ALI is similar to that of SLI. Williams et al. (2008) reviewed studies on language abilities, neurobiology, and genetic factors. They compared ALI and SLI and found that there is not enough evidence to explain ALI in terms of comorbid SLI. As in the case of Kjelgaard and Tager-Flusberg (2001), while impairments in articulation is commonly found in SLI, their study did not find articulatory impairments in either their borderline or the language-impaired subgroups of ASD. Moreover, following the clinical classification of language disorder by Allen (1989) and Allen and Rapin (1980) (summarized in Table 1.1), Rapin and Dunn (2003) reported the percentages of (1) mixed receptive-expressive language disorder, (2) expressive disorder, and (3) high order processing in preschool children with SLI as 50%, 35%, and 15% respectively, while they were 63%, 0%, and 37% in ALI.

With mixed conclusions in the literature, it remains unclear whether the language impairments in ASD are SLI-like. To better tackle the issue, Williams et al. (2008) suggested an alternative strategy to subgrouping children with ASD based on a narrower range of language performance, including their nonword repetition, sentence repetition, and tense

Table 1.1: Clinical classification of language disorder in preschool children.

A. Mixed receptive/expressive disorders	
- Verbal ability agnosia	Phonologic decoding so profoundly impaired that the children understand no language and therefore are nonverbal or virtually so
- Phonologic-syntactic subtype	Comprehension impaired but equal to or superior to language production. Expressive language sparse, in rudimentary, poorly articulated sentences, vocabulary impoverished
B. Expressive disorders	
- Verbal dyspraxia	Extremely dysfluent expression despite normal or near normal comprehension. Although verbal dyspraxia may be associated with oromotor deficits and overall clumsiness, these motor deficits are not severe enough to account for the profoundly impaired expressive deficit which is postulated to be at the level of retrieval of the commands for verbal expression
- Phonologic programming subtype	fluent and unintelligible, or with small distorted expressive vocabularies and simplified syntax.
C. Higher order processing disorders	
- Lexical syntactic subtype	Severe word finding deficit resulting in dysfluent language, syntax often immature. Expression may start as fluent jargon
- Semantic pragmatic subtype	Expressive language fluent, echolalic, often verbose and scripted, with verbal perseveration, unusual word choices, and impaired conversational use of language. Comprehension more impaired than production

Adapted from Rapin and Dunn, 2003: pp. 168.

marking errors, which are well-established clinical markers of SLI. It is beyond the scope of this dissertation to address the issue. However, it is assumed that uniformity in language profiles in children with ASD cannot be expected. Thus, there is potential for having two or more subgroups of children with ASD. These potential subgroups may also have different develomental trajectories of language acquisition. *The ALI group in this dissertation refers to the group of children with ASD with language impairments but the impairments do not necessarily resemble SLI.*

1.3.2 Domains of language deficits in autism

Delayed speech is not only a common early symptom of autism, but also of many other conditions, e.g., intellectual disability, hearing loss, cerebral palsy, etc. It is thus crucial to evaluate the child's characteristics of speech, language, and non-verbal communication, in order to distinguish various disorders from autism (American Academy of Pediatrics, Committee on Children with Disabilities, 2001). Additionally, studying the language characteristics of children with autism helps determine whether their language is merely delayed or is also deviant from the typical.

While pragmatic and discourse deficits are perceived to be central to the characteristics of autism spectrum disorders (for reviews, see Lord and Paul, 1997; Tager-Flusberg, 1999; Wilkinson, 1998), impairments on other levels of language are increasingly investigated in the literature (e.g., Bailey et al., 1996; Bartak et al., 1975; Eigsti et al., 2011; Tager-Flusberg and Joseph, 2003), suggesting that the language deficits in children with ASD can be more fundamental, involving different areas of language. The extent to which each area is impaired is still debatable.

Boucher (2012) reviewed the relevant literature on language and autism and summarized the commonality between the language profiles of ALI and ALN. According to her, preschool children with ASD have delayed and deviant language, especially with regards to idiosyncratic semantic processing and impaired articulation and syntax (cf. phonologic-syntactic subtype in Table 1.1). Over time, at school age, 'ASD-typical' language profiles arise having the following characteristics:

1. Children with ASD achieve proficiency in articulation and syntax appropriate to their mental age (MA).
2. Morphological errors and idiosyncratic semantic processing persist.
3. Although the above pattern is ASD-typical, the degrees of the impairments depend on each individual profile, with language in ALI being more severely affected.

Boucher's summary is useful as an overview of language abilities across the spectrum, although the literature that her summary is based on is still worth discussing. Studies on morphological impairments in school-age ALI children that were mentioned in her review paper involve errors in personal pronouns, tense marking, and other grammatical words, including articles and conjunctions (Bartolucci et al., 1980; Botting and ContiRamsden, 2003; Dobbinson, 2000; Roberts et al., 2004; Tager-Flusberg et al., 1990; Waterhouse and Fein, 1982). Morphological deficits in ALN were not as clearly discussed and presented in the review paper. The overall attention in the ASD literature was also placed on inflectional morphology much more than derivational morphology. Moreover, the claim about morphological deficits is partially based on studies on personal pronouns, which may be confounded by the children's pragmatic abilities. This poses questions on whether morphological deficit happens across the spectrum and what domains of morphology are affected.

As for the studies on semantics reviewed in Boucher (2012), idiosyncratic or repetitive use of vocabulary was found across the spectrum (Perkins et al. 2006 for ALI, e.g., an extensive use of the word 'usually'; Volden and Lord 1991 for ALN, e.g., 'It makes me want to go as deep as *economical* with it' interpreted to mean 'withdraw as much as possible'). Semantic relatedness was also reported to have no facilitation effect on word recall tasks in school-age children with ALI (Fyffe and Prior, 1990). School-age children with ALN, on the other hand, were found to have intact use of semantic category cues for word recall task (Whitehouse et al., 2007). However, their processing of semantic related terms in real time hinted that the ALN semantic processing may be different regardless of their surface capability. Dunn and Bates (2005) found no significant enhancement of the N4 ERP component in the semantically-unrelated condition in 8 and 11 year-old children with ALN. The typically-developing controls, on the other hand, showed significant enhancement in response to semantic unexpectedness. Even though that leads to Boucher's conclusion that anomalies in semantic processing is ASD-typical, many other studies on real-time semantic processing that were not mentioned in her review paper reported comparable or enhanced performance in ASD compared to TD (Haebig et al., 2015; Harper-Hill et al., 2014a; Walenski et al., 2008). Due to these contradictory results, more studies on real-time semantic processing in children ASD should be conducted to gain more insights on the issue.

1.4 Scope and aim of the dissertation

The previous section points to the striking fact that there is still a huge lack of consensus on the basic issues regarding language and autism. This may be due to the numerous complexities in this area of research. First, the ASD population is especially heterogeneous in their language abilities, making it more difficult to pinpoint in which area of language the deficits lie. Second, the domain of language impairment in the SLI population also varies greatly from individual to individual. The complication in SLI stems from the fact that the diagnostic criteria are currently unclear with regards both to which tests to use and to what should be the appropriate cut-off points. Third, the goals of clinical assessment is very different from those of the scientific study of language. Most measures were designed for clinical purposes and not linguistic purposes. This leads to the use of different methods and procedures that may lack the sensitivity to detect fine-grained details in linguistics. Fourth, most of the knowledge we have on language and autism are from studies in English whose language-specific properties may have influenced the results.

The experiments in this dissertation were designed to cover the morphological, semantic, and pragmatic aspects of language, which have been claimed to be areas where subjects with ASD typically struggle with. The overall aim is to examine the following broader hypotheses:

1. **The Abstract Representation Difficulty Hypothesis:** *children with ASD (perhaps limited to the subgroup with co-morbid language impairments) have difficulties activating abstract lexical representations as effectively as TD children, partly due to their hyperattention to the phonetic details of speech* (Baron-Cohen et al., 2009; Eigsti and Fein, 2013; Jones et al., 2009; Remington and Fairnie, 2017).

2. **The Pragmatic over Grammatical Deficit Hypothesis:** *Pragmatics is predicted to be particularly difficult for all groups of children with ASD, while morphological and semantic aspects of language are relatively intact.* This hypothesis is based on the fact that pragmatic impairments are more consistently found in the literature, whereas their lexical and grammatical tests have yielded mixed results.

3. **The Cognitive Factor Hypothesis:** *Similar effects from developmental factors like age are expected for both groups of children. On the other hand, cognitive factors such as nonverbal intelligence quotient (NVIQ) and nonverbal working memory may correlate more with the ASD than the TD performance on linguistic tasks.* This is hypothesized as children with ASD may require more cognitive resources and effort in order to achieve the same level as their TD peers. An alternative explanation is

that children with ASD have a defective system for certain area of language processing, leading to the takeover or the compensation by their intact cognitive systems (Livingston and Happé, 2017; Ullman and Pullman, 2015).

Linguistic studies on autism in different languages can shed some lights on new or more detailed aspects that have been previously overlooked. In particular, Thai offers a new perspective due to its various properties. For instance, Thai is a tonal language, allowing us to probe pitch sensitivity in children with ASD using lexical stimuli. Thai is also an isolating language, having very few inflectional morphemes but a lot of derivational word formation processes, including an abundance of compounds. Since previous studies on morphological abilities of children with ASD were almost solely based on inflectional morphology, studying the ability of children with ASD with regards to compounding, a highly productive word formation process, will broaden our knowledge on derivational morphology and its interaction with semantics in autism. In addition to these aspects, pragmatics can also be extensively studied in Thai since it plays an important role in the language in a number of ways. For example, Thai has a highly complex pronominal system with over 50 personal pronouns (Cooke, 1968) and other kinds of personal reference terms. This allows for a good opportunity to explore grammar in parallel with pragmatics.

1.5 Overview

1.5.1 Data collections

In my study, each child completed a wide range of tasks, thus creating a unique language profile for each individual. Every experiment is carefully controlled to precisely focus on its own specific questions. The data collections for the dissertation were done in two phases. The first phase involved 3 linguistic tasks and 1 cognitive task. The second phase comprised 6 linguistic tasks and 5 cognitive/developmental tasks. These experiments make up a comprehensive data set that can be to explore the language profiles of the children in detail.

The first data collection was completed in Summer 2016. Children with ASD (n = 29; 5 female; M Age = 9;10; M Ravens NVIQ[2] = 97.8) and their typically-developing controls (TD; n = 67; 12 Female; M Age = 9; M Ravens NVIQ = 112.95) were recruited from (1) Kasetsart University Laboratory School, Center for Educational Research and Development and (2) La-or Utis Demonstration School. One participant with ASD was classified in his medical records as having Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), while the remaining were all classified as having Autistic Disorder (AD).

The second data collection in Fall 2017 recruited a total of 91 children from Kasetsart University Laboratory School, Center for Educational Research and Development. There were 32 children with ASD (3 Female; M Age = 9;8; M NVIQ = 95.5) and 59 TD children (10 Female; M Age = 7;11; M NVIQ = 116.6). Among the 32 children with ASD in the second data collection, 19 children were the same individuals that participated in the experiments in 2016. All the participants with ASD in 2017 were classified as having AD. All participants from both years had normal hearing and normal or corrected-to-normal vision.

The studies were approved by the Institutional Review Board of the University of Pennsylvania. The parents of all the children provided written consent for them to participate in the study. The children and their parents were informed of their rights to withdraw from the study at any time. The children received toys and school supplies as compensation.

[2] All the children were administered the Ravens Standardized Progressive Matrices (Raven et al., 2000) which serves to measure the non-verbal intelligence quotient (NVIQ). Standard scores were calculated using the norms in the 1979 British Standardisation of the Standard Progressive Matrices (Detailed table in Raven 2000, pp. 39-40), following the practice done in Thailand where the British norms were used (Department of Mental Health, Ministry of Public Health, 2012). The conversion was done by first obtaining the percentile ranks for the raw score by age of each participant, using the mentioned norms. This step removes the correlations between age and IQ. The percentile ranks were then converted to z-scores, with a mean of zero and a standard deviation of one. Standard scores were then computed to an IQ unit using the Deviation IQs method, a common practice in psychological tests since the Stanford-Binet Test (Terman, 1916), by multiplying each z-score to a standard deviation of 15, before adding a mean of 100.

1.5.2 Chapters

This dissertation consists of 5 chapters. The 3 main chapters correspond with the 3 main hypotheses to be explored in this dissertation. Further background is provided for the specific topic of each chapter.

Chapter 2 is concerned with the effects of morphology, semantics, and acoustic sensitivity on the children's lexical processing. The chapter begins by providing the relevant theoretical and methodological background, followed by a literature review on lexical processing in autism. It then proceeds to presenting the methodology and the results of three main experiments on related issues. The first set of experiments investigates whether semantics is a prerequisite for the morphological processing of Thai compounds. The second set of experiments explores the question of what kind of information in the auditory input, phonological or non-phonological, affects lexical processing.

Chapter 3 explores the children's performance on semantic and pragmatic tasks. The focus of this chapter include presupposition, implicature, and deixis. The first set of experiments is concerned with the production and comprehension of personal reference terms in Thai. This set of experiments relate to the issues of presupposition, person deixis, and social deixis. The second experiment directly compares lexical presupposition, implicated presuppositions, and implicature.

Chapter 4 provides each child's individual language profile. It also introduces more cognitive factors into the picture. Their performance on various tasks in the previous chapters is summarized along with different cognitive and developmental factors. These profiles are scrutinized, seeking for detectable patterns to be discussed.

Chapter 5 concludes. Summaries of each chapter's major findings along with open questions are presented.

Chapter 2

Lexical Processing

2.1 Introduction

This chapter examines the validity of the Abstract Representation Difficulty Hypothesis, which states that the activation of abstract lexical representations of speech by children with ASD, or a subgroup of them, is not as effective as their TD peers. The primary focus of this chapter is to compare the performance across these groups in order to better inform our view on the language capacity of children with autism. Nevertheless, the experiments in this chapter were not designed to be a clinical test of their language capacity, but rather were designed with linguistic and psycholinguistic motivations, involving real-time processing. The results of each experiment are, therefore, discussed with by adult data or trends of adult results in the previous cross-linguistic literature.

The chapter begins with a presentation crucial concepts and terminology, followed by a literature review on the theoretical and methodological background. Specifically, it provides information on the connection between psycholinguistic and linguistic theories, models of lexical processing, and the representations of abstract and episodic information. It then provides a literature review on lexical processing and autism before proceeding to the details of the conducted experiments. Section 2.5 presents three sets of experiments. The first set of experiments deals with the effects of morphology and semantics on the children's performance on lexical processing tasks. The latter experiments further investigate the effects of acoustic factors, including stress, lexical tones, and talker-gender switch, on lexical processing.

2.2 Concepts and terminologies

2.2.1 Linguistic and psycholinguistic concepts

Morphology In linguistics, *morphology* is commonly described as the study of *words*, their internal structure, and their formation. While this subdiscipline of grammar may have been studied by the first linguists in the history, the term *morphology* came into use only centuries after the terms for other subdisciplines as *phonology* or *syntax* (Haspelmath and Sims, 2013). The term *morphology* was originally coined by Johann Wolfgang von Goethe for biology to refer to the study of the forms of living organisms (Aronoff and Fudeman, 2010). In linguistics, morphologists are interested in how *complex words* are formed by grammatical rules from the *primitive* elements: *morphemes*.

Complex word A word is made up of a sequence of sounds from a certain language. Some sounds may be broken down into *phonological* features (e.g., [± voice], [± nasal]), while others may instead contain *syntacticosemantic* (henceforth, *synsem*) features, i.e., grammatical or functional meanings, as their basic representations. For instance, the final /t/ sound in words such as *waste*, *act*, *adopt*, etc. can be distinguished from the final /t/ in words such as *passed*, *lacked*, or *stopped*. The final /t/ in the latter set of words is a *morpheme* that is composed of the synsem feature [+past], to denote past tense. On the other hand, leaving out the /t/ sound in the first set of words (*[weɪs], *[æk], *[əˈdæp]) does not result in non-past tense meaning for those words. Moreover, synsem features can be realized phonologically differently by their phonological or morphological contexts. For instance, the feature [+past] surfaces as /d/ after words ending in non-t/d voiced consonants, e.g. *joined* or *bored*, in default cases. In this dissertation, **complex words** refer to *multimorphemic words*. It is important to note that this is not the same as being featurally complex (Embick, 2015). For example, the English words *I* or *we* contain both a first person feature [+1] and a number feature [±pl]. Yet they are not *complex words* by the definition in this dissertation. By contrast, words such as *bent*, *left*, or *bit* are complex as they are composed of more than one morpheme: their core basic meaning and the synsem feature [+past].

The morpheme as a syntactic object The previous description indicates that I assume *morphemes* to be discrete pieces that inevitably involve the mapping between sound and meaning. In this dissertation, I follow (Embick, 2015) in treating *morphemes* as the *primitive* units for syntactic operations, using the *Distributed Morphology* (henceforth, DM) framework. Accordingly, I also assume two types of morphemes in the grammar: *functional morphemes* and *Roots*. *Functional morphemes* possess closed-class synsem features (e.g., [±past] or [±pl]) and have no phonological features, while *Roots* (e.g., $\sqrt{\text{House}}$ or $\sqrt{\text{Sleep}}$) make up the open-class vocabulary and they do not contain synsem features but do have underlying phonological representations. In the psycholinguistic literature, the term *stem* is generally used, as a less technical notion of the term *Root*, to refer to the remaining morpheme after the removal of all functional morphemes in a word (Goodwin Davies, 2018). As seen earlier, the same morphemes can surface differently as conditioned by their phonological or morphological contexts (e.g., the plural morpheme in English can surface as /s/ as in *cats* or /z/ as in *dogs*). These conditioned variants of morphemes are referred to as **allomorphs**. Within the DM framework, *words* are not architecturally different from phrases. It is the *morphemes* that are the theoretical primitive object to be syntactically operated on. Thus, it is not essential to define the notion of *word* theoretically. This dissertation assumes the informal, non-technical use of the term **word**, which are more in accordance with what language users are familiar with, rather than a theoretical object.

Complex word formation Morphology is traditionally divided into *inflectional* morphology and *derivational* morphology. **Inflection** generally relates different forms of the same word without creating a new lexical meaning nor forming a new **lexical category** (e.g., noun, verb). For instance, *classes* and *classed* are inflected forms of *class*. Inflection often includes features such as tense, number, gender, person, case, etc. On the other hand, **derivation** generally forms new words, thus creating new lexical meanings and *sometimes* forming new lexical categories. For example, *classify*, *classy*, *classic*, *classical* are derived from *class*. Inflection and derivation share similar means of formation such as **affixation**: *suffixes* (e.g., *touch-es, touch-able*), *prefixes* (e.g., *re-touch*), etc. Another common morphological process apart from inflections and derivations is *compounding*. While like derivation, **compounding** also forms a new word, the formation process *typically* involves two or more free lexical elements, e.g., *blackboard*, *football*, *wallpaper*, *without*, etc. However, the distinction between *derivation* and *compounding* is not always clear-cut. A fuzzy boundary between the two processes arise in the cases of elements that are **bound**, i.e., not being able to appear freely without attaching to other elements (e.g., *vis-* in *visible*), but also carry a robust lexical meaning, e.g., *derm* in *dermatology*. Moreover, compounds may undergo diachronic change, being subject to altered phonological, structural, and semantic behaviors (Bauer et al., 2013; Lieber, 2017; Trips, 2013). Over time, their free elements may themselves become affixes, with an unclear timeline for the completion of the transition (Bauer, 2005; Lieber, 2017) (see Bauer et al., 2013; Lieber, 2017; Lieber and Štekauer, 2011; Olsen, 2014; Ralli, 2010 for more discussion).

Under the DM framework, there is no theoretical distinction between inflectional and derivational morphology because both inflectional and derivational morphemes are syntactic terminals that are similarly operated on (Embick, 2015, pp. 47). Derivational morphemes in DM function as a *categorizer* for the Roots. Roots are *always* combined with their categorizer to denote their lexical category. Their categorical defining heads can either be derivational morphemes (e.g., *n*, *v*, *a*: noun, verb, adjective) or null. Compounding in DM, on the other hand, is "a word-sized unit containing two or more Roots" (Harley, 2011, pp. 130).

Lexical processing Lexical processing refers to the retrieval of a representation of lexical entries from the mental lexicon. The process is done through the matching between a sensory representation of a stimulus and its representation stored in the mental lexicon.

Lexical access does not refer to the actual processing but to the final outcome where the meaning is accessed (Taft, 2001). A key topic in lexical processing concerns the processing of morphologically complex words. Different models of morphological processing have been proposed regarding what should be stored in the lexicon and how it is retrieved. (see Section 2.3.1 for details.)

2.2.2 Methodological issues

2.2.2.1 Time-course

While grammarians make use of **offline** (i.e., conscious or calculated) data, psycholinguists often employ **online** (i.e., real-time, time-sensitive) data as the basis for their theoretical claims. Psycholinguistic experiments often involve very fine-grained time-course, measured in *milliseconds* (henceforth, ms). In psycholinguistics, time-course serves as a window to language processing stages. While *offline* data are regarded as involving *post-lexical* processing (Ingram, 2007, pp. 227), *online* data allow for an exploration of earlier processing stages. Not only is time-course related to language processing stages, it is also associated with the activation of representations. Only abstract representations have been argued to be retained *long-term* (i.e., over minutes or longer), while specific variation of each linguistic instance is unlikely to leave traces over a long period of time (Kouider and Dupoux, 2009). Owing to such importance in the psycholinguistic literature, time-course is monitored in the following aspects.

1. **Time-course as a factor in experimental manipulations**
   (a) *Exposure time to the stimuli* Exposure time generally relates to the intensity of effects and the processing stages. In some cases, it also correlates with what part of the stimuli is presented to the participants.
   (b) *Time until the next exposure* Psycholinguistic studies control for the time between stimuli that are intended to be sequential as the amount of time may affect the fading of facilitation or other effects of interest. Important terms in this respects are *stimulus onset asynchrony* (SOA), which is measured from the

beginning of one stimulus to the beginning of the next stimulus. Another related term is **interstimulus interval** (henceforth, ISI), which is the time between two stimuli. In this dissertation, it specifically refers to the time from either the end of the sound file or after the response, whichever is later, to the beginning of the next stimuli. Certain studies also make use of *lags*, which generally involve one or more intervening items between the critical pairs of stimuli. These relate to what is retained in memory and what levels of representation have been reached.

2. **Time-course as experimental results** Time-course is not only an important consideration in experimental design but is also an object of interest itself, when it comes to the behavioral response from the participants. **Reaction time** (henceforth, RT), also referred to as response time or response latency, is the time unit measured from the beginning of the stimulus presentation until the response has been made. It is one of the most widely used measures in cognitive and behavioral studies. RTs can be affected by many factors, such as the stimuli characteristics, participants, trial sequence, task familiarity, fatigue, etc. (Baayen and Milin, 2010). In general, reaction times can be seen as a measurement of processing cost (Milin and Feldman, 2018, pp. 249), with longer RTs correlating with higher processing cost.

2.2.2.2 Modality

Modality in psycholinguistics is used to refer to the means of stimuli presentation, including visual and auditory modalities. The auditory modality is the first and foremost modality for natural (spoken) language acquisition. The native language of an individual is not related to for their ability to read and write in that language. While the spoken language is *acquired* natively, reading and writing are *taught*. Sign languages are no exception. While the visual modality is necessary for sign languages, *native signers* use their hand gestures in the same manner as speech signals, before learning to read and write.

In experimental settings, differences between the visual and auditory modalities necessitate careful consideration. Goodwin Davies (2018, pp. 23-24) summarized five important ways stimulus presentations in the two modalities may differ. First, while visual stimuli are presented as a whole and may be processed bilaterally (e.g., Rastle et al., 2004), auditory stimuli are incrementally unfolded over time and, therefore, require linear processing. Second, auditory stimuli necessarily contain speaker properties and variations, while visual stimuli in standard orthography do not. Third, visual stimuli and auditory stimuli do not have a one-to-one association with each other. While visual presentation usually do not represent phonological and allomorphic variations, auditory presentation necessarily do. Fourth, phonetic details, such as coarticulation of speech sounds, must be present in the auditory modality. Last, the two modalities involve very different time-course. While it takes a reader 200 ms to process one word, the same amount of time covers only part of a syllable in spoken language (Baayen, 2014, pp. 100). It is worth noting that the time-course for sign languages, on the other hand, can be radically different from reading, even though they share the same modality.

Given such differences, linguistic forms presented in the auditory modality may be distinctly represented and yield different experimental results from the ones presented visually. While psycholinguistic research in general is conducted in both modalities, research on morphological processing is mainly based on visual presentations of stimuli. It is, therefore, necessary to investigate the same questions on morphological processing in the auditory modality as well.

2.2.2.3 Priming

Priming is the unconscious influence from the exposure to one stimulus on a response to a following stimulus. The priming technique has been widely used to investigate lexical processing. Priming experiments involve the use of one preceding stimulus, referred to as *primes*, to activate a subsequent one, called *targets*. Obtained priming effects are viewed as evidence for certain associations, e.g., sound, meaning, or structural associations, between the primes and the targets.

In visual priming experiments, the duration of prime presentation may be manipulated to target different stages of word recognition. A **masked priming** experiment involves a presentation of $\geq$500 ms forward mask, a short unnoticeable presentation of visual primes at around 30-60 ms, and a presentation $\geq$500 ms target (Forster and Davis, 1984). As the primes are not consciously perceived, masked priming paradigm targets the early pre-lexical processing stage. Moreover, the method is used to reduce any strategic processing whereby the participants anticipate upcoming stimuli (Forster et al., 1987). Nevertheless, strategic effects do not completely disappear even in masked priming experiments. Studies have found that an increase in proportion of related trials consequently leads to an increase in facilitation effects (Bodner and Masson, 2003; Feldman and Basnight-Brown, 2008).

While in masked priming experiments, primes are unnoticeably presented, **overt priming** experiments involve longer exposures of auditory or visual primes at $\geq$ 230 ms. Therefore, overt priming is used to investigate the lexical processing and integrative processes across words (Milin and Feldman, 2018). Owing to the primes being consciously perceived in overt priming paradigm, it is subject to more strategic effects. A reduced proportion of tested primes and their targets helps weaken such effects (Napps and Fowler, 1987).

2.2.2.4 The lexical decision task

The lexical decision task is extensively used to inform theories on morphological processing. In this task, participants are asked to determine whether a string of letters or sequence of sounds is an actual, existing word in a language or not. The nature of the lexical decision task requires the inclusion of both word and nonword fillers. *Nonwords* in this dissertation are equivalent to *pseudowords*. They are nonexistant but possible words in a particular language, meaning that they only contain the phonemes of this language and respect its phonotactics. For instance, *famp* or *vap* can be nonwords or pseudowords in English.

The lexical decision task may be designed with *between-target* or *within-target* manipulations (Milin and Feldman, 2018). *Between-target* designs involve different related prime-target pairs across conditions. Each of target is also mapped with an unrelated prime, which is matched in properties, e.g., frequency, with its related prime. For instance, one condition may involve the target *move*, paired with its related prime *movement* and its unrelated control prime *payment*, while another condition may involve the target *grief*, paired with its related prime *sorrow* and its control prime *elbow*. In contrast to such design, *within-target* designs keep the targets constant across conditions. Each target is mapped with different primes. For instance, the same target *depart* can be mapped to the prime *department* in one condition and to *departure* in another condition. Milin and Feldman (2018) pointed out one distinct advantage of the *within-target* design that since the same target is used across conditions, potential confounds regarding the target properties can be avoided. Rigorous statistical implementations are needed for the *between-target* designs to control for such confound.

2.3 Theoretical and methodological background

Grammatical theory and models of psycholinguistic processing both seek to understand abstract representations of human language. While grammatical theory puts more emphasis on the structure of language itself, psycholinguistics is concerned with how humans process and acquire language. The two subfields are concerned with both theorizing and employing empirical evidence to assess their theoretical claims. The nature of the empirical evidence that grammatical theory employs, however, is the *offline* output from language speakers, while psycholinguistic theory attempts to account for *online* language processing. It is, therefore, not trivial to map theories from the two subfields together (Goodwin Davies, 2018; Lewis and Phillips, 2015). Owing to the nature of the empirical evidence it employs, psycholinguistics may cover the use of various methodological techniques, such as eye-tracking or brain-imaging. It also takes into account various language-external factors, such as cognitive factors or time-course factors, which inevitably affect online language processing. Additionally, psycholinguistic experiments allow for different questions to be asked. Not only are they able to probe the processing of abstract information in language, information that varies by or is specific to each language signal can also be investigated. This section provides the background for two main topics of discussion that are the focus of the experiments in this chapter. First, it discusses the literature on morphological processing. Second, it introduces the debate in the spoken word recognition literature on the abstractness of representations.

2.3.1 Models of morphological processing

As morphemes and words inevitably involve sound, structure, and meaning, morphological theories vary on the status of the *morpheme* and the connection between morphology and other subfields of linguistics, namely phonology, syntax, and semantics. While the DM framework, which has been adopted in this dissertation, views morphemes as syntactic objects, maximizing the interface transparency between morphology and syntax, other morphological theories may adopt the lexicalist view of grammar, which views the lexicon as being independent from syntax, (see a review in Carstairs-McCarthy, 1992.) or deny the existence of morphemes to begin with (e.g., the amorphous theory (Anderson, 1992)). In parallel, psycholinguistic models of morphological processing are based on their different hypotheses on at least three aspects (Milin and Feldman, 2018; Goodwin Davies, 2018):

1. Morphological rules and representation The first question that divides models of morphological processing into two main groups is on whether explicit morphological rules and representations are assumed in the models. While morphemes have their status and representation in the lexical knowledge in the *combinatorial lexicon-based* approach, the *learning-based* approach does not assume explicit rules and representations of morphemes. The combinatorial approach assumes rules for composing morphological units into complex words. Stems in this approach contain their core meaning and can further combine with other units to create new words. The learning-based approach, instead, focuses on the level of learnability and processing costs from the mapping between form and function/meaning. For instance, the Naive Discrimination Reader model (Baayen et al., 2011) views the level of difficulty in learning the relations of words or units as dependent on how distinct or *discriminable* they are from the relevant units. This model assumes no constant core meaning of lexical entries. In this view, forms such as *watch*, *watched*, *watching*, or *watcher* are not related based on their root or core representation but only by their similarity in the contexts they occur in. Some learning-based models (e.g., Seidenberg and Gonnerman, 2000; Gonnerman et al., 2007), however, still assumes that morphological units are involved in the form-meaning mapping (Marantz, 2013).

2. Morphological decomposition and storage The next question to which models of lexical processing differ in their answer is on how morphologically complex words are processed or retrieved. The two extreme ends involve *single mechanism* of either *full listing* or *full decomposition*. Full listing models (e.g., Butterworth, 1983; Seidenberg and Gonnerman, 2000) proposes that all words are listed as a whole-word unit in memory. Full decomposition models (e.g., Marslen-Wilson et al., 1994; Taft, 2004; Stockall, 2004), on the other hand, maintain that complex words undergo morphological decomposition, meaning that they are always derived by grammar and not stored as a complex unit in memory (Embick, 2015). Other hybrid *dual-mechanism* models hold that word recognition involves both full-listing and decomposition routes. Dual-mechanism models vary on factors determining which route to be taken. One variety (e.g., Marslen-Wilson and Tyler, 1998; Pinker and Ullman, 2002) posits that 'regular' complex words that are formed by rules, e.g., *worked*, *played*, are decomposed, while other 'irregular' forms, e.g., *ran*, *spoke*, are listed as a whole unit. Other varieties of dual-mechanism model concerns factors, such as frequency or familiarity (e.g., Baayen et al., 1997; Burani and Caramazza, 1984; Caramazza et al., 1988).

3. Phonological and semantic contribution to morphological decomposition Another related major question is whether there is **Independent Morphological Processing** (henceforth, IMP; Bacovcin et al. 2017), allowing morphological processing to happen independently of phonological or semantic overlaps. This issue stems from the methodological confound of morphological priming that morphologically related words (e.g., *played*-PLAY, *marker*-MARK) are highly likely have phonological (or orthographic) and semantic overlaps with each other (Marslen-Wilson, 2007). Such overlaps in form or meaning are referred to the literature as phonological and semantic **transparency**, respectively. To tackle this issue of whether morphological processing can be reduced to merely the semantic and phonological transparency between the complex words and their Roots, the literature often compares between at least two of the five main experimental conditions. The first condition is when the primes are **morphologically related and semantically transparent** (henceforth, **MS**) to the target, for instance, prime: *departure* - target: DEPART. The second condition, in contrast, involves primes that are merely **morphologically related but semantically opaque** (henceforth, **M**) with the target, for instance, *department*-DEPART. The third condition includes primes that are not etymologically morphologically related but appear to be morphologically related to the target, i.e., the **pseudo-derived condition** (henceforth, **pseudo-M**), for instance, *pigment*-PIG. This pseudo-M condition is not always explicitly separated from the M condition in some studies but these two conditions are treated as being inherently different in this dissertation. The above conditions are only sufficient to answer the question about the role of semantic transparency on decomposition. However, it still has not dealt with potential phonological confound. The fourth condition deals with this question by including primes that are **merely phonologically related** (henceforth, **Ph**) to the targets, for instance, *figment*-PIG. It is worth noting that in visual priming studies, it is the orthographic overlap that they investigated. The last condition is a simple semantic priming condition with primes that are **merely semantically related** (henceforth, **S**) to the target, for example, *garbage*-TRASH.

The same questions above are not restricted to affixed words but also extend to the processing of compound words.[1] Compounding is considered to be a more primitive word formation process than affixation in the history of human language (Dressler, 2006; Jackendoff, 2002). Since compounds are formed by combining existing lexical items, novel compounds can be instantly understood without any prior encounter. Such a fundamental characteristic of compounds is the reason why they should be easily segmentable so their

[1]In the literature on compound processing, compound words are more finely classified into the following four groups based on the position of their transparent constituents, including transparent-transparent (TT; e.g., carwash, flagpole), opaque-transparent (OT; e.g., strawberry, dashboard), transparent-opaque (TO; e.g., doughnut, staircase), and opaque-opaque (OO; e.g., hogwash, windfall). (see for instance, El-Bialy et al., 2013; Libben, 2006; inter alia). Such distinctions are beyond the scope this dissertation.

meaning can be interpreted based on their constituent words. At the same time, certain compounds have idiosyncratic meanings that are hardly interpretable through the combination of meanings of their constituents. Thus, it should also be possible for compounds to be stored as a whole unit with their idiosyncratic meanings (Libben, 2006). Models on compound processing are in parallel with those on affixed word processing. *Full listing* models (e.g., Schreuder and Baayen, 1997) posited that compound words, e.g., breakfast, stopwatch, hometown, are mentally represented as a whole unit. The hybrid *dual-route* models (e.g., Sandra, 1990), on the other hand, propose that only the semantically opaque compounds, e.g., deadline, fleabag, are represented as a whole, while the semantically transparent ones, e.g., bedroom, birthday, are morphologically decomposed. *Full decomposition* models argue that compounds are processed after the decomposition into their constituents, e.g., break-fast, stop-watch, home-town. According to these models, only these constituents are mentally represented before being combined back into the compound. Researchers have attempted to account for semantic transparency within the full decomposition model, arguing that they do not affect the decomposability of compounds, but rather create a semantic incongruity between the meaning of whole compounds (e.g., strawberry) and the meaning obtained from their constituents (e.g., straw + berry). The inappropriate meaning acivation is then inhibited, resulting in the lack of priming effects by semantically opaque compounds in some studies (Libben and de Almeida, 2002; Libben et al., 2004; Libben, 2006).

2.3.2 Experimental results on morphological processing

Researchers have investigated morphological decomposition and the IMP hypothesis by focusing on the relations in forms (orthographic or phonological) and in meanings between primes and their targets. Several visual masked-priming experiments have consistently shown that there is an early decomposition of complex or seemingly complex words, regardless of whether the primes and the targets are semantically related to each other. The results from the visual masked priming experiment by Longtin et al. (2003) showed priming effects in the MS condition (e.g., *gaufrette* ‘wafer’ - GAUFRE ‘waffle’), the M condition (e.g., *fauvette* ‘warbler’ - FAUVE ‘wildcat’), and also the pseudo-M condition (e.g., *baguette* ‘little stick’, ‘baguette’ - BAGUE ‘ring’). On the other hand, the purely orthographically related condition (e.g., *abricot* ‘apricot’ - ABRI ‘shelter’) yielded no priming effects, unlike the other conditions. Similar results were reported in English (Beyersmann et al., 2016; Feldman et al., 2004; Marslen-Wilson et al., 2008; Rastle et al., 2000, 2004) and in Dutch (Diependaele et al., 2005, 2009). For instance, Rastle et al. (2004) found priming effects were for both Condition MS (e.g., *cleaner*-CLEAN) and Condition M/Pseudo-M (e.g., *department*-DEPART, *corner*-CORN). However, when the primes and the targets are merely related in forms with no pseudo-derived relation (e.g., *brothel*-BROTH), no priming effects were found. Such results suggest that early morphological decomposition occurs at the prelexical stage of visual word recognition. At this morpho-orthographic decomposition stage, complex and seemingly complex words are automatically decomposed, regardless of semantic transparency (Rastle et al., 2000; Rastle and Davis, 2008).

Apart from prelexical processing obtained from masked priming experiments with unconsciously perceived primes, overt priming was used as another method to explore the issue of semantic transparency and morphological effects. Contrary to the uniform results in masked priming studies, overt priming studies yielded mixed results. Various studies found semantic relatedness to be a precondition for morphological effects, as seen in French cross-modal priming and English visual priming results (e.g., priming effects obtained in *distrust*-TRUST but not *successor*-SUCCESS; see Feldman et al. 2004; Longtin et al. 2003; Marslen-Wilson et al. 1994; Rastle et al. 2000). In contrast to these findings, Smolka et al. (2014) and their previous study (Smolka et al., 2009) have found a clear morphological priming effects in German complex verbs in both visual (200 ms of prime; 300 stimulus onset asynchrony (SOA)) and cross-modal (with an inter-stimulus interval (ISI) of 1500 ms) overt priming experiments. Significant priming effects were present in the morphologically related condition (e.g., *entbinden* ‘deliver’ - BINDEN ‘bind’), but not in the semantically transparent but morphologically unrelated condition (*zuschnuren* ‘tie’ - BINDEN ‘bind’), and nor in the form related but morphologically unrelated condition (*abbilden* ‘depict’ - BINDEN ‘bind’).

With regards to purely auditory priming experiments, Bacovcin et al. (2017) explored IMP by avoiding the phonological relatedness confound. The targets in their four target conditions, BARE STEM (*snow*), PAST TENSE (*snowed*), PAST TENSE RHYME CONTROL (*code*), and EMBEDDED CONTROL (*grove*: embedded *grow*), each combined with the two constant primes, either RHYME prime (*dough*) or NON-RHYME prime (*void*). They found that only the BARE STEM and the PAST TENSE conditions yielded significant rhyme priming effects. Given such a carefully controlled experiment, their results support the IMP hypothesis that morphological processing is independent of phonological overlaps in the auditory modality. However, this study is limited to inflectional affix priming. Future studies of this type on stem priming or derivational affix priming, compared to other kinds of word formation, would further inform the IMP hypothesis.

Even though the mentioned issues are the most prominent in the literature, other fine-grained details have also been considered in morphological processing research. The above summary of literature hints on other distinctions to be made while exploring the literature on morphological processing, namely processing stage (prelexical versus lexical), modality (visual versus auditory versus cross-modal), and cross-linguistic differences (see Amenta and Crepaldi, 2012 for further review). The cross-linguistic differences stem from the fact that languages differ in their complexity of word-internal morphological structures. Some languages have concatenative morphology, with morphemes being ordered sequentially and continuously one after another (e.g., affixation *east-ern* or compounding *blue-bird*), while some have non-sequential, discontinuous integration of roots (e.g., transfixation *ZiMRa* 'singing' from the root *ZMR*, which relates to 'sing' in Hebrew). Even within the same word formation processes, experiments on different languages may also yield different results. This sparks off yet another debate on whether language-specific grammatical rules are required to explain the difference in cross-linguistic experiment results (Frost, 2012; Frost et al., 2005; Milin and Feldman, 2018; Smolka et al., 2014). A relevant issue is the interplay between morphological or lexical properties and these morphological processing models. Multimorphemic words may be represented or processed differently depending on many factors such as different affix types (inflectional versus derivational or prefix versus suffix), stem types (bound versus free), lexical category (noun, verb, etc.).

2.3.3 The abstractness of representations

Surface variations are inevitable in speech signals. An **abstract representation**, such as phoneme, morpheme, word, sentence, and meaning. may be expressed differently in each of its occurrence. Inter-speaker variations are always evident in speech, for each speaker has different pitch, vowel space, etc., specific to each person's identity. Their sociolinguistic variations, such as gender and dialectal variations, further contribute to the variability in speech signals across speakers. Intra-speaker variations are also difficult to control. Having the same person uttering the same abstract information rarely results in the exact same details in the speech signal. Factors such as duration, prosody, and emotion, are likely changed in each instance of speech. Such **token-specific** details may also be referred to as **episodic** information. While the word *episodic* is also used in the memory and processing model literature, this dissertation restricts its use to specific details in the speech signal, without explicitly assuming its association with 'episodic' memory.

Central questions about the topic include how we are able to abstract away from token-specific details and what kinds of information are stored in the mental representation of speech. Classical speech perception studies found that listeners divide acoustic continuum into clearly bounded phonemic categories, with abrupt shifts in perception from one category to another. Listeners are also able to discriminate phonemes better at their boundaries rather than in the middle of their category (Liberman et al., 1957). Such *categorical perception* of speech signal suggests that certain token-specific details are discarded through *speech normalization* (Mullennix et al., 1989) in order to perceive abstract representations. In contrast, *perceptual learning* studies have found that with training, listeners can learn to use phonetic details to alter their categorical perception boundaries (Eisner and McQueen, 2006; Kraljic and Samuel, 2005; Norris et al., 2005, among others). Acoustic details have also been shown to be imitated in shadowing experiments (Nielsen, 2011). The perceptual learning and shadowing studies suggests that episodic or token-specific details may still be retained for imitation or learned for shifting category boundaries. Models of speech perception and representation are concerned with these two contrary views on the effect of token-specific details (see Wilder, 2018). This dissertation makes use of the distinctions between abstract and token-specific information in the speech signal to investigate whether the Abstract Representation Difficulty Hypothesis holds at the phonological level. Previous studies on speech perceptual abilities in children with ASD are provided in Section 2.4.2.

2.3.4 Lexical processing and speech perception studies in Thai

While the auditory modality is the basic modality for language, most word recognition studies in Thai target the effects of Thai orthography on reading or visual-word processing. The past studies have specifically investigated the effects such as the writing of consonant, vowels, and tonal information (Winskel, 2011; Winskel et al., 2012; Winskel and Perea, 2014, among others), space between words (Kohsom and Gobet, 1997; Winskel et al., 2009). Studies on speech perception in Thai mainly deals with linguistic background and tonal perception (Burnham and Francis, 1997; Kaan et al., 2008; Schaefer and Darcy, 2014; Wayland and Guion, 2014, inter alia) or voice onset time (VOT) contrasts (Curtin et al., 1998; Gandour et al., 1986; Pater, 2003). None of the studies to date have been done on morphological or semantic effects or on the effects of tones on Thai lexical processing.

2.4 Lexical and auditory processing in children with autism

2.4.1 Lexical processing in autism

Lexical knowledge in the ASD literature mainly refers to the children's knowledge and conceptual understanding of words and vocabularies. Research on lexical processing in children and adolescents with autism largely focuses on the effects of semantics, with a limited number of studies on the effects of morphology. On the one hand, some studies show enhanced or comparable performance of children with ASD to TD children in lexical processing. In a study by Walenski et al. (2008), high-functioning children with autism (n = 21, all male, M full scale IQ = 106.52) and their TD controls (n = 53; 27 female, M IQ male = 116.69, M IQ female = 115.78) completed a picture naming task, containing 96 pictures of animals, tools, fruits, vegetables, and buildings. Overall, children with autism did not show significant differences in accuracy nor reaction time from both the control boys and girls. However, when only the low frequency words were taken into account, children with autism were found to respond significantly faster than the control boys, but not the girls.

Such enhanced effects reported in Walenski et al. (2008) were not found in other experimental reports on lexical processing. Yet, a few studies reported comparable performance in lexical decision tasks by children with ASD and TD children. Haebig et al. (2015) recruited children with ASD (n = 27; 4 females, M age = 9;6), children with SLI (n = 28; 14 females, M age = 10), and TD controls (n = 27; 4 females, M age = 9;1) to complete a continuous auditory lexical decision task of 40 disyllabic words and 40 disyllabic nonwords. Half of the tested items (20) in the task had dense 'semantic' networks, according to the University of South Florida Free Association Norms (Nelson et al., 1998)[2], while the other half had sparse networks. In their study, words with higher free association networks were found to increase the accuracy in the lexical decision task of the children in all the groups, with the least effects in the SLI group. The response times, however, did not differ between words with low or high scores on the norm. However, when matched with children with SLI on receptive vocabulary, children with ASD had faster response times to words with dense networks. Haebig et al. (2015) concluded that the similar results between the ASD, SLI, and TD groups support that the mechanisms underlying semantic processing across the three groups of children are comparable.

In a series of studies by Harper-Hill et al. (2014a,b), four lexical decision tasks were

[2]It is worth noting that what Haebig et al. (2015) referred to as 'semantic networks' are in fact not necessarily 'semantic'. The Free Association Norms (Nelson et al., 1998) were created by asking 6,000 participants 'to write the first word that came to mind that was meaningfully related or strongly associated' to each of the 5,019 stimulus words (An average of 149 (SD = 15) participants per 100-120 words). Free associations in this context, thus, include any kind of association, including phonetic associations like rhyming.

implemented to test semantic priming effects in different modalities. Harper-Hill et al. (2014a) explored the semantic priming paradigm with one experiment having (1) spoken word primes and spoken word targets and one having (2) written word primes and spoken word targets. Harper-Hill et al. (2014b) extended the same semantic priming paradigm to one experiment with (3) spoken word primes and written word targets and one with (4) written word primes and written word targets. All the experiments in Harper-Hill et al. (2014a,b) were administered to the same groups of children with ASD (n = 18; 4 females, M age = 11;10) and their TD controls (n = 14; 6 females, M age = 11;5) over multiple sessions. The first two experiments in Harper-Hill et al. (2014a) shared the same 36 critical prime-target pairs with half being related in category membership, e.g., dress-socks. and half being unrelated, while the last two experiments in Harper-Hill et al. (2014b) shared 30 pairs. Lexical decision was made only for the target words. Each experiment was conducted with a minimum period of 10 days after the previous session. Harper-Hill et al. (2014a) found that semantic relatedness facilitated response times and positively affects the accuracy in both the ASD and TD groups in the unimodal (auditory-auditory) experiment, but not in the cross-modal (visual-auditory) experiment. The results in Harper-Hill et al. (2014b) also showed that both ASD and TD children demonstrated modality-shift processing costs, with semantic priming effect being absent in the cross-modal (auditory-visual) experiment but present in the unimodal (visual-visual) experiment. Additionally, Harper-Hill et al. (2014b) found a three-way interactional effect between age, participant groups, and semantic relatedness in the unimodal written prime/target experiment. Their post-hoc analysis demonstrated that when both primes and targets were written words, semantic priming effects were only present in younger participants with ASD, and not in older participants with ASD or the younger and older TD groups. In this series of experiments, children with ASD demonstrated the same lexical processing efficiency as TD children with regards to semantic priming. In parallel, there is preliminary evidence for a written word processing advantage by children with ASD at a younger age and higher language competency and attentional capacities.

More recent studies explored whether children with ASD use semantic information in incremental language processing. A total of 26 Mandarin-speaking children with ASD (*M* age = 5;7) and 49 TD children (of which 25 are age-matched (*M* age = 5;7) and 24 are matched for Mean Length of Utterance and verbal IQ (*M* age = 4;7)) completed an eye-tracking study by Zhou et al. (2019). The study employed 8 target items in each of the two conditions. One condition is a 'bias' condition where the description contains semantic-constraining verbs (e.g., *read* a book), as opposed to the other 'neutral' condition with neutral verbs (e.g., *find* a book). Participants were instructed to simply listen to spoken sentences while looking at the pictures, which contain the target object and two other distractor objects. Children with ASD, along with their age-matched and verbal-IQ-matched TD peers, were found to equally exhibit anticipatory eye movement in the 'bias' verb condition. Venker et al. (2019) conducted a very similar study on 20 children with ASD, comparing the results among the children with ASD (*M* age = 4;8) without a TD control group. They also employed the two types of verbs in a looking-while-listening task. They found the semantic anticipation performance to be correlative with the children's overall receptive language skills, as measured by the Auditory Comprehension and Expressive Communication scales of the Preschool Language Scales, 5th Edition (PLS-5; Zimmerman et al., 2011). The findings in both studies suggest that a subgroup of children with ASD also employ information from the semantically constrained verbs in incremental language processing in a similar, i.e., not deviant, fashion as the TD children. There is further evidence from Venker et al. (2019) that such incremental language processing may be delayed in some group of children with ASD with lower overall language comprehension skills. This indicates that individuals with ASD can still be highly varied in their language skills and the incorporation of semantic information in their language processing.

While the above studies found semantic or lexical knowledge in children with ASD to be either enhanced or normal, many other studies on lexical processing in children with ASD pose a more complex picture, involving groups of children with ASD with lower performance than the TD controls. Kamio et al. (2007) recruited children and adolescents with ASD (n = 11; 2 females, M age = 14;3) and their TD controls (n = 11; 2 females, M age = 14;5) for a visual priming lexical decision task. During the task, primes were presented for 250 ms, followed by the presentation of targets for 4000 ms. The participants were instructed to read both the primes and targets but make a lexical decision only for the targets. The experimental prime conditions for targets (e.g., boat) include semantically closely-related primes (e.g., ship), semantically less-related primes (e.g., bike), phonologically rhymed primes (e.g., vote), and a control prime (++++). The participants with ASD were found to perform as accurately as the TD controls across conditions. Additionally, the participants with ASD did not differ in their RTs from the TD participants in any experimental condition. The priming effects for each condition was computed by subtracting the RTs of each condition from the RTs of the control condition. The semantic priming effects were found to be significant in the TD group, but not in the ASD group. The results seem to suggest poorer semantic processing in the ASD group compared to the TD groups. On the other hand, the priming effects were not present in the phonologically related condition in either of the participant groups. The absence of phonological priming effects in this study may be confounded by the visual presentation of the rhymed prime-target pairs, instead of an auditory presentation, undermining the rhyming nature of their relationship.

Speirs et al. (2011) compared the performance on masked priming lexical decision between children with high-functioning autism (n = 11; all male, M age = 14;11), children with Asperger's disorder (n = 11; all male, M age = 14;10), and typically-developing children (n = 11; all male, M age = 14;8). The task consists of 48 targets, each paired with 4 kinds of primes, including identity primes (e.g., blue), homophone primes (e.g., blew), orthographic control primes (e.g., blog), and all-letter-different primes (e.g., sand). Overall, identity priming effects (identity primes versus all-letter-different primes) were obtained in all the participant groups. No phonological priming effects (homophone primes versus orthographic control primes) were observed in any of the groups. However, for orthographic identity priming (identity primes versus homophone primes), significant effects were found in both the TD group and the Asperger's disorder group, while the high-functioning autism group did not display such effects. Instead, an orthographic similarity effect (orthographic control primes versus all-letter-different primes) was found to be significant for the high-functioning autism group, but not for the other groups. The lack of orthographic identity priming but the presence of orthographic similarity suggest that even though both Asperger's disorder and high-functioning autism are both on the spectrum, they may display different lexical processing patterns, with the high-functioning autism group having structurally different and possibly delayed lexical processing system.

Other basic lexical processing studies also indicate high variability in performances across individuals with ASD. Barone et al. (2019) explored basic spoken word comprehension across 11 semantic categories, including *animals, vehicles, toys, food and drink, clothing, body parts, furniture and rooms, household objects, outside things, people,* and *actions*. Children with ASD (n = 24; 5 females, M age = 43.5 months (range 24-61)) and their TD controls (n = 21; 3 females, M age = 31.4 months (range 21-42)) were recruited to take various standardized measures and a spoken word recognition task. In each trial, two pictures of the same semantic category were presented side by side for 5000 ms. The auditory stimulus matched with one of the images was then played within a carrier phrase "Look at the x". A total of 102 auditory stimuli were used in the study. Using an eye tracker, number and time of fixation on the target image after the word onset were used as an accuracy measure. In the TD group, a significantly higher proportion of children were in the group with over 60% accuracy rate and in the group with 50-60% accuracy rate, compared to in the group with lower than 50% accuracy rate. The proportion of children with ASD, on the other hand, did not differ across accuracy groups, suggesting a higher interindividual variability in word comprehension in the ASD group.

Similarly, an ERP study by DiStefano et al. (2019) sets out to investigate basic semantic processing in children with ASD in a non-priming paradigm. Both verbal (n = 15; 2 females, M age = 7;5) and minimally verbal (n = 18; 4 females, M age = 7;8) children with ASD in the age range of 5-11 years old were recruited, along with their age-matched TD controls (n = 18; 5 females, M age = 7;8). Using a picture-word matching paradigm, 60 visual stimuli were each presented for 500 ms before either matched or mismatched auditory stimuli were played. The results showed that the expected N400 effect for mismatched semantic information was equally present in both ASD groups, but with a longer latency than the TD group. This suggests that the children with ASD do process semantic information but at a slower rate. Previous ERP findings are inconsistent as to whether N400 effects are present in children with ASD or not (for absence of N400, see Cantiani et al., 2016; Dunn and Bates, 2005; McCleery et al., 2010; for intact N400, see Coderre, 2017; Fishman et al., 2011; Méndez et al., 2009). DiStefano et al. (2019) discussed that such inconsistent findings can be due to the heterogeneity across ASD individuals and sample sizes. In this study alone, the variability in all of the ERP measures across the ASD individuals was found to be substantial.

While most lexical processing studies on ASD deal solely with semantic processing, Riches et al. (2012) investigated both morpho-syntactic and semantic contribution to lexical comprehension by adolescents with SLI (n = 14; 1 female, M age = 15;4), children with autism with impaired language (ALI; n = 16; all male, M age = 14;8) and with normal language (ALN; n = 14; all male, M age = 15;3), and TD children (n = 17; 7 females, M age = 14;5). The study aimed at testing the children's comprehension of conventional noun-noun lexical compounds (LCs; e.g., sunglasses, raincoat), synthetic compounds (SCs; e.g., cat chaser, donkey kicker), and novel roots compounds (RCs; e.g., snail woman, monkey magazine). Using a picture selection task, the participants were asked to choose the picture that matched with the auditory stimuli, with the carrier phrase *It's/He's/She's a* + COMPOUND in the LC and RC conditions and the carrier phrase *Look at the* + COMPOUND in the SC condition. Each trial consisted of the correct picture and a distractor picture. In the LC and RC conditions, the distractor picture showed the two nouns in the compound with no relationship between them, whereas in the SC condition, the distractor picture showed a reversed order of thematic roles (e.g., for *cat chaser*, it showed a cat chasing something). Riches et al. (2012) found that the groups of adolescents with ALI and SLI, but not the TD and ALN groups, performed significantly less accurately in the SC condition compared to the LC and RC condition. Further analysis showed that while adolescents in other groups took significantly longer time to process the SC and RC conditions than the LC condition, both of the ASD groups's RTs were not affected by experimental conditions. The authors concluded that significantly poorer comprehension, as indicated by the lower accuracy, in the SC condition may be a marker for language impairment in adolescents with and without ASD. No difference across conditions in ASD could be attributed their generally slower RTs than other groups of participants. It is worth noting that the LC and RC conditions in this study involve only compounding in their word-formation process, whereas the SC condition also involves a derivational suffix *-er*, which first combined with verbs to form the nouns in the condition. Hence, my interpretation of their results is that the lower comprehension rate in the SC condition by both the ALI and SLI groups can be largely attributed to their failure at suffixing the verbal part of the second component of the compound, rather than compounding itself.

Other studies on morphological processing deal with non-lexical domains such as sentences to explore morphosyntactic processing in people with autism. For instance, grammaticality judgement tasks were used in such studies with mixed results. In Eigsti and Bennetto (2009), participants with autism of an age range from 9 to 17 years old (n = 21, M age = 13;5) and their matched TD controls (n = 22, M age = 13;4) were tested on their grammaticality judgement ability. A wide range of grammatical errors were included in the test, involving errors in past tense, aspect, pluralization, pronominal markers, determiners, auxiliaries, questions, and word order. Out of the 13 categories, the third-person singular, the progressive, and past tense marking were found to be the only types of errors to which participants with ASD were significantly less sensitive than the TD group. The ASD group was also found to have the significantly less performance sensitivity than the TD group when the errors occurred at the end of longer sentences with 10-11 words. These results suggest that there is subtle grammatical impairment in people with autism with a potential correlation with working memory. Weismer et al. (2017) further explored morphosyntactic processing and its relationship with nonverbal working memory. In their study, children with ASD (n = 27, M age = 9;7), children with SLI (n = 21, M age = 9;11), and TD children (n = 36, M age = 9;6) participated in a grammatical judgement task and a nonverbal working memory task. In the grammatical judgement task, participants were asked to listen to 56 sentences (28 ungrammatical and 28 grammatical) and determine their grammaticality. The ungrammatical sentences were mainly had errors involving the omission of grammatical morphemes, including regular past tense markers and auxiliary markers. The TD group was found to have significantly better performance than the SLI group. While the ASD group's performance is in between the TD and the SLI groups, it is not found to be significantly different from either group. This study further regrouped the children based on whether they had language impairment or not. The children with language impairment (n =30) were found to be less accurate and slower at error detection than the children with normal language (n =54). None of the groups differed in their performance on the nonverbal working memory task. In contrast to Eigsti and Bennetto (2009)'s study, however, this study found higher performance sensitivity and faster reaction times in detecting errors that occurred later in the sentences. With regards to the relationship between the performance of nonverbal working memory and morphosyntactic processing tasks, nonverbal working memory is predictive of the detection of later errors for the TD and ASD groups, but not predictive for the SLI group, possibly because of the lack of variance in performance sensitivity in the SLI group, as opposed to the heterogeneity of the other groups. This study's contradictory results to Eigsti and Bennetto (2009) led them to conclude that later errors may be easier to detect than earlier errors due to the higher availability of contextual information, decreasing the demand on working memory in sentence parsing as the sentence wraps up. The fact that these two studies found interesting differences based on sentence lengths suggests that even though words and phrases may not be theoretically distinguished in certain linguistic theories, concrete differences, such as length, may still play an important role in distinguishing between the two domains of mental processing. The results found in one domain may, thus, not generalize to the other.

In addition to the studies on school-aged children with ASD as described above, other studies in the ASD literature mostly reported semantic deficits in various forms, including difficulties understanding non-literal or figruative language such as metaphors and indirect speech (e.g., Chahboun et al., 2015; Tager-Flusberg, 2006; Vermeulen, 2001; Volden and Phillips, 2010; Vulchanova et al., 2015), difficulties understanding mental state verbs, e.g., think, know, wonder, (e.g., Baron-Cohen et al., 1994; Kazak, Collis, & Lewis, 1997; Kelley, Paul, Fein, & Naigles, 2006; Tager-Flusberg, 1992; Ziatas, Durkin, & Pratt,1998), difficulties drawing inferences (Losh & Capps, 2003; Norbury & Bishop, 2002), among others.

In sum, while consistent results in various studies suggest that children with ASD struggle with non-literal and less concete semantic information, the overall picture of research studies on basic lexical processing in ASD indicate high variability across individuals. The language performance by children with ASD in various studies suggests that there can potentially be at least two subgroups of children with ASD, even in the verbal population. With limited previous knowledge on the interaction between morphology and semantics in the lexical domain in children with autism, research in this area is needed to expand our knowledge on the broader linguistic abilities of children with ASD.

2.4.2 Speech perception and auditory processing in autism

Prior to the process of assigning of words to their meaning, the bases for lexical knowledge involve speech perception and segmentation. Compelling results on the topic were found in several studies relating lexical delays in autism with their enhanced sensitivity to auditory contrasts. Jones et al. (2009) tested 72 adolescents with autism (M age = 15;6) and 48 age- and IQ-matched controls (M age = 15;6) on their ability to discriminate the differences in frequency, intensity, and duration in pairs of sounds. No difference was found between the two groups. However, they found that a subgroup of 20% of the adolescents with ASD performed exceptionally well on frequency discrimination task with the score of 1.65 SDs above the mean of the control group. Additionally, these individuals with ASD had average IQ but a history of delayed first words. The results from this study are consistent with other reported findings that pitch discrimination ability is enhanced in children, adolescents, and adults with ASD with a history of delayed language onset (Bonnel et al., 2010; Eigsti and Fein, 2013).

While the above studies involve non-speech stimuli such as pure tones in their experiments, various studies compared between speech and non-speech stimuli to explore whether auditory sensitivity is limited to non-speech stimuli and whether there is a speech-specific deficit in categorical perception or not. Wang et al. (2017) employed lexical tone linguistic stimuli and harmonic non-speech stimuli in an ERP study with 16 Mandarin-speaking children with autism (M age = 10.4) and 15 TD controls (M age = 10.3). A 10-step lexical tone continuum was created for monosyllabic speech stimuli. Out of the 10 levels, three tones were chosen at Level 1, 5, and 9 to create a within-category pair (1 and 5) and a between-category pair (5 and 9). The two categories correspond with Tone 2 and Tone 4 in Mandarin. Non-speech stimuli were generated to match in fundamental frequency, amplitude, and duration to the speech stimuli. A total of 600 stimuli were presented using a passive oddball paradigm. Participants were instructed to watch a muted movie and ignore the presented auditory stimuli. The children with ASD were found to elicit significantly different Mismatch Response amplitudes between within-category and between-category conditions only in non-speech contexts, but not in speech contexts. The TD group, on the other hand, showed significantly different amplitudes between the two conditions in both speech and non-speech contexts. Similar ERP studies also investigated the children with ASD's neural sensitivity to lexical tones and pure tones. Yu et al. (2015) found that Mandarin-speaking children with autism (6-12 years) have enhanced neural sensitivity in the non-speech (pure tones) condition, but not in the speech (lexical tones) condition. Similarly, Zhang et al. (2019) compared between the pitch perception of speech and non-speech stimuli in Cantonese-speaking children with ASD (n = 16, M age = 10;5) and their TD controls (n = 16, M age = 9;6). They found that the TD controls showed stronger mismatch negativity responses than the children with ASD in the lexical tone condition. While they did not find enhanced neural sensitivity to non-speech stimuli in the ASD group as in Yu et al. (2015), they found similar mismatch negativity responses between the ASD and

TD groups. The results of these above studies demonstrate that the children with ASD have speech-specific categorical perception deficit, since non-speech stimuli yielded either normal or enhanced responses.

You et al. (2017) extended the research from pure tones and lexical tones to vowel and consonant continuum in French-speaking TD children (n = 19, M age = 10;4), children with ASD with normal language (n = 6, M age = 10;10), and language-impaired children with ASD (n = 10, M age = 10;6). In a categorical identification task, the children were asked to indicate which vowel (/i/ or /y/) or consonant (/b/ or/d/) they heard. In the categorical discrimination task, they were asked to answer whether two sounds they heard belonged to the same category or not. The ASD group performed significantly worse in the categorical identification task, but not in the categorical discrimination task. The authors then concluded that children with ASD struggle with categorical *precision*, rather than categorical *perception*, which may have not been teased apart in the earlier ERP studies. Huang et al. (2018) conducted an ERP study on vowel duration, which is not phonological in Mandarin, and pure tones with school-age Mandarin-speaking children with autism and TD children. Contrary to the previous studies, the deficit in the mismatch negativity responses is not restricted to speech signal. In fact, they found diminished mismatch negativity responses in pure tone condition, but not in the vowel length condition. This leads to their conclusion that the speech-specific deficits may be restricted to phonemic contrasts, instead of allophonic contrasts such as vowel length in Mandarin. While these two studies provide interesting remarks on the nature of categorical perception deficits in children with autism, more research is needed to reach a clear conclusion.

As for studies on adolescents and adults with ASD, Bonnel et al. (2003), among others, also found enhanced pitch sensitivity in non-speech stimuli. Chiodo et al. (2019), on the other hand, observed no reduced performance on the perception of speech stimuli in either the group of adults with ASD with or without a history of speech onset delay. Stewart et al. (2017) found categorical perception of the linguistic voice onset time contrast (/g/ vs /k/) to be on par between ASD and TD adults. Additionally, it was found to be correlated with their ability to read, lexical decision task performance, and verbal IQ.

All in all, a large group of studies observed categorical perception deficits in linguistic stimuli, but not in non-linguistic stimuli. The nature of categorical perception deficits and the improvement in their adulthood remain to be explored by future studies.

2.5 Experiments

This section reports the results from four experiments. The first two experiments (Experiment 1.1 and 1.2) share the theme of the processing of compounds. Experiment 2 asks whether there is an effect of stress and lexical tones on lexical processing. Experiment 3 expands to an inquisition into an effect of the voice switch between talker/gender on lexical processing. All of the experiments involve real-time processing tasks, using auditory stimuli. Before presenting the specific details of each experiment, the shared methods and analysis procedure between these four experiments are provided.

2.5.1 Shared methods

The auditory stimuli were recorded by me, a female native speaker of Standard Thai (age 25/26, Bangkok origin), in a sound-attenuated room using a Logitech h390 microphone with a sampling rate of 44.1kHz. Specifically for Experiment 3, additional stimuli were recorded by a male native speaker of Standard Thai (age 27, Bangkok origin). The experiments were run using the software PsychoPy2 (Peirce, 2007) on a 13" screen laptop with Intel Core i5, 2.19GHz processor. Participants responded using the keys z and m on the laptop keyboard, marked with brightly-colored stickers with a check mark and an X.

2.5.2 Shared data removal and analysis procedure

2.5.2.1 Subgrouping criteria

For the reliability of the main response time (RT; measured from the onset of the sound file) analysis, the children in both participant groups were subgrouped into two performance groups: Group 1 and Group 2. In their lexical decision tasks, Harper-Hill et al. (2014a,b) excluded both the TD and children with ASD with fewer than 60% of raw data points remaining after the removal of inaccurate responses and responses with extreme RTs. In this dissertation, this metric is used to separate the children into two groups. Group 1 comprises the children who have above 60% of the raw data points, including fillers, remaining after the removal of inaccurate and extreme responses. This group of children was included in both the accuracy analysis and the main RT analysis. In contrast, only the accuracy data were explored for the children in Group 2. Since Experiment 2 was embedded as fillers of Experiment 1.2 and vice versa, their two subgroups consist of the same participants. Details of the participants in each group are summarized in Table 2.1.

Table 2.1: Subgroups of participants in Experiment 1.1, 1.2, 2, and 3.

		Experiment 1.1		Experiment 1.2 and 2		Experiment 3	
		Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
N (Female N)	ASD	16 (4)	13 (1)	13 (2)	19 (1)	24 (0)	8 (0)
	TD	63 (13)	4(0)	41 (6)	18 (4)	58 (0)	1 (0)
M Age	ASD	9;11	8;9	10;5	9;1	9;6	10;1
	TD	8;10	6;9	8;5	6;11	8	5;7
M NVIQ	ASD	109.67	83.21	105.88	88.4	102.74	73.8
	TD	113.97	96.98	120.36	110.07	117.44	104.58

The adult participants are native speakers of Thai, demographically mixed, and they were recruited through personal contacts and word-of-mouth. All reported normal hearing and normal or corrected-to-normal vision. None of the adult participants scored lower than 70% in all of the experiments, therefore, no exclusion has been made. Table 2.2 shows the details for each of the experiments.

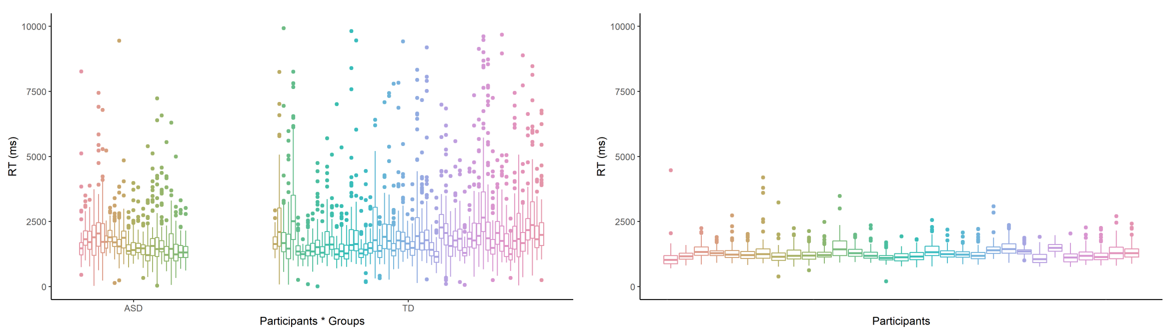
Table 2.2: Adult participants in Experiment 1.1, 1.2, 2, and 3.

	Experiment 1.1	Experiment 1.2 and 2	Experiment 3
N (Female N)	30(20)	42(27)	31(20)
M Age	34.77	36.53	37.81

2.5.2.2 Pre-analysis outlier treatment

After the overall accuracy percentages were obtained from the data, practice trials and fillers were removed. The remaining experimental trials were used for statistical analyses and models for accuracy. I adopted the outlier treatment methods by Baayen and Milin (2010), which allows for minimal initial data trimming before analyzing the RT data.

After the participants have been subgrouped, the child participants in Group 1 and the adult participants with over 70% accuracy (all of the adult participants) underwent the next steps of data trimming. Prime-target pairs of which the responses to *either* their prime *or* their target was incorrect were removed. Pairs with extreme RTs to either the prime or the target were then excluded. The cut-off points for extreme RTs were set differently for children and for adults. Figure 2.1 show the child versus adult individual raw RT distributions in the experimental trials of Experiment 3. For children, the extreme RTs were set to <200 and >5500 ms, while they were set to <250 and >3500 ms for adults.



(a) Children. (b) Adults.

Figure 2.1: A comparison between the child versus the adult individual distribution of raw RTs in the experimental trials of Experiment 3.

The remaining data were visualized and tested with the Shapiro-Wilk Test to determine the best transformation. The natural log transformation was found to be the best transformation for data sets of all of the RT experiments in this chapter. Afterwards, outlier trimmings were performed on each participant and on each item for which the distribution was not normal according to their Shapiro-Wilk results. In Experiments 1.1 and 1.2, outlier trimmings were performed only on the log-transformed target RTs. On the other hand, owing to the fact that Experiment 2 and 3 are repetition priming experiments where the difference between prime and target RTs are crucial to the calculation of priming effects, both the log-transformed target RTs and prime RTs were trimmed. Table 2.3 and 2.4 summarize the data trimming procedures and percentages of data removal before the final linear mixed regression models were fitted for each experiment.

Table 2.3: Percentages of data removal by experiment (Children in Group 1).

	Children in Group 1												
		Experiment 1.1			**Experiment 1.2**			**Experiment 2**			**Experiment 3**		
	Removal of Experimental Items	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed
1	Inaccurate responses to primes/target	3792	609	16.06%	2430	523	21.52%	2376	483	20.33%	4920	669	13.60%
	A-priori data trimming												
2	Extreme responses (<200 and >5500 ms) both primes and targets	3183	135	4.24%	1907	96	5.03%	1893	63	3.33%	4251	182	4.28%
3	Trimming by subject (target)	3048	77	2.53%	1811	49	2.71%	1830	54	2.95%	4069	63	1.55%
4	Trimming by item (target)	2971	47	1.58%	1762	19	1.08%	1776	26	1.46%	4006	46	1.15%
5	Trimming by subject (prime; If applicable)	NA	NA	NA	NA	NA	NA	1750	44	2.51%	3960	43	1.09%
6	Trimming by item (prime; If applicable)	NA	NA	NA	NA	NA	NA	1706	34	1.99%	3917	25	0.64%
	Total removal by a-priori data trimming		*259*	*8.14%*		*164*	*8.60%*		*221*	*11.67%*		*359*	*8.45%*
7	Model criticism	2924	58	1.98%	1743	38	2.18%	1672	44	2.63%	3892	91	2.34%

Table 2.4: Percentages of data removal by experiment (Adults).

	Adults												
		Experiment 1.1			***Experiment 1.2***			***Experiment 2***			***Experiment 3***		
	Removal of Experimental Items	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed	Initial data points	No. removed	% removed
1	Inaccurate responses to primes/target	1440	60	4.17%	1680	44	2.62%	1610	21	1.30%	1860	37	1.99%
	A-priori data trimming												
2	Extreme responses (<250 and >3000 ms) both primes and targets	1380	28	2.03%	1636	5	0.31%	1554	11	0.71%	1823	9	0.49%
3	Trimming by subject (target)	1352	29	2.14%	1631	20	1.23%	1543	31	2.01%	1814	11	0.61%
4	Trimming by item (target)	1323	35	2.65%	1611	4	0.25%	1512	5	0.33%	1803	3	0.17%
5	Trimming by subject (prime; If applicable)	NA	NA	NA	NA	NA	NA	1507	22	1.46%	1800	25	1.39%
6	Trimming by item (prime; If applicable)	NA	NA	NA	NA	NA	NA	1485	10	0.67%	1775	8	0.45%
	Total removal by a-priori data trimming		*92*	*6.67%*		*29*	*1.77%*		*79*	*5.08%*		*56*	*3.07%*
7	Model criticism	1288	26	2.02%	1607	41	2.55%	1475	28	1.90%	1767	36	2.04%

2.5.2.3 Modeling

Mixed effects logistic regression models were run separately on the accuracy data of children in Group 1, children in Group 2, and adults in each experiment, using the `lme4` package (Version 1.1.12; Bates et al. 2015) with the extension `lmerTest` package (Version 2.0.32;

for obtaining p-values; Kuznetsova et al. 2016) in the R software (Version 3.3.1; R Core Team 2016) and `MuMIn package` (Version 1.43.6; for obtaining marginal and conditional r-squared; Barton 2019). For logistic regression models, the `bobyqa` optimizer from the `minqa` package (Version 1.2.4; Bates et al. 2014) was applied. The default treatment coding scheme was used to compare between each categorical group. Baseline conditions and participant groups were re-leveled to obtain comprehensive pairwise comparisons of factors. Confidence intervals were reported at 95%. As for the RT data, a linear mixed-effects model was only applied to the children in Group 1 and the adults, using the same software and packages. For the RT data, post-fitting model criticism was performed to remove the outliers situating at least 2.5 standard deviations away from the mean in both tails. The results from the refitted models are presented in the next section.

2.5.3 Experiment 1: Processing of compounds

Thai is an *isolating language*. It has a very small number of morphemes per word and little affixation in inflectional morphology (Dryer, 2013). Word formation processes in Thai heavily rely on free Roots. Compounding is one of such processes, employing two or more free Roots to create a new word. The newly created words can be of different lexical categories or have unrelated meaning to the meaning(s) of their component(s). As seen in Examples 1-2, the meaning of some compound words are derived more transparently from one or both of their components (e.g., 1a, 2a) while some may be not as transparently related to their components.

(1) *Compound nouns*:

a. náːm (water)	hɔ̌ːm (fragrant)	=	nám-hɔ̌ːm	perfume
b. mɛ̂ː (mother)	lèk (iron)	=	mɛ̂-lèk	magnet
c. pàːk (mouth)	kaː (crow)	=	pàk-kaː	pen

(2) *Compound verbs*:

a. sàŋ (to order)	sɔ̌ːn (to teach)	=	sàŋ-sɔ̌ːn	to teach (someone a lesson)
b. jɯːn (to stand)	jan (to support)	=	jɯn-jan	to insist, to confirm
c. tɯ̀ːn (to wake up)	tên (to dance)	=	tɯ̀n-tên	to be excited/nervous

In this study, we explored the effects of semantic transparency on morphological priming, in the case where compounds are the prime. Experiment 1.1 (done in 2016) and Experiment 1.2 (2017) were both continuous lexical decision experiments with auditory priming that were aimed at examining the morphological and semantic effects on lexical access of Thai compound nouns and verbs.

2.5.3.1 Semantic association test and critical stimuli

Initially, candidate base verbs and nouns were selected along with their pairs in every condition. These bases are monosyllabic, monomorphomic, and have one dominant meaning.[3] All the selected words are appropriate for children.[4] Following Smolka et al. (2014), words in each candidate pair were first rated by native speakers (non-participants in the actual lexical decision experiment) for their semantic relationship on a scale from (1) completely unrelated to (7) highly related. Critical stimuli had to be rated higher than 4 for Conditions MS and S and lower than 3 for Conditions M. Additionally, the pairs in Conditions Ph and C also had to be rated lower than 3.

For Experiment 1.1, a total of 180 pairs were tested for semantic association so as to determine which candidates will be included in the critical set. Seventy-nine native speakers of Thai (55 females, M age = 34.9) were recruited for the semantic association test. A one-way ANOVA was used to test for the group difference in their mean ratings and

[3] All but eight bases take only one meaning. The eight bases have one dominant meaning but also some other meanings. However, we ensured that primes in Condition M are not semantically related to any meaning of the base. For instance, the base *tɔ̀ː* (‘extend’) can also mean ‘build’ in certain contexts. The prime of M type for this base, i.e., *tɔ̀ː-sûː* (‘fight’), was then chosen to avoid both meanings.

[4] While every item in the experiment was appropriate for children in terms of its politeness and sensitivity, the age of acquisition for those words is unknown. I attempted to choose relatively frequent and easy words as much as possible. Due to the limitation on the synonyms of basic nominal targets, nine primes in Condition S of Experiment 1.1 are words that are less commonly used, including highly formal or royal terms. The data trimming process should be able to account for some of the children’s difficulties in understanding the primes.

syllable lengths. The results showed a highly significant difference in mean ratings across prime types, $F(2{,}141) = 541$, $p < 0.001$. A Tukey's HSD Post Hoc Test was performed on the results, indicating that the MS and S conditions are not significantly different from each other (p=0.997), while the M condition differs from both MS ($p < 0.001$) and S ($p < 0.001$) conditions. Mean syllable lengths also show no significant difference across conditions ($F(2{,}141) = 0.234$, p=0.792). This holds true for every pair of conditions in the post-hoc test.

For Experiment 1.2, additional 140 pairs were rated by 51 adult Thai native speakers (33 females, M age = 33.04). The semantic association ratings are highly significant across conditions ($F(3{,}176) = 699.1$, $p < 0.001$). The post-hoc test revealed significant differences for every pair of conditions ($p < 0.001$), except for Ph-C conditions (p=0.998). Moreover, all the conditions are not significantly different on mean syllable lengths ($F(3{,}176) = 1.241$, p=0.296), with no difference between any pairs in the post-hoc test. Mean ratings for the critical pairs in Experiment 1.1 and 1.2 are shown in Table 2.5.

All of the stimuli in Experiment 1.1 and 1.2 are listed in Appendix A.

Table 2.5: Stimulus characteristics of primes and targets in Experiment 1.1 and 1.2.

	Experiment 1.1		Experiment 1.2	
	Syllable length	Relatedness score	Syllable length	Relatedness score
Target	1 (0; 1-1)	-	1 (0; 1-1)	-
MS	2.02 (0.14; 2-3)	5.87 (0.61; 4.1-6.8)	2.02 (0.15; 2-3)	5.77 (0.62; 4.1-6.63)
M	2.02 (0.14; 2-3)	2.24 (0.43; 1.5-3.1)	2 (0; 2-2)	2.15 (0.39; 1.54-2.9)
S	2.06 (0.56; 1-4)	5.89 (0.79; 4.3-6.9)	-	-
Ph	-	-	2.04 (0.21; 2-3)	1.63 (0.51; 1-2.85)
C	-	-	2 (0; 2-2)	1.62 (0.48; 1-2.75)

Note: The numbers presented are *mean (SD: range)*.

2.5.3.2 Fillers

Both experiments contain fillers randomly paired with each other to prevent the strategic effect. Fillers comprised of words fillers, which are semantically unrelated to the test set, and nonwords. Nonwords were created by replacing the consonant(s), vowel(s), or tone(s) of real words, while conforming to the phonotactics of Thai. The number of syllables and lexical stress serve as a cue to the morphological structure of the nonwords. The ratio of the number of syllables in the word stimuli and the nonword stimuli is balanced, i.e., same ratio of monosyllabic, disyllabic, etc. for both words and nonword stimuli. Characteristics of fillers in Experiment 1.2 are the same as those in Experiment 1.1. One major difference between the fillers of the two experiments is that 65% of the word fillers in Experiment 1.2 are an embedded experiment on sensitivity to full/neutralized tones in unstressed syllables (Experiment 2).

After the fillers were added, the proportion of the critical primes and targets to the whole set of stimuli were reduced to 30% in Experiment 1.1 and 25% in Experiment 1.2. The proportion of semantically-related primes and targets to the entire set of stimuli were reduced to 20% in Experiment 1.1 (including Condition MS and S) and 25% in Experiment 1.2 (Condition MS and all the stimuli in the embedded Experiment 1.2), while that of morphologically-related items to the entire material was reduced to 20% in Experiment 1.1 (Condition MS and M) and 30% in Experiment 1.2 (Condition MS, M, and all the stimuli in the embedded Experiment 1.2).

2.5.3.3 Stimuli and procedure

A target noun or verb was paired with primes of different types. The relationship between primes and targets varies across conditions. Experiment 1.1 consisted of the morphologically-and-semantically related condition (MS), the morphologically-related condition (M), and the semantically-related condition (S). Experiment 1.2 comprised the MS condition, the M condition, the phonologically-related condition (Ph), where the first element of the prime rhymes, i.e., sharing vowels, codas, and tones[5], with the target, and the control condition (C), where primes and targets were not related in any way. Example test items are provided in Table 2.6. The differences between Experiment 1.1 and 1.2 are summarized in Table 2.7.

The primes are compound words, with the exception of eleven monomorphemic nominal primes in Condition S. The prime-target pairs were distributed across lists, according to the Latin Square design, such that each target appeared only once in each list. Each list contained the same number of stimuli from every priming condition, which were distributed across eight blocks. Each participant participated in only one experimental list.

Table 2.6: Example test items.

Target	**MS**	**M**	**S**	**Ph**	**C**
lâw 'tell'	lâw khǎːn 'tell (a story)' < 'tell' + 'cry out'	lâw riːan 'study' < 'tell' + 'study'	bɔ̀ːk klàːw 'notify' < 'tell' + 'say'	k^{h}âw caj 'understand' < 'enter' + 'heart'	dɯ̀ːm dàm 'indulge' < 'drink' + *NA*
klàn 'sift, distill'	klàn krɔːŋ 'screen' < 'distill' + 'filter'	klàn klɛːŋ 'mistreat', 'defame' < 'distill' + 'tease'	hɯ̀ːat ra-hɤ̌ːj 'evaporate'< 'dry up' + 'evaporate'	pàn pùːan 'be frantic/chaotic' < 'shake' + 'cause turmoil'	k^{h}wîːaŋ t^{h}íŋ 'throw away' < 'throw' + 'dump'
p^{h}ráʔ 'monk'	p^{h}ráʔ-sǒŋ 'monk' < 'monk' + 'monk'	p^{h}ráʔ-ʔèːk 'leading actor' < 'monk' + 'one'	nák bùaːt 'priest' < 'expert' + 'ordain'	fák fɛːŋ 'gourd' < 'gourd' +'cucurbita pepo'	lín c^{h}ák 'drawer' < 'tongue' + 'pull'
náːm 'water'	náːm taː 'tear' < 'water' + 'eye'	náːm taːn 'sugar', 'brown' < 'water' + 'palm'	k^{h}ɔ̌ːŋ lěːw 'liquid' < 'thing' + 'liquidy'	klâːm nɯːa 'muscle' < 'muscle' + 'meat'	k^{h}oːm faj 'lamp' < 'lamp' + 'fire'

Note: Experiment 1.1 includes Conditions MS, M, and S, while Experiment 1.2 includes Conditions MS, M, Ph, and C. In each condition, the IPA transcription is provided on the first line. The meaning of the entire compound is provided on the second line, while the meaning of each component is on the third line.

Table 2.7: Design differences between Experiment 1.1 and 1.2.

	Experiment 1.1	Experiment 1.2
ISI	800-900 ms	400-600 ms
Conditions:	MS, M, and S	MS, M, Ph, and C
Test items:	144 pairs over 3 lists (48 pairs per list; 16 pairs per list per condition) - 26 target nouns - 22 target verbs	180 pairs over 4 lists (45 pairs per list; 11-12 pairs per condition) - 24 target nouns - 21 target verbs
Fillers:	30% Test items 40% Non-word fillers 30% Word fillers	20% Test items 50% Non-word fillers 30% Word fillers

The experiment began with 10 practice trials. During the session, a fixation cross

[5] Five words in Condition Ph do not have a complete rhyme, but they differ in no more than one additional element.

appeared at the center of the screen. Each auditory stimulus was presented through child-friendly/adult headphones with an interstimulus interval (ISI) of 800-900 ms in Experiment 1.1 and 400-600 ms in Experiment 1.2. The instruction was given both verbally and on the screen. Participants were asked to press the button with a check mark with their dominant hand, when they heard a sound they understood or had heard being used in the language, or press the other button when they heard a sound which was nonsense or had not been heard being used in the language. They were also instructed to do so as accurately and as fast as possible. No feedback was given after each trial. The experiment lasted approximately 25 minutes with three self-administered breaks.

2.5.3.4 Modeling

For the accuracy models, run only on the child data, the data were subset based on the *performance group* (Group 1 or Group 2). Using the same factors, the accuracy models for each performance group were run separately. Both models contained 11 fixed effects factors, including *prime condition* (MS, M, or S for Exp1.1 and MS, M, Ph, or C for Exp1.2), *word type* (noun or verb; average across word types on the intercepts), *z-scored duration of target*, *z-scored trial number*, *z-scored interstimulus interval* (ISI; measured in ms), *prime accuracy* (average on the intercept), *log-transformed RTs to primes*, *participant group* (ASD or TD), *z-scored Ravens nonverbal IQ*, *z-scored age*, and *gender* (average across genders on the intercepts). Moreover, the interactions between *prime condition* and *participant group*, along with two random effects factors (random intercepts for participants and items) were also included in the models. For the effect of prime condition and participant group, dummy coding was used to relevel to the desired baseline.

The reaction time models contained 10 fixed effects factors for the child data and 8 factors for the adult data, using the same contrast coding schemes. The factors include *prime condition*, *word type*, *z-scored duration of target*, *z-scored trial number*, *z-scored ISI*, *log-transformed RTs to primes*, *participant group* (only for the child data), *z-scored NVIQ* (only for the child data), *z-scored age*, and *gender*. Interactional effects were coded between *prime condition* and *participant group* in the child data. Two random effects factors of participants and items were also included in the models.

2.5.3.5 Results: Experiment 1.1 and 1.2

2.5.3.5.1 Accuracy

Mean accuracy per prime-target relationship and participant groups of both Experiment 1.1 and Experiment 1.2 is detailed in Table 2.8. No logistic regression models were performed on the adult accuracy data due to little variance in accuracy across experimental conditions.

Table 2.8: Accuracy percentages by condition in Experiment 1.1 and 1.2.

	Accuracy (%)										
	Condition	Adults		Group 1				Group 2			
				ASD		TD		ASD		TD	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Exp1.1	M	97.76	5.19	92.02	9.72	95.84	5.18	71.2	24.45	68.28	15.85
	MS	98.98	2.33	90.63	9.9	96.53	5.87	67.36	22.1	72.58	22.37
	S	96.13	7.29	89.89	15	95.95	5.75	72.11	20.11	59.66	22.74
Exp1.2	C	97.93	4.57	82.87	12.47	81.04	13.70	70.61	28.06	65.15	24.51
	M	99.39	2.90	94.52	8.56	89.84	12.29	54.74	32.02	69.91	23.19
	MS	100.00	0.00	93.12	9.90	91.33	10.07	60.81	28.23	72.56	28.98
	Ph	94.75	7.36	94.46	6.95	84.61	12.85	57.26	29.66	68.64	31.47

As an overall data visualization, Figure 2.2 presents mean accuracies for Experiment 1.1, showing the performance of the four subgroups of children (ASD/TD by Performance group 1/2) in the morphologically related condition (M), the morphologically and semantically related condition (MS), and the semantically related condition (S). The children in performance group 1 of Experiment 1.1 exhibited similar accuracy rates across conditions, while the children in performance group 2 show more variance across conditions. Figure 2.3 shows mean accuracies for Experiment 1.2, including the control condition (C), the M condition, the MS condition, and the phonologically related condition (Ph). Overall, the accuracy rates are the lowest in the control condition for both the children with ASD and the TD children in Group 1. As for the TD children in Group 2, even though the accuracy rates are lower than those of Group 1, a similar pattern of accuracy levels remains, with the control condition having the lowest accuracy. The children with ASD in Group 2, on the other hand, had the highest accuracy rates in the control condition.

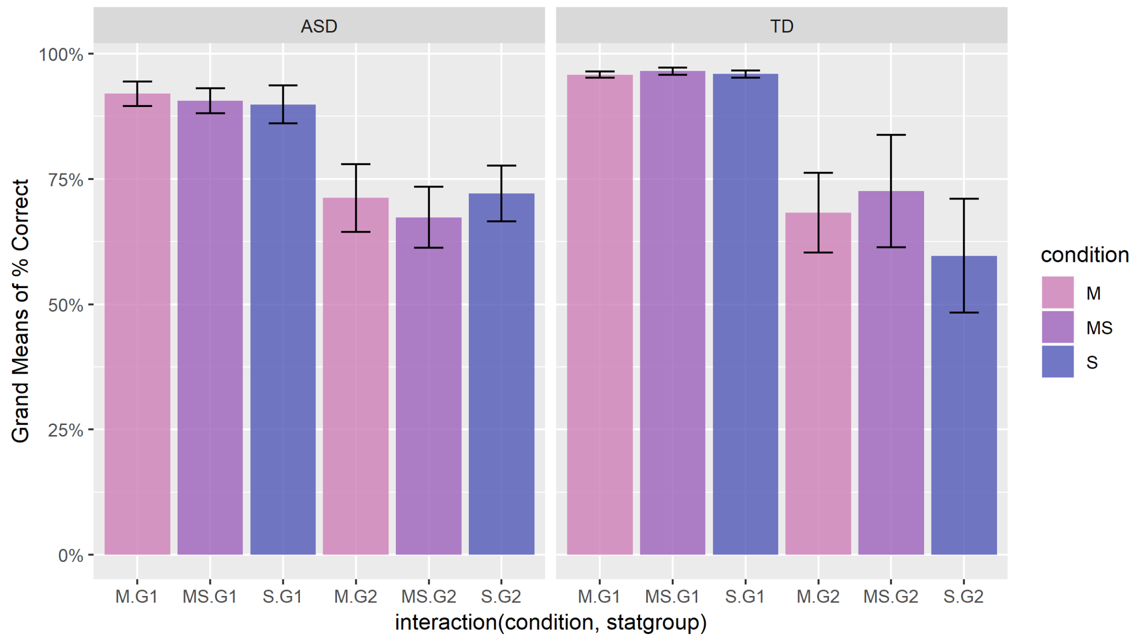


Figure 2.2: Experiment 1.1 - Mean target accuracies for each condition (M/MS/S) by participant (ASD/TD) and performance groups (Group 1/Group 2).

Experiment 1.1: According to the logistic regression model for accuracy as summarized in Table 2.9, children with ASD in Group 1 showed no significant difference in the accuracy in Condition MS, compared to the other two conditions (Condition M: β=0.259, p=0.448; Condition S: β=0.012, p=0.969). The same model with the TD children in Group 1 as the reference level also yields similar results that the accuracy in Condition MS is not different from that in Condition M (β=-0.221, p=0.600) nor in Condition S (β=-0.687, p=0.090). Compared with the TD children, children with autism have significantly lower accuracy rates in the MS condition (β=1.097, $p<0.01$) and the S condition (β=1.094, $p<0.01$), but performed on par with the TD group in the M condition (β= 0.699, p=0.078).

On average for all the children in Group 1, both NVIQ (β=0.336, $p<0.01$) and age (β=0.273, p=0.047) are found to significantly affect accuracy. Gender yields a significant effect, with female children having higher accuracy (β=0.758, p=0.035). Prime accuracy is a highly significant predictor for target accuracy (β=0.931, $p<0.001$). Longer ISIs seem to significantly lower the accuracy (β=-0.194, p=0.017). Other factors have not been found to

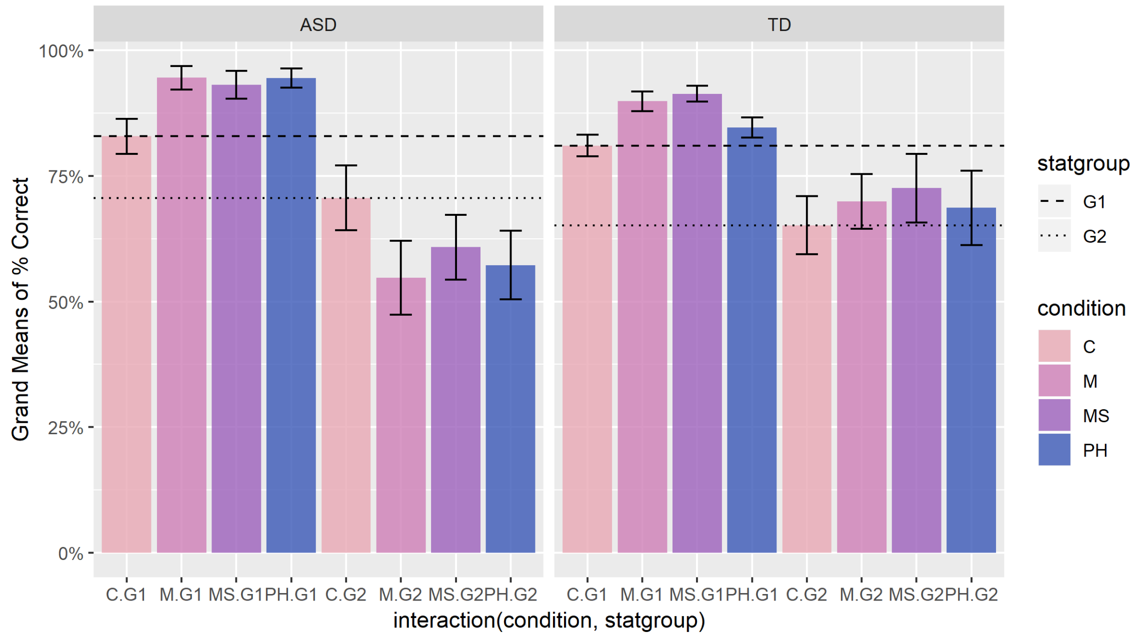


Figure 2.3: Experiment 1.2 - Mean target accuracies for each condition (C/M/MS/Ph) by participant (ASD/TD) and performance groups (Group 1/Group 2), with reference lines at the control condition.

be significant.

As for the children with ASD in Group 2, Condition MS had less accurate performance, but not significantly less accurate, than the other two conditions (Condition M: β=0.258, p=0.275; Condition S: β=0.278, p=0.243). The TD children in Group 2 performed the most accurately in the MS condition but not significantly different from the other two conditions (Condition M: β=-0.221, p=0.600; Condition S: β=-0.687, p=0.090). With an exception of the prime accuracy, which positively affect the target accuracy (β=0.536, p<0.01), other factors seemed irrelevant in the performance of the children in Group 2. However, one major takeaway on the difference between the ASD and TD groups lie in the pattern of accuracy rates across conditions. While the children with ASD of Group 2 performed the most accurately in the S condition and the least accurately in the MS condition, the opposite pattern is found in the TD children of Group 2. Given such reversed performance, the interactional effect between participant groups and experimental conditions showed that the difference between the accuracy of the MS condition and that of the S condition

Table 2.9: Experiment 1.1: Summary of the accuracy model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: MS, ASD)	1.979	0.399	1.196	2.762	**<.001**
Prime condition					
MS vs M in ASD	0.259	0.341	-0.410	0.928	0.448
MS vs S in ASD	0.012	0.323	-0.621	0.646	0.969
MS vs M in TD	-0.221	0.422	-1.048	0.606	0.600
MS vs S in TD	-0.687	0.405	-1.480	0.106	0.090
Word type (Noun vs Verb)	-0.195	0.212	-0.611	0.222	0.360
Duration of target	0.009	0.106	-0.199	0.217	0.932
Trial number	-0.059	0.104	-0.264	0.146	0.574
ISI	-0.194	0.081	-0.353	-0.034	**0.017**
Prime accuracy (Correct vs Incorrect)	0.931	0.183	0.572	1.289	**<.001**
Log-transformed prime RT	0.010	0.076	-0.140	0.160	0.898
Participant group (ASD vs TD; Cond. M)	0.699	0.397	-0.079	1.477	0.078
Participant group (ASD vs TD; Cond. MS)	1.097	0.392	0.329	1.865	**<.01**
Participant group (ASD vs TD; Cond. S)	1.094	0.381	0.347	1.842	**<.01**
NVIQ	0.336	0.122	0.096	0.576	**<.01**
Age	0.273	0.137	0.004	0.543	**0.047**
Gender (Female vs Male)	0.758	0.359	0.054	1.461	**0.035**
Prime cond. x Participant Group					
(MS vs M) x (ASD vs TD)	-0.398	0.481	-1.217	0.422	0.341
(MS vs S) x (ASD vs TD)	-0.003	0.405	-0.797	0.792	0.995
N Primes	144				
N Targets	48				
N Subjects	79				
N Datapoints	3792				
Marginal R^2 / Conditional R^2	0.132 / 0.305				
Δ Marginal R^2 / Δ Conditional R^2	0.027 / 0.062				

Note: The baseline is the first argument in the above scheme (x vs y).

significantly differ across participant groups (β=-0.965, p=0.04). The accuracy model for the children in performance group 2 of Experiment 1.1 is summarized in Table 2.10.

Experiment 1.2: According to the logistic regression accuracy models for the children with ASD in Group 1 as shown in Table 2.11, the accuracy rates for the control condition are significantly lower than all the other three conditions (Condition M: β=1.411, p=0.001; Condition MS:β=1.098, p<0.01; Condition Ph: β=1.359, p=<0.01). No significant difference in accuracy rates was found between Condition M and Condition MS (β=-0.313, p=0.529) nor Condition Ph (β=-0.052, p=0.921) in the ASD group. The TD children in

Table 2.10: Experiment 1.1: Summary of the accuracy model for the children in Group 2.

Performance group: Group 2

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: MS, ASD)	0.782	0.690	-0.570	2.134	0.257
Prime condition					
MS vs M in ASD	0.258	0.236	-0.205	0.721	0.275
MS vs S in ASD	0.278	0.239	-0.189	0.746	0.243
MS vs M in TD	-0.221	0.422	-1.048	0.606	0.600
MS vs S in TD	-0.687	0.405	-1.480	0.106	0.090
Word type (Noun vs Verb)	0.069	0.171	-0.265	0.404	0.684
Duration of target	0.071	0.085	-0.095	0.237	0.403
Trial number	-0.080	0.085	-0.247	0.088	0.350
ISI	-0.024	0.086	-0.192	0.144	0.778
Prime accuracy (Correct vs Incorrect)	0.536	0.182	0.179	0.893	**<0.01**
Log-transformed prime RT	0.049	0.087	-0.121	0.218	0.575
Participant group (ASD vs TD; Cond. M)	-0.327	0.775	-1.846	1.192	0.673
Participant group (ASD vs TD; Cond. MS)	1.152	0.775	-1.366	1.670	0.845
Participant group (ASD vs TD; Cond. S)	-0.152	0.775	-1.670	1.366	0.845
NVIQ	0.100	0.294	-0.477	0.676	0.735
Age	-0.027	0.379	-0.770	0.716	0.943
Gender (Female vs Male)	0.295	1.094	-1.850	2.440	0.787
Prime cond. x Participant Group					
(MS vs M) x (ASD vs TD)	-0.479	0.484	-1.427	0.470	0.323
(MS vs S) x (ASD vs TD)	-0.965	0.470	-1.886	-0.044	**0.040**
N Primes	144				
N Targets	48				
N Subjects	17				
N Datapoints	816				
Marginal R^2 / Conditional R^2	0.032 / 0.237				
Δ Marginal R^2 / Δ Conditional R^2	0.024 / 0.178				

Note: The baseline is the first argument in the above scheme (x vs y).

Group 1 also had the lowest accuracy rates in the control condition, being significantly different from Condition M (β=0.833, p<0.001) and Condition MS (β=1.015, p<0.001), but not from Condition Ph (β=0.270, p=0.152). Similar to the children with ASD, the TD children also did not perform significantly differently in Condition M, compared to Condition MS (β=0.182, p=0.439). However, they performed significantly less accurately in the Ph condition than the M condition (β=-0.563, p<0.01). While the children with ASD and the TD children performed on par in accuracy for each individual condition, the accuracy rate of the Ph condition was significantly more different from that of the control condition in the ASD group, compared to the TD group in performance group 1 (β=-1.089, p=0.022), according to the interactional effect between prime condition and participant group.

Apart from experimental conditions, age was also found to play a highly significant role on the average performance of both groups (β=0.492, p<0.001). Other factors with significant effects on accuracy are word type, with verbs yielding lower accuracy rates (β=-0.785, p=0.001), and the prime accuracy (β=0.532, p<0.001).

The children with ASD in Group 2 displayed a deviant pattern of accuracy across conditions. While the other groups of children, including the TD children in Group 2, scored the lowest in the control condition, the children with ASD in Group 2 scored the highest in the control condition. The logistic regression model on their accuracy, summarized in Table 2.12, exhibited significantly higher accuracy rates in the control condition than all the other conditions (Condition M: β=-0.958, p<0.001, MS: β=-0.622, p=0.012, and Ph: β=-0.824, p=0.005). In contrast, for the TD children in Group 2, the accuracy in the control condition was not significantly different from other conditions, with a similar pattern of accuracy as that of the TD children in Group 1. Moreover, the interactional effects between experimental conditions and participant groups reveal that the children with ASD and the TD children in Group 2 performed at significantly different accuracy rates in Condition C, compared to Condition M (β=1.251, p<0.001), MS (β=1.096, p<0.01), and Ph (β=1.044, p<0.01). Other significant factors for all the children in Group 2 are NVIQ (β=0.746, p<0.01) and word type, with nouns yielding more accuracy than verbs (β=-0.296, p=0.025).

2.5.3.5.2 Response time

Both Experiments 1.1 and 1.2 employed within-target designs, keeping the targets constant across experimental conditions. Therefore, the reaction times to the targets of each condition are directly compared in the RT analysis. The RT analysis is performed only on the adult data and the child data in performance group 1 for reliability of the results. Average response times for each condition are presented in Table 2.13.

Experiment 1.1: Figure 2.4 presents the distribution of log-transformed target RTs of

Table 2.11: Experiment 1.2: Summary of the accuracy model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: C, ASD)	1.426	0.356	0.728	2.125	**<.001**
Prime condition					
C vs M in ASD	1.411	0.436	0.557	2.265	**0.001**
C vs MS in ASD	1.098	0.409	0.296	1.899	**<.01**
C vs Ph in ASD	1.359	0.437	0.502	2.217	**<.01**
M vs MS in ASD	-0.313	0.497	-1.288	0.661	0.529
M vs Ph in ASD	-0.052	0.520	-1.071	0.968	0.921
C vs M in TD	0.833	0.207	0.428	1.239	**<.001**
C vs MS in TD	1.015	0.215	0.595	1.436	**<.001**
C vs Ph in TD	0.270	0.189	-0.100	0.641	0.152
M vs MS in TD	0.182	0.235	-0.279	0.643	0.439
M vs Ph in TD	-0.563	0.213	-0.979	-0.146	**<.01**
Word type (Noun vs Verb)	-0.785	0.244	-1.263	-0.306	**0.001**
Duration of target	0.080	0.120	-0.156	0.316	0.505
Trial number	-0.179	0.100	-0.376	0.018	0.075
ISI	-0.005	0.066	-0.135	0.125	0.943
Prime accuracy (Correct vs Incorrect)	0.532	0.152	0.234	0.830	**<.001**
Log-transformed prime RT	0.115	0.062	-0.006	0.236	0.062
Participant group (ASD vs TD; Cond. C)	0.410	0.326	-0.230	1.049	0.210
Participant group (ASD vs TD; Cond. M)	-0.168	0.446	-1.042	0.705	0.706
Participant group (ASD vs TD; Cond. MS)	0.327	0.425	-0.506	1.160	0.441
Participant group (ASD vs TD; Cond. Ph)	-0.679	0.439	-1.540	0.182	0.122
NVIQ	-0.010	0.068	-0.142	0.123	0.886
Age	0.492	0.106	0.283	0.700	**<.001**
Gender (Female vs Male)	-0.080	0.256	-0.582	0.421	0.754
Prime cond. x Participant Group					
(C vs M) x (ASD vs TD)	-0.578	0.480	-1.519	0.363	0.229
(C vs MS) x (ASD vs TD)	-0.082	0.460	-0.985	0.820	0.858
(C vs Ph) x (ASD vs TD)	-1.089	0.475	-2.019	-0.159	**0.022**
(M vs MS) x (ASD vs TD)	0.495	0.549	-0.581	1.572	0.367
(M vs Ph) x (ASD vs TD)	-0.511	0.561	-1.611	0.589	0.363
N Primes	180				
N Targets	46				
N Subjects	54				
N Datapoints	2430				
Marginal R^2 / Conditional R^2	0.163 / 0.292				
Δ Marginal R^2 / Δ Conditional R^2	0.071 / 0.128				

Note: The baseline is the first argument in the above scheme (x vs y).

the adults with a combined box and density plot. The children's response time distribution is provided in Figure 2.5. Generally, the adults' response times are faster than the children's

Table 2.12: Experiment 1.2: Summary of the accuracy model for the children in Group 2.

Performance group: Group 2

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: C, ASD)	2.189	0.558	1.096	3.281	**<.001**
Prime condition					
C vs M in ASD	-0.958	0.245	-1.438	-0.477	**<.001**
C vs MS in ASD	-0.622	0.247	-1.106	-0.137	**0.012**
C vs Ph in ASD	-0.824	0.246	-1.305	-0.342	**<.001**
M vs MS in ASD	0.336	0.232	-0.119	0.791	0.148
M vs Ph in ASD	0.134	0.230	-0.317	0.585	0.561
C vs M in TD	0.293	0.247	-0.191	0.777	0.236
C vs MS in TD	0.475	0.251	-0.018	0.967	0.059
C vs Ph in TD	0.221	0.247	-0.263	0.704	0.371
M vs MS in TD	0.182	0.253	-0.314	0.677	0.473
M vs Ph in TD	-0.073	0.249	-0.561	0.416	0.771
Word type (Noun vs Verb)	-0.296	0.132	-0.554	-0.038	**0.025**
Duration of target	-0.045	0.066	-0.175	0.084	0.494
Trial number	0-0.004	0.064	-0.130	0.122	0.951
ISI	0.097	0.062	-0.024	0.218	0.115
Prime accuracy (Correct vs Incorrect)	-0.022	0.135	-0.286	0.242	0.871
Log-transformed prime RT	0.052	0.069	-0.083	0.187	0.450
Participant group (ASD vs TD; Cond. C)	-0.835	0.661	-2.131	0.462	0.207
Participant group (ASD vs TD; Cond. M)	0.416	0.656	-0.870	1.702	0.526
Participant group (ASD vs TD; Cond. MS)	0.262	0.659	-1.030	1.553	0.691
Participant group (ASD vs TD; Cond. Ph)	0.210	0.657	-1.078	1.497	0.750
NVIQ	0.746	0.258	0.242	1.251	**<.01**
Age	0.601	0.349	-0.082	1.284	0.085
Gender (Male vs Female)	31.384	0.765	-0.116	2.884	0.070
Prime cond. x Participant Group					
(C vs M) x (ASD vs TD)	1.251	0.347	0.570	1.931	**<.001**
(C vs MS) x (ASD vs TD)	1.096	0.351	0.407	1.785	**<.01**
(C vs Ph) x (ASD vs TD)	1.044	0.348	0.361	1.727	**<.01**
(M vs MS) x (ASD vs TD)	-0.154	0.344	-0.828	0.519	0.653
(M vs Ph) x (ASD vs TD)	-0.207	0.339	-0.870	0.457	0.542
N Primes	180				
N Targets	46				
N Subjects	37				
N Datapoints	1665				
Marginal R^2 / Conditional R^2	0.152 / 0.477				
Δ Marginal R^2 / Δ Conditional R^2	0.130 / 0.409				

Note: The baseline is the first argument in the above scheme (x vs y).

in all of the condition, having less variance in the distribution. This raw data visualization should be interpreted with caution. Refer to the corresponding models for significance

Table 2.13: Average response times by participant by condition in Experiment 1.1 and 1.2.

	Reaction Times (Milliseconds)						
	Condition	Adult		ASD		TD	
		weighted M	*weighted SD*	*weighted M*	*weighted SD*	*weighted M*	*weighted SD*
Exp1.1	MS	881.00	138.11	1280.01	278.72	1364.71	226.71
	M	921.52	149.52	1301.27	278.23	1368.23	218.5
	S	953.75	111.07	1321	278.02	1410.26	270.69
Exp1.2	MS	834.48	86.33	1130.23	244.31	1169.88	235.98
	M	901.19	88.68	1168.41	182.54	1309.70	268.68
	Ph	1001.38	110.61	1475.56	325.84	1412.64	241.95
	C	1021.39	105.12	1351.74	206.01	1366.46	243.65

levels.

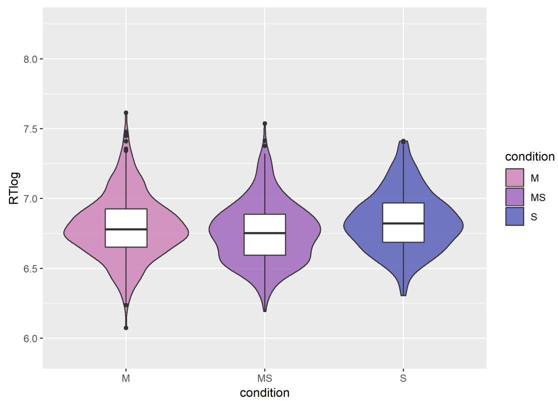


Figure 2.4: Experiment 1.1: Response time distribution of the adults.

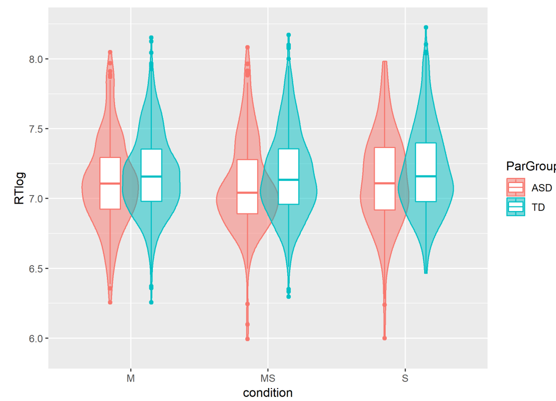


Figure 2.5: Experiment 1.1: Response time distribution of the children in Group 1.

A linear mixed-effects model was fitted to log-transformed RTs to targets in Experiment 1.1 (see Table 2.14.). The adults performed significantly faster in the MS condition than both the M condition (β=0.040, p<0.001) and the S condition (β=0.072, p<0.001). Significant predictors other than experimental conditions for the adults' target RTs include target duration (β=0.032, p<0.001), trial number (β=-0.030, p<0.001), and the response times to the primes (β=0.051, p<0.001).

In contrast to the adults' performance, the children in both groups did not display any statistical difference between their reaction times across conditions (see Table 2.15.). For the ASD group, the reaction times to the targets in Condition MS are the fastest but not significantly different from Condition M (β=0.026, p=0.313) nor Condition S (β=0.032, p=0.218). The TD group performed similarly, with the MS condition not yielding significantly faster

Table 2.14: Experiment 1.1: Summary of the reaction time model for the adults.

Adults:

	Log-transformed RT				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept	6.762	0.025	6.712	6.811	**<.001**
Prime condition					
MS vs M	0.040	0.011	0.019	0.061	**<.001**
MS vs S	0.072	0.011	0.050	0.094	**<.001**
Word type (Noun vs Verb)	-0.002	0.017	-0.036	0.032	0.901
Duration of target	0.032	0.009	0.015	0.048	**<.001**
Trial number	-0.030	0.008	-0.046	-0.015	**<.001**
ISI	0.007	0.005	-0.002	0.016	0.115
Log-transformed prime RT	0.051	0.005	0.041	0.062	**<.001**
Age	0.030	0.021	-0.011	0.071	0.162
Gender (Male vs Female)	0.038	0.048	-0.055	0.131	0.433
N Primes	144				
N Targets	48				
N Subjects	30				
N Datapoints	1261				
Marginal R^2 / Conditional R^2	0.17/0.475				

Note: The baseline is the first argument in the above scheme (x vs y).

RTs than the M condition (β=0.005, p=0.699) nor the S condition (β=0.023, p=0.075). No interactional effect between experimental conditions and children's participant groups was found. Age, but not NVIQ, played a highly significant role in speeding the overall RTs of both ASD and TD groups (β=-0.066, p<0.001). Other significant factors include trial number (β=-0.033, p<0.001) and response times to the primes (β=0.088, p<0.001).

Figure 2.6 and 2.7 plot predicted response times from the models summarized in Table 2.14 and 2.15. The response times are predicted for each categorical variable at the z-score of 0, i.e., the mean, of all the other continuous variables in the models. The points represent the predicted mean RTs, while the notches are the predicted confidence intervals at 95%. The position of the notches are not indicative of statistical significance. The graphs should be interpreted in conjunction with their corresponding models.

Experiment 1.2: The log-transformed RT distribution is presented in Figure 2.8 for

Table 2.15: Experiment 1.1: Summary of the reaction time model for the children in Group 1.

Performance group: Group 1

	Log-transformed RT				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept	7.164	0.034	7.10	7.23	**<.001**
Prime condition					
MS vs M in ASD	0.026	0.026	-0.02	0.08	0.313
MS vs S in ASD	0.032	0.026	-0.02	0.08	0.218
MS vs M in TD	0.005	0.013	-0.02	0.03	0.699
MS vs S in TD	0.023	0.013	-0.00	0.05	0.075
Word type (Noun vs Verb)	0.024	0.017	-0.01	0.06	0.166
Duration of target	0.004	0.008	-0.01	0.02	0.675
Trial number	-0.033	0.008	-0.05	-0.02	**<.001**
ISI	-0.007	0.005	-0.02	0.00	0.146
Log-transformed prime RT	0.088	0.005	0.08	0.10	**<.001**
Participant group (ASD vs TD; Cond. M)	-0.021	0.035	-0.091	0.048	0.546
Participant group (ASD vs TD; Cond. MS)	-0.001	0.035	-0.07	0.07	0.985
Participant group (ASD vs TD; Cond. S)	-0.009	0.036	-0.080	0.061	0.797
NVIQ	0.006	0.012	-0.02	0.03	0.626
Age	-0.066	0.013	-0.09	-0.04	**<.001**
Gender (Male vs Female)	0.017	0.03	-0.04	0.07	0.579
Prime cond. x Participant Group					
(MS vs M) x (ASD vs TD)	-0.021	0.029	-0.08	0.03	0.465
(MS vs S) x (ASD vs TD)	-0.009	0.029	-0.07	0.05	0.767
N Primes	144				
N Targets	48				
N Subjects	79				
N Datapoints	2866				
Marginal R^2 / Conditional R^2	0.175 / 0.305				

Note: The baseline is the first argument in the above scheme (x vs y).

the adult data and Figure 2.9 for the child data. For Experiment 1.2, in addition to the boxplot, Figure 2.10 shows the priming effects in each condition for the adults and the children. The priming effects are obtained by subtracting the weighted mean RTs of the M, MS, and Ph conditions from the weighted mean RT by subject of the control condition. In general, both groups of children had slower RTs in the control condition than in Conditions M and MS. Condition Ph, on the other hand, yielded slower reaction times than the control condition on average. Models were fitted to reaction times to targets to determine their significance levels.

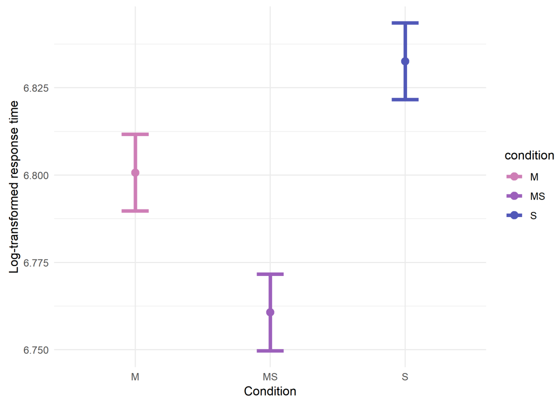


Figure 2.6: Experiment 1.1: The model's predicted response times for the adults.

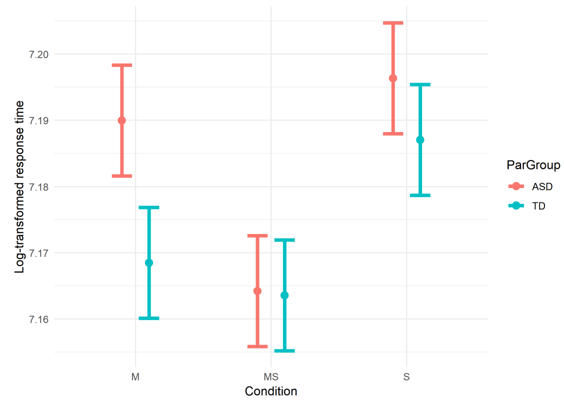


Figure 2.7: Experiment 1.1: The model's predicted response times for the children.

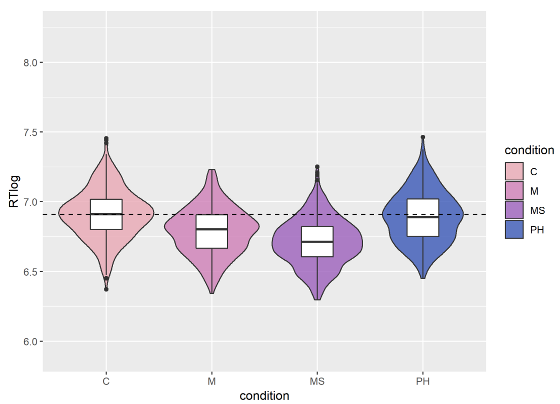


Figure 2.8: Experiment 1.2: Response time distribution of the adults.

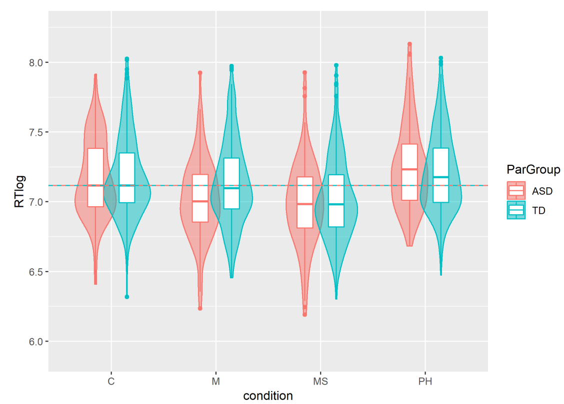


Figure 2.9: Experiment 1.2: Response time distribution of the children in Group 1.

Response times to targets were modeled in linear mixed-effects models separately for adults and for children. The reference levels for each statistical model were set at the control condition and altered to the M condition in order to obtain all the relevant pairs. The facilitation effects of each condition were investigated by comparing each condition to the control condition. Relevant pairwise comparisons that were explored in the statistical models include:

1. Conditions C and M: Testing the facilitation effects of the M experimental condition
2. Conditions C and MS:Testing the facilitation effects of the MS experimental condition
3. Conditions C and Ph: Testing the facilitation effects of the Ph experimental condition

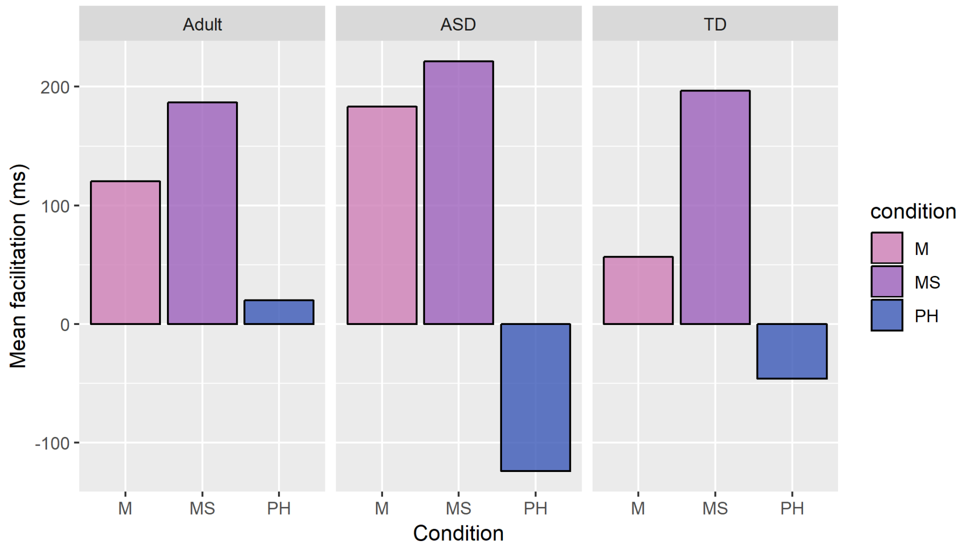


Figure 2.10: Experiment 1.2: Mean facilitation.

and the effects of phonological relatedness

4. Conditions M and MS: Testing the effects of semantic transparency

5. Conditions M and Ph: Testing the morphological effects

The children with ASD's RTs to the targets were significantly facilitated in Conditions M (β=-0.145, p<0.001) and MS (β=-0.205, p<0.001), compared to the control condition. On the other hand, Condition Ph was found to be marginally significantly slower the control condition (β=0.055, p=0.076). Further pairwise comparisons show that the RTs to the targets in Condition M are highly significantly different from Condition Ph (β=0.200, p<0.001) and marginally significantly different from Condition MS (β=-0.060, p=0.055).

As for the TD children, significant priming effects were also found in Condition MS (β=-0.161, p<0.001) and to a lesser extent in Condition M (β=-0.045, p=0.015). No significant facilitation effect of Condition Ph was obtained (β=0.023, p=0.224). The RTs of Condition M were significantly faster than those of Condition Ph (β=0.068, p<0.001), while being significantly slower than those of Condition MS (β=-0.116, p<0.001). While both the children with ASD and the TD children did not display a significant difference in reaction times to the Ph condition and the control condition, the children with ASD were found to

Table 2.16: Experiment 1.2: Summary of the reaction time model for the adults.

Adults:

	Log-transformed RT				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept	6.909	0.019	6.872	6.945	**<.001**
Prime condition					
C vs M	-0.130	0.010	-0.149	-0.111	**<.001**
C vs MS	-0.196	0.010	-0.215	-0.177	**<.001**
C vs Ph	-0.027	0.010	-0.046	-0.007	**<.01**
M vs MS	-0.066	0.010	-0.085	-0.047	**<.001**
M vs Ph	0.104	0.010	0.084	0.123	**<.001**
Word type (Noun vs Verb)	0.013	0.019	-0.025	0.050	0.517
Duration of target	0.041	0.010	0.022	0.060	**<.001**
Trial number	-0.020	0.008	-0.035	-0.005	**0.010**
ISI	0.000	0.004	-0.007	0.007	0.943
Log-transformed prime RT	0.037	0.004	0.029	0.045	**<.001**
Age	-0.001	0.012	-0.024	0.023	0.942
Gender (Male vs Female)	0.012	0.025	-0.037	0.060	0.641
N Primes	179				
N Targets	46				
N Subjects	42				
N Datapoints	1566				
Marginal R^2 / Conditional R^2	0.271 / 0.505				

Note: The baseline is the first argument in the above scheme (x vs y).

respond significantly more slowly to the targets in the Ph condition than the TD children (β=-0.108, p=0.010).

As for the interactional effects between conditions and participant groups, the children with ASD had a significantly higher priming effect in Condition M (β=0.100, p<0.01), compared to the TD children. Moreover, the children with ASD displayed a significantly greater difference between the response times to Conditions M and Ph, compared to the TD children (β=-0.132, p<0.001). The difference in RTs between Conditions M and MS, on the other hand, is not significantly different across participant groups (β=-0.056, p=0.117).

Similar to Experiment 1.1, age was found to have highly significant effects on the response times to targets on average of both participant groups (β=-0.087, p<0.001). Other

Table 2.17: Experiment 1.2: Summary of the reaction time model for the children in Group 1.

Performance group: Group 1

	Log-transformed RT				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept	7.213	0.038	7.138	7.288	**<.001**
Prime condition					
C vs M in ASD	-0.145	0.031	-0.207	-0.084	**<.001**
C vs MS in ASD	-0.205	0.031	-0.265	-0.145	**<.001**
C vs Ph in ASD	0.055	0.031	-0.006	0.115	0.076
M vs MS in ASD	-0.060	0.031	-0.120	0.001	0.055
M vs Ph in ASD	0.200	0.031	0.139	0.261	**<.001**
C vs M in TD	-0.045	0.019	-0.082	-0.009	**0.015**
C vs MS in TD	-0.161	0.018	-0.197	-0.125	**<.001**
C vs Ph in TD	0.023	0.019	-0.014	0.061	0.224
M vs MS in TD	-0.116	0.018	-0.151	-0.080	**<.001**
M vs Ph in TD	0.068	0.019	0.031	0.105	**<.001**
Word type (Noun vs Verb)	0.066	0.020	0.027	0.106	**<.01**
Duration of target	0.021	0.010	0.001	0.040	**0.045**
Trial number	-0.026	0.008	-0.041	-0.011	**0.001**
ISI	0.004	0.006	-0.007	0.015	0.474
Log-transformed prime RT	0.085	0.006	0.073	0.098	**<.001**
Participant group (ASD vs TD; Cond. C)	-0.076	0.041	-0.157	0.005	0.068
Participant group (ASD vs TD; Cond. M)	0.024	0.041	-0.057	0.105	0.565
Participant group (ASD vs TD; Cond. MS)	-0.032	0.041	-0.112	0.048	0.434
Participant group (ASD vs TD; Cond. Ph)	-0.108	0.041	-0.188	-0.027	**0.010**
NVIQ	0.005	0.010	-0.014	0.024	0.594
Age	-0.087	0.014	-0.115	-0.059	**<.001**
Gender (Male vs Female)	0.022	0.038	-0.052	0.096	0.564
Prime cond. x Participant Group					
(C vs M) x (ASD vs TD)	0.100	0.036	0.029	0.171	**<.01**
(C vs MS) x (ASD vs TD)	0.044	0.036	-0.026	0.114	0.215
(C vs Ph) x (ASD vs TD)	-0.031	0.036	-0.102	0.039	0.383
(M vs MS) x (ASD vs TD)	-0.056	0.036	-0.126	0.014	0.117
(M vs Ph) x (ASD vs TD)	-0.132	0.036	-0.203	-0.060	**<.001**
N Primes	180				
N Targets	46				
N Subjects	54				
N Datapoints	1705				
Marginal R^2 / Conditional R^2	0.303 / 0.417				

Note: The baseline is the first argument in the above scheme (x vs y).

significant predictive factors include word type (β=0.066, p=0.01), the RT to the primes (β=0.085, p<0.001), trial number (β=-0.026, p=0.001), and target duration (β=0.021, p=0.045).

Figure 2.11 and 2.12 plot the predicted RTs for the models fitted to their data sets, as summarized in Table 2.16 and 2.17.

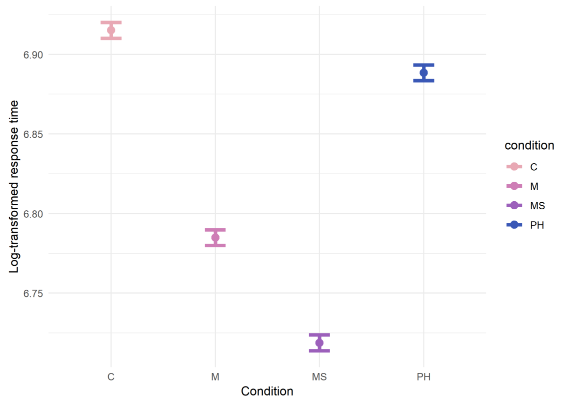


Figure 2.11: Experiment 1.2: The model's predicted response times for the adults.

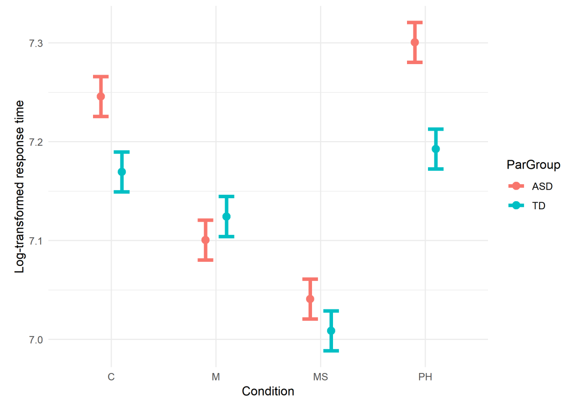


Figure 2.12: Experiment 1.2: The model's predicted response times for the children.

2.5.4 Interim discussion and conclusions

Experiment 1.1 aims to investigate whether there is Independent Morphological Processing (IMP) of Thai compounds in the ASD versus the TD groups. The three experimental conditions were designed to distinguish morphological effects from semantic transparency effects. In terms of reaction times, while the adults responded significantly faster to targets in the morphologically and semantically transparent condition (Condition MS; e.g., *ná:m-ta:* 'tear' - *ná:m* 'water') than the purely morphologically related condition (Condition M; e.g., *ná:m-ta:n* 'sugar' - *ná:m* 'water') and the purely semantically transparent condition (Condition S; e.g., k^h*ɔ̆:ŋ-lě:w* 'liquid' - *ná:m* 'water'), both the children with ASD and the TD children in performance group 1 did not display a statistical difference in reaction times across conditions. The accuracy rates also do not vary by condition for the children in Group 1. The children in performance group 2, on the other hand, performed significantly differently in terms of the accuracy rates of between Conditions MS and S, with the TD group having a bigger difference between the two conditions.

It cannot be definitively concluded from the results in Experiment 1.1 whether morphological processing is independent from semantic transparency in the processing of Thai compounds, based on the presence of a significant difference between the response times to the targets of Condition MS and M in the adults and the lack of such difference in the children. This is owing to the fact that the experiment does not test for the artifact of phonological relatedness effects, which may arise from the fact that the first element of the targets in Condition M is not only morphologically related but also phonologically related to the targets. A general conclusion that can be made from Experiment 1.1 is that a word can be highly facilitated by its morphologically and semantically related (MS) compound in native adult Thai speakers, to the extent that surpasses the conditions where the primes only share either the semantic or the morphological information. Such highly distinct facilitation effects of the MS-related primes are not yet present in both the typically-developing children and the children with ASD, at least with an interstimulus interval (ISI) of 800-900 ms.

To further investigate this issue, Experiment 1.2 included a phonologically related condition (Ph), where the first element of the prime rhymes with the target. It also include a control condition (C), where primes and targets share no phonological, morphological, nor semantic relatedness. Moreover, as longer ISIs were found to decrease the accuracy rates for the children in performance group 1, the ISIs in Experiment 1.2 were lowered to 400-600 ms.

With a faster-paced task, the overall RT analysis of the adult data reveals significant priming effects, i.e., difference in RTs from Condition C (*kʰoːm-faj* 'lamp' - *náːm* 'water'), in all of the conditions, including Condition M (*náːm-taːn* 'sugar' - *náːm* 'water'), Condition MS (*náːm taː* 'tear' - *náːm* 'water'), and Condition Ph (*klâːm-nɯːa* 'muscle' - *náːm* 'water'). On the other hand, both the TD children and children with ASD have significant facilitation effects in Condition MS and Condition M, while the Ph condition yielded slower, but not significantly different, reaction times, compared to the control condition. While similar patterns were found in both participant groups, the children with ASD have a significantly higher degree of priming effects in Condition M than the TD children. This leads to significantly greater morphological effects (difference between M and Ph) in the

ASD group than the TD group.

One point of discussion is why there is no priming effect in the phonologically related prime condition in both participant groups. Two potential factors are discussed here. One factor that may play a role in slowing down the processing of Condition Ph is that the targets in Condition Ph do not rhyme with the final syllable of the compounds. Previous literature with auditory lexical decision tasks systematically found facilitation effects of rhyme overlap between primes and target in final syllables (Monsell and Hirsh, 1998; Norris et al., 2002; Slowiaczek et al., 2000; Spinelli et al., 2001). When the overlap is not in the final syllable, however, Radeau et al. (1989) found significant inhibition effect in pairs of simplex words such as **PA**LAIS-**PA**RURE. In our study, to completely match with Condition M and MS, targets in Condition Ph rhyme with the first part of the compounds. Our experiment, thus, yielded similar results to the study on simplex words, with Condition Ph not having facilitation effects, yet insignificant inhibition effects. Our results suggests that the children in Group 1 processed the entire compounds, not only just the first element; otherwise, the same kind of priming effects would have been present.

Another potential factor is the nature of stress in Thai compounds. Compounds in Thai have a different stress pattern from their phrasal peers. The stress pattern changes from the primary stress falling on both words to having only one primary stress as observed in Peyasantiwong (1986). The phrasal meaning is only denoted when the primary stress falls on both syllables (3). Unstressed syllables in compounds undergo phonological alternations by vowel shortening or syllable shortening, as seen in (4), with boldface denoting stress. With vowel length being contrastive in Thai, i.e., potentially distinguishing meaning of a word, such cue may be notable by Thai speakers.

(3) a. **rɔːŋ** **tʰáːw**
support underneath foot
'to support underneath a foot/feet'

b. rɔŋ **tʰáːw**
support underneath foot
'shoe' *'to support underneath a foot/feet'

(4) *Vowel/syllable shortening*:

hŭ:a (head)	$\mathbf{k^h}$**àw** (knee)	=	hŭa-$\mathbf{k^h}$**àw**	knee
ta: (eye)	**pla:** (fish)	=	ta-**pla:**	corn (toe)
ná:m (water)	**ta:** (eye)	=	nám-**ta:**	tear

(Peyasantiwong, 1986)

Goodwin Davies (2018) discussed potential accounts for the priming effects that are obtained from forms with and without allomorphy. Those include the accounts where the priming effects target phonological representations that are (1) mediated by semantic representations, (2) mediated by syntactic representations, (3) mediated by shared underlying phonological representations between two forms, or (4) not mediated by shared underlying representations. Because all Thai compounds involve vowel and syllable shortening in their unstressed first syllable, the forms of the primes are, therefore, not exactly the same as their targets, not only in the Ph condition, but also in the M and MS conditions. If phonological priming effects are mediated by underlying phonological representations, participants may need to recover the fully-stressed forms from the unstressed primes in all of these experimental conditions to get the facilitation effects. Such facilitation was effectively present in the M and MS conditions, but not in the Ph condition in the child data and to a significantly smaller extent in the Ph condition in the adult data (cf. Condition M versus Ph). This indicates that the non-exact phonological mapping between the primes with unstressed first syllables and the targets is not a contributing factor to the absence of priming effects in the Ph condition. While this may be due to the rhyme overlap in the first rather than the final syllable as stated in the previous paragraph, the fact that other conditions except for the Ph condition yielded significant priming effects suggests certain differences between their processing. The recovery of the underlying phonological representations can be done in parallel with the morphological and semantic mapping between primes and targets in the MS condition (5) and the morphological mapping in the M condition (6). The primes in the Ph condition, on the other hand, requires an indirect mapping to the targets (7), which may have additionally contributed to its difference from the other conditions.

(5) <u>Condition MS:</u>

nám-taː $\xrightarrow[\text{MORPHOSYNTACTIC} \mid \text{SEMANTIC MEDIATION}]{\text{PHON. UR}}$ *náːm*

(6) <u>Condition M:</u>

nám-taːn $\xrightarrow[\text{MORPHOSYNTACTIC MEDIATION}]{\text{PHON. UR}}$ *náːm*

(7) <u>Condition Ph:</u>

klâm-nɯːa $\xrightarrow{\text{PHON. UR}}$ klâːm $\xrightarrow{\text{RHYME}}$ *náːm*

Given the results that the M and Ph conditions consistently differ across participant groups, the Independent Morphological Processing (IMP) hypothesis, i.e., a morphological effect is independent of phonological and semantic effects, tentatively holds with regards to the phonological effects. Future research involving the direct phonological mapping between primes and targets in both of the conditions is required to make a more definite conclusion. As for semantic transparency, since facilitation effects were obtained in both the M and MS conditions, it supports the hypothesis that semantic transparency does not have to be a precondition for morphological effects. Semantic transparency, however, can significantly heighten the priming effects of Condition MS, compared to M in both the adults and the two groups of children in performance group 1.

The accuracy rates also reflect a similar pattern as the RT data. The control condition yielded lower accuracy rates, compared to the M and MS conditions, but not the Ph condition in the TD children and children with ASD of Group 1. Even though the children in Group 2 are not included in the RT analysis, the difference in the children with ASD and the TD children's patterns of accuracy is compelling. The TD children in Group 2 had a similar pattern of accuracy rates across experimental conditions, with the control condition having the lowest accuracy rates. The children with ASD in Group 2, on the other hand, had significantly higher accuracy in the control condition, compared to all the other conditions. The results seem to suggest that this group of children with ASD pay extra attention to the differences, instead of the similarities, between primes and targets. This is in line with the DSM-V criterion that children with autism may exhibit hyper- or hyporeactivity to sensory input or display unusual sensory interests (American Psychiatric

Association, 2013). It is unclear, however, whether the differences they pay attention to are morphological, semantic, or as basic as acoustic differences.

The two groups of children with ASD displayed different characteristics in lexical processing. While the children with ASD in Group 2 pay extra attention to the prime-target differences, the children with ASD in Group 1 seem to be extra sensitive to their morphological similarities. This can be seen from the results in Experiment 1.2 that the children with ASD in performance group 1 displayed highly significant greater difference in response times between the M condition and the Ph condition than their TD peers, due to their significantly higher facilitation effects in the M condition and their significantly slower response times to the targets in the Ph condition. The study shows that morphological priming effects can be obtained independent of semantic transparency (cf. Condition C versus M). The conclusion about effects of phonology on morphological processing is merely tentative in this study due to the indirect mapping between the primes and targets in the Ph condition. In sum, this study highlights different layers of lexical processing. It adds to the literature that a subgroup of children with ASD can have enhanced performance on the processing of compounds, as a part derivational morphology, without necessarily having enhanced sensitivity to semantic transparency.

As seen from the results of the experiments, similarities and differences between primes and targets influence the performance of both subgroups of children with ASD. Puzzles remain on the nature of the similarities or differences they pay attention to. The next experiments further explore whether such heightened sensitivity is due to acoustic differences and what kind of acoustic differences influence their processing. Experiments 2 (Fall 2017) was set up to test the effects of full/neutralized tones in unstressed syllables on lexical processing. In contrast, Experiment 3 (Fall 2017) were designed to test the children's sensitivity to other non-phonological acoustic differences, including talker/token switch. Both of the experiments were repetition auditory priming experiments. Simplex words were used in both experiments. More details of the methods are presented below.

2.5.5 Experiment 2: Effects of Thai stress and tones on lexical access

The results from Experiment 1.2 report an insignificant facilitation effect for the phonological condition in both the TD children and the children with ASD. Potential accounts for the absence of its priming effect (see the discussion in Section 2.5.4) include the phonological relatedness in the initial rather than the final syllable of the primes and the potential mediation by the underlying phonological representations, requiring the extra step of morphological processing. This experiment aims to explore the effects of phonological underlying representations in detail. This is to investigate the children with ASD's sensitivity to acoustic information that is not crucial to the lexical processing.

Standard Bangkok Thai consists of five lexical tones varying in pitch height and contour shape (Abramson, 1962; Naksakun, 1977). Being a tonal language, Thai employs tonal contrasts in differentiating lexical items. Table 2.18 presents Bangkok Thai tone inventory, adapted from Pittayaporn (2016, pp.191).

Tone	Phonetic characteristics	Transcription	Gloss
1	mid	[kʰaː]	'to be stuck'
2	low	[kʰàː]	'galangal'
3	high falling	[kʰâː]	'value, fee'
4	high	[kʰáː]	'trade'
5	low rising	[kʰǎː]	'leg'

Table 2.18: Bangkok Thai tone inventory

Similar to compounds, disyllabic simplex[6] words in Thai also involve stress weakening in their first syllable. Syllables ending with a short vowel on the surface are analyzed as having an underlyingly glottal stop in the coda. Such syllables contain only one tone-bearing unit and thus carry only either a high tone or a low tone (Peyasantiwong, 1986). If this type of syllable serves as the first syllable of a disyllabic simplex words, stress weakening is manifested by glottal stop deletion and tone neutralization. A version of two simple phonological rules for this type of stress weakening is adapted from Peyasantiwong (1986) and provided in (8) and (9). Examples for this type of words are provided in (10). Although

[6]Some of these words are likely historically complex and are often loanwords. Synchronically speaking, they are regarded as simplex by native speakers of Standard Thai.

speakers of Thai more commonly pronounce their surface forms in their natural speech, the full and intermediate forms are also used in 'hyperarticulated' (Bennett, 2005) or 'isolated' (Henderson, 1949) speech styles. The acoustic cue merely indicates a difference in speech styles but does not affect the lexical meaning of these words.

(8) $CVʔ \rightarrow CV$ / $[_{word}$ ___ $\sigma]$ [7]

(9) $CV_{[\text{-mid tone}]} \rightarrow CV_{[\text{+mid tone}]}$ / $[_{word}$ ___ $\sigma]$

(10)

Full	Intermediate	Surface	
tʰáʔ.leː	tʰá.leː	tʰa.leː	'sea'
cʰáʔ.niː	cʰá.niː	cʰa.niː	'gibbon'
tàʔ.puː	tà.puː	ta.puː	'nail'
kùʔ.làːp	kù.làːp	ku.làːp	'rose'

Even though previous autism research studies on acoustic sensitivity in tonal languages, including Mandarin Chinese and Cantonese, also employ lexical tones as their stimuli, these studies mainly concern speech and categorical perception (see Section 2.4.2). Studies that probe into the connection between underlying phonological representations and lexical processing are still lacking. Experiment 2 aims to explore the children's sensitivity to the acoustic cue of full tone, instead of the usual neutralized tone. The forms of the primes in the experiment are the intermediate forms, where the glottal stop is deleted but the tone is still in its full form. This is to ensure that the phonological effects discussed in this study are restricted to the tonal information and not the vowel length information from the presence or absence of a glottal stop.

2.5.5.1 Stimuli

In this experiment, 44 disyllabic simplex words (22 nouns: 22 verbs) with a consonant followed by the vowel [a], i.e., *Ca* structure, as their first syllable. Half of the words have a high tone as their underlying tone, whereas the other half has an underlying low tone,

[7] C: consonant; V: vowel; ʔ: glottal stop; σ: syllable

before the underlying tones are neutralized to mid tone. Audio recording methods can be found in Section 2.5.1. Two recordings of each word, one pronounced with its full tone and one with its neutralized tone, were selected to create four main experimental conditions summarized in Table 2.19.

Table 2.19: Experiment 2 example prime-target pairs formed from 1 word *ma-naaw* 'lime'

Condition	Prime	Target	Pairs per list
Neutralized-Neutralized (NN)	ma.naaw (M)	ma.naaw (M)	11
Neutralized-Full (NF)	ma.naaw (M)	má.naaw (H)	11
Full-Full (FF)	má.naaw (H)	má.naaw (H)	11
Full-Neutralized (FN)	má.naaw (H)	ma.naaw (M)	11

The list of the stimuli in Experiment 2 are provided in Appendix A.

2.5.5.2 Procedure

The experiment is repetition priming experiment through a continuous lexical decision task with the ISIs of 400-600 ms. The test items contain 176 pairs distributed over 4 lists (44 pairs per list; 11 pairs per condition). The proportion between test items and fillers are 20% test items: 50% non-word fillers: 30% word fillers, where 20% of the word fillers are the test items in Experiment 1.2.

2.5.5.3 Modeling

Similar to Experiment 1.2, the target accuracy models were performed only on the children, with two separate models for children in *performance groups* 1 and 2. Both models contained the 11 fixed-effects factors, including *condition* (NN, NF, FF, and FN), *word type*, *z-scored duration of target*, *z-scored trial number*, *z-scored interstimulus interval* (ISI), *prime accuracy*, *log-transformed RTs to primes*, *participant group* (ASD or TD), *z-scored Ravens nonverbal IQ*, *z-scored age*, and *gender*. The models additionally include interactions between *condition* and *participant group*, along with two random effects factors for participants and test items. Dummy coding was employed for baseline re-levelling.

The data were trimmed and analyzed using procedures described in Section 2.5.2. Since

Experiments 2 and 3 are repetition priming experiments, meaning that the primes and targets are the same words (differing only in their forms), both the log-transformed target RTs and the log-transformed prime RTs were trimmed. Models were fitted to the difference between the prime and the target RTs in each trial in proportion to the RTs to the prime (11):

(11) $\frac{log(PrimeRTs) - log(TargetRTs)}{log(PrimeRTs)}$

The relative fraction is to ensure no effect of general speed in responding to the primes. Each model contained 8 fixed-effects factors for the child data and 6 factors for the adult data, using the same contrast coding schemes. The factors include *condition*, *word type*, *z-scored target duration*, *z-scored trial number*, *z-scored ISI*, *participant group* (only for the child data), *z-scored NVIQ* (only for the child data), *z-scored age*, and *gender*. Interactional effects were coded between *condition* and *participant group* in the child data. Two random effects factors of *participants* and *items* were also included in the models.

2.5.5.4 Results

2.5.5.4.1 Accuracy

Average accuracy per condition and participant groups in Experiment 2 is provided in Table 2.20. Figure 2.13 presents an overall data visualization with mean accuracy in the four experimental conditions with neutralized-tone primes and neutralized-tone targets (NN), neutralized-tone primes and full-tone targets (NF), full-tone primes and full-tone targets (FF), and full-tone primes and full-tone targets (FN), comparing between the four subgroups of children (ASD/TD by Performance group 1/2). Overall, the accuracy rates are the highest in the NN condition for both the children with ASD and the TD children in Group 1. The pattern of accuracy rates across conditions among the children in performance group 2 is different, with the NN condition having relatively low mean accuracy rates, compared to the other conditions.

According to the logistic regression model for accuracy as summarized in Table 2.21, the

Table 2.20: Percentages of accuracy by condition in Experiment 2.

	Condition	Adults		Group 1 ASD		Group 1 TD		Group 2 ASD		Group 2 TD	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Exp2	NN	98.77	4.01	90.21	8.67	88.03	11.58	58.37	24.11	70.20	25.68
	NF	98.58	4.90	86.01	11.51	83.81	14.30	61.24	28.56	69.19	29.27
	FF	98.14	4.90	89.51	8.97	81.60	15.28	57.89	31.96	76.26	24.38
	FN	98.39	4.41	86.01	10.24	86.47	12.55	59.81	29.27	72.22	29.16

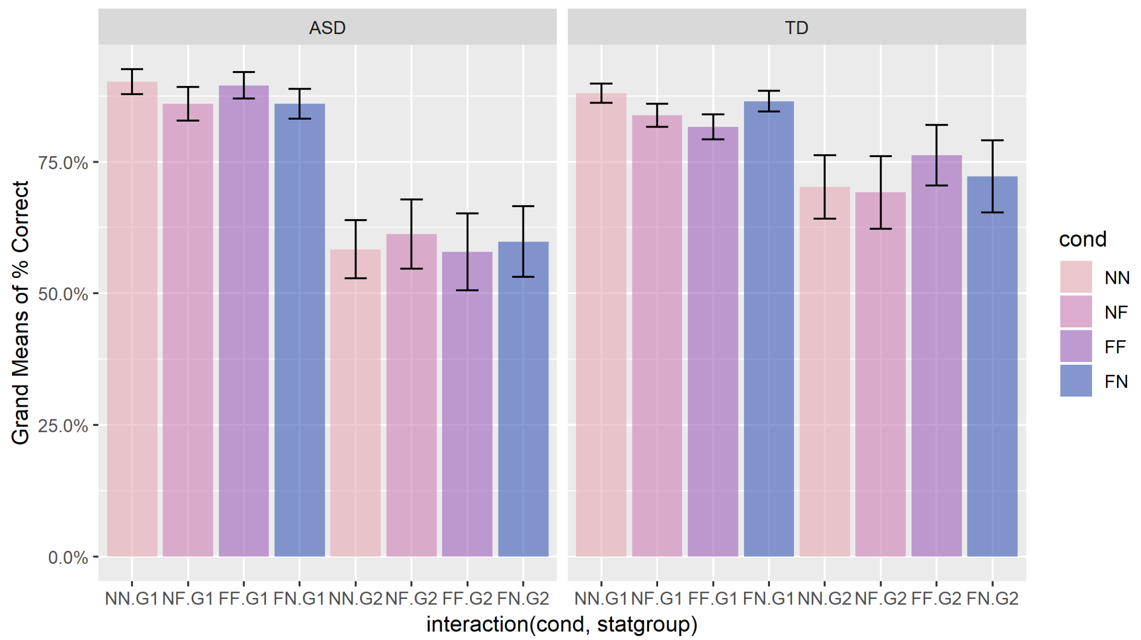


Figure 2.13: Experiment 2 - Mean target accuracy for each condition (NN/NF/FF/FN) by participant groups (ASD/TD) and performance groups (Group 1/Group 2), with reference lines at the NN condition.

children with ASD in Group 1 showed no significant difference in accuracy across conditions. The same also holds true with the TD children in Group 1. Compared with the TD children, children with autism have performed on par with the TD group every condition, with only the FN condition yielding marginally significantly lower accuracy than the TD group (β=0.690, $p<0.060$). On average for all the children in performance group 1, prime accuracy is found to be the most significant predictor for target accuracy (β=2.067, $p<0.001$). Additionally, age (β=0.443, $p<0.001$), but not NVIQ (β=0.058, $p=0.389$), significantly affects accuracy.

Table 2.21: Experiment 2: Summary of the accuracy model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: NN, ASD)	1.139	0.408	0.339	1.938	**<.01**
Condition					
NN vs NF in ASD	-0.804	0.459	-1.703	0.094	0.079
NN vs FF in ASD	-0.206	0.481	-1.149	0.737	0.668
NN vs FN in ASD	-0.633	0.425	-1.466	0.200	0.136
FF vs NF in ASD	-0.598	0.413	-1.408	0.212	0.148
FF vs FN in ASD	-0.427	0.447	-1.304	0.450	0.340
NN vs NF in TD	-0.345	0.282	-0.897	0.207	0.220
NN vs FF in TD	-0.502	0.280	-1.052	0.047	0.073
NN vs FN in TD	-0.046	0.234	-0.504	0.412	0.844
FF vs NF in TD	0.157	0.212	-0.259	0.573	0.460
FF vs FN in TD	0.456	0.276	-0.085	0.998	0.099
Word type (Noun vs Verb)	-0.407	0.214	-0.826	0.011	0.056
Duration of target	0.040	0.107	-0.169	0.249	0.708
Trial number	0.108	0.090	-0.068	0.284	0.227
ISI	0.026	0.070	-0.111	0.163	0.711
Prime accuracy (Correct vs Incorrect)	2.067	0.150	1.772	2.361	**<.001**
Log-transformed prime RT	-0.036	0.067	-0.166	0.095	0.593
Participant group (ASD vs TD; Cond. NN)	0.102	0.410	-0.700	0.905	0.803
Participant group (ASD vs TD; Cond. NF)	0.562	0.360	-0.145	1.268	0.119
Participant group (ASD vs TD; Cond. FF)	-0.194	0.388	-0.953	0.566	0.617
Participant group (ASD vs TD; Cond. FN)	0.690	0.367	-0.030	1.409	0.060
NVIQ	0.058	0.067	-0.074	0.190	0.389
Age	0.443	0.104	0.238	0.647	**<.001**
Gender (Female vs Male)	0.110	0.255	-0.389	0.609	0.666
Condition x Participant Group					
(NN vs NF) x (ASD vs TD)	0.459	0.481	-0.484	1.403	0.340
(NN vs FF) x (ASD vs TD)	-0.296	0.499	-1.275	0.683	0.553
(NN vs FN) x (ASD vs TD)	0.587	0.483	-0.360	1.534	0.224
(FF vs NF) x (ASD vs TD)	0.755	0.463	-0.152	1.663	0.103
(FF vs FN) x (ASD vs TD)	0.883	0.466	-0.030	1.797	0.058
N Primes	88				
N Targets	88				
N Subjects	54				
N Datapoints	2376				
Marginal R^2 / Conditional R^2	0.220 / 0.356				
Δ Marginal R^2 / Δ Conditional R^2	0.113 / 0.183				

Note: The baseline is the first argument in the above scheme (x vs y).

The children in Group 2 also showed no significant difference in their performance across conditions, as summarized in Table 2.22. The experimental factors play no role in

Table 2.22: Experiment 2: Summary of the accuracy model for the children in Group 2.

Performance group: Group 2

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: NN, ASD)	1.441	0.512	0.437	2.444	**<.01**
Condition					
NN vs NF in ASD	0.192	0.234	-0.267	0.650	0.413
NN vs FF in ASD	0.014	0.234	-0.444	0.472	0.952
NN vs FN in ASD	0.068	0.232	-0.387	0.522	0.769
FF vs NF in ASD	0.177	0.231	-0.274	0.629	0.442
FF vs FN in ASD	0.054	0.234	-0.404	0.512	0.818
NN vs NF in TD	-0.020	0.259	-0.527	0.487	0.939
NN vs FF in TD	0.483	0.269	-0.044	1.010	0.072
NN vs FN in TD	0.136	0.259	-0.372	0.644	0.600
FF vs NF in TD	-0.503	0.265	-1.022	0.016	0.058
FF vs FN in TD	-0.347	0.269	-0.875	0.181	0.197
Word type (Noun vs Verb)	-0.122	0.123	-0.363	0.119	0.321
Duration of target	0.079	0.064	-0.047	0.204	0.220
Trial number	0.090	0.064	-0.034	0.215	0.156
ISI	0.084	0.062	-0.038	0.205	0.177
Prime accuracy (Correct vs Incorrect)	0.137	0.136	-0.129	0.403	0.312
Log-transformed prime RT	0.110	0.067	-0.023	0.242	0.104
Participant group (ASD vs TD; Cond. NN)	0.183	0.604	-1.000	1.366	0.762
Participant group (ASD vs TD; Cond. NF)	-0.028	0.604	-1.212	1.155	0.963
Participant group (ASD vs TD; Cond. FF)	0.652	0.608	-0.539	1.844	0.283
Participant group (ASD vs TD; Cond. FN)	0.251	0.605	-0.935	1.437	0.678
NVIQ	0.658	0.233	0.202	1.114	**<.01**
Age	0.530	0.318	-0.094	1.154	0.096
Gender (Female vs Male)	1.777	0.716	0.374	3.179	**0.013**
Condition x Participant Group					
(NN vs NF) x (ASD vs TD)	-0.211	0.345	-0.887	0.464	0.540
(NN vs FF) x (ASD vs TD)	0.469	0.352	-0.221	1.159	0.183
(NN vs FN) x (ASD vs TD)	0.068	0.347	-0.613	0.749	0.845
(FF vs NF) x (ASD vs TD)	-0.680	0.351	-1.369	0.008	0.053
(FF vs FN) x (ASD vs TD)	-0.401	0.353	-1.093	0.291	0.256
N Primes	88				
N Targets	88				
N Subjects	37				
N Datapoints	1628				
Marginal R^2 / Conditional R^2	0.179 / 0.452				
Δ Marginal R^2 / Δ Conditional R^2	0.150 / 0.380				

Note: The baseline is the first argument in the above scheme (x vs y).

predicting their accuracy rates. While age is a significant predictor for the accuracy rates of the children in Group 1, non-verbal IQ significantly affects the accuracy rates of the children in Group 2 in this experiment (β=0.658, $p<0.01$). The gender of the children in Group 2 also influenced their overall accuracy rates (β=1.777, $p=0.013$).

2.5.5.4.2 Response time

Average response times to primes and targets in each condition are presented in Table 2.23. The adults generally have faster response times and less variance in response time distributions than the children in all of the conditions. Overall, the TD children seem to be slightly slower than the children with ASD in processing the primes. This partly results in generally higher differences between their raw reaction times to primes and targets than the ASD group's as shown in Figure 2.14. To account for the effects of their general processing speed of the primes, linear regression models were performed on the relative differences between the prime and target RTs, described earlier in Section 2.5.5.3.

Table 2.23: Average response times by participant by condition in Experiment 2.

Reaction Times (Milliseconds)							
	Condition	Adult		ASD		TD	
		M	*SD*	*M*	*SD*	*M*	*SD*
Prime RTs	NN	1055.33	178.96	1313.78	372.36	1491.57	421.59
	NF	1069.46	189.31	1414.48	449.02	1463.68	398.53
	FF	1069.69	194.42	1328.39	340.57	1439.91	462.55
	FN	1055.69	190.07	1327.77	418.17	1391.54	387.04
Target RTs	NN	790.81	140.87	1036.04	395.52	1028.73	321.83
	NF	817.16	150.82	1114.62	397.49	1115.30	339.92
	FF	791.14	145.20	1009.23	325.58	1033.48	309.18
	FN	822.19	156.86	1096.65	371.51	1055.15	301.21

Figure 2.14 presents the raw difference between prime and target RTs in milliseconds. Such raw differences are only an approximation to the actual effects. Refer to the models for significance levels. Figure 2.15 and 2.16 present the distribution of the calculated relative facilitation in combined box and density plots for the adult and the child data respectively. Both boxplots share the same scale on the y-axis, showing that the adults' relative prime-target differences are more uniformly distributed, compared to the children's. The plotted values in the two density plots are later modelled in linear mixed-effects regression models.

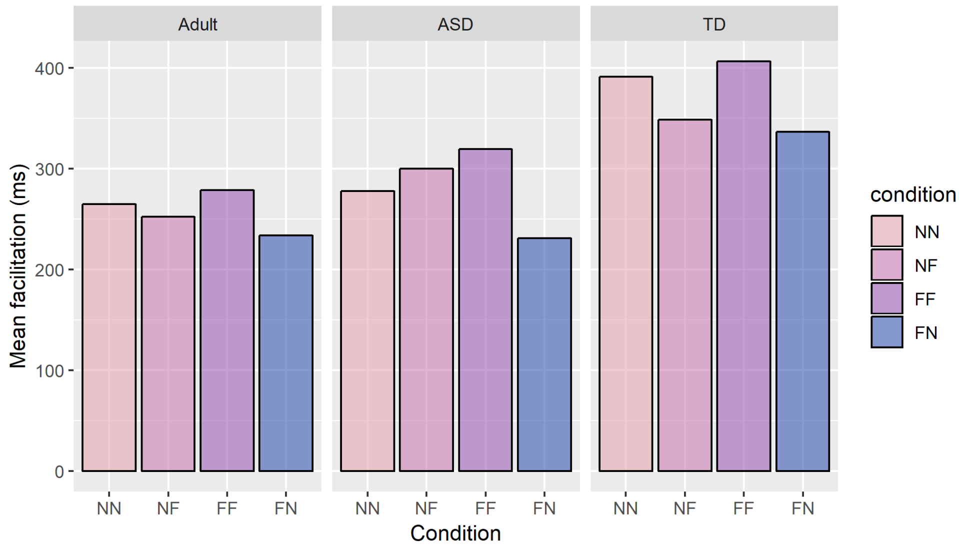


Figure 2.14: Experiment 2: Mean facilitation.

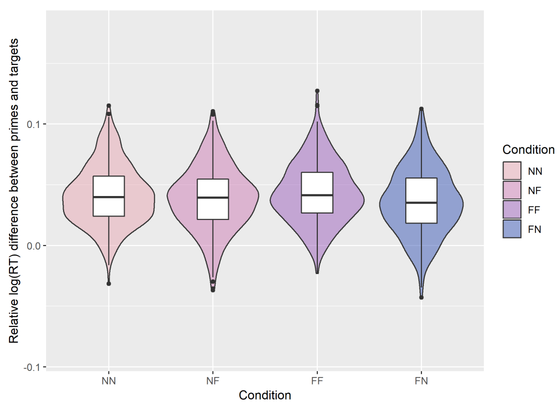


Figure 2.15: Experiment 2: Relative difference between log-transformed RTs to primes and targets by adults.

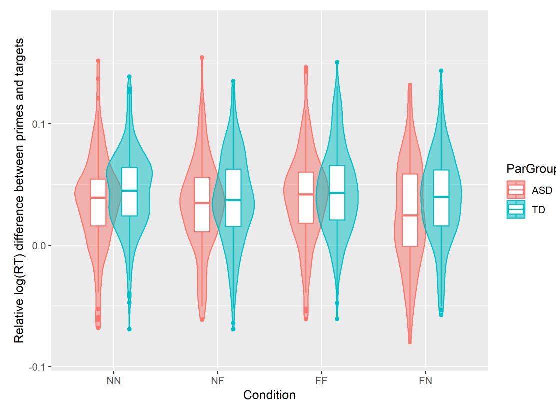


Figure 2.16: Experiment 2: Relative difference between log-transformed RTs to primes and targets by children in Group 1.

A linear mixed-effects model was fitted to the relative prime-target difference in the adult data, as summarized in Table 2.24. The FN condition seems to yield the least facilitation effects, being significantly different from the facilitation effects of the NN condition (β=-0.006, p<0.001) and the FF condition (β=-0.06, p<0.01). The NF condition also yielded significantly lower facilitation than the FF condition (β=-0.004, p=0.02). Other conditions do not differ in facilitation effects from each other. Apart from the experimental conditions, trial number (β=0.005, p<0.001) were also found to be significant predictors for the relative prime-target RT difference.

Table 2.24: Experiment 2: Summary of the reaction time model for the adults.

Adults:

	Raw prime-target RT difference				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: NN)	0.043	0.002	0.038	0.048	**<.001**
Condition					
NN vs NF	-0.004	0.002	-0.008	0.001	0.123
NN vs FF	0.000	0.002	-0.004	0.005	0.860
NN vs FN	-0.006	0.002	-0.009	-0.002	**<.001**
FF vs NF	-0.004	0.002	-0.007	-0.001	**0.016**
FF vs FN	-0.006	0.002	-0.011	-0.002	**<.01**
Word type (Noun vs Verb)	0.001	0.002	-0.002	0.005	0.478
Duration of target	-0.001	0.001	-0.003	0.001	0.174
Trial number	0.005	0.001	0.003	0.007	**<.001**
ISI	-0.001	0.001	-0.002	0.001	0.324
Age	0.002	0.002	-0.002	0.005	0.365
Gender (Male vs Female)	-0.004	0.004	-0.012	0.003	0.280
N Primes	88				
N Targets	88				
N Subjects	42				
N Datapoints	1447				
Marginal R^2 / Conditional R^2	0.055/0.313				

Note: The baseline is the first argument in the above scheme (x vs y).

The TD children also displayed the highest facilitation effects in the NN condition, being significantly different from the FN condition (β=-0.007, p=0.02) and the NF condition, as seen in Table 2.25. The children with ASD, on the other hand, did not show significant differences across conditions, although a marginal difference was found between the FF and the FN conditions (β=-0.009, p=0.06). As for individual experimental conditions, priming effects were obtained at different levels between the two groups of children in the NN condition (β=0.015, p=0.01) and in the FN condition (β=0.014, p=0.02), with the children with ASD experience less facilitation than the TD children. Additionally, similar to the models on response times in Experiments 1.1 and 1.2, age (β=0.006, p<0.01) but not NVIQ (β=0.002, p=0.20) significantly enhances the facilitation effects on average across participant groups and conditions. Additionally, trial number positively affects facilitation effects (β=0.005, $p<0.001$).

Table 2.25: Experiment 2: Summary of the reaction time model for the children in Group 1.

Performance group: Group 1

	Raw prime-target RT difference				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: NN, ASD)	0.031	0.005	0.021	0.041	**<.001**
Condition					
NN vs NF in ASD	-0.001	0.005	-0.010	0.008	0.782
NN vs FF in ASD	0.003	0.005	-0.006	0.013	0.478
NN vs FN in ASD	-0.006	0.005	-0.015	0.003	0.219
FF vs NF in ASD	-0.005	0.004	-0.013	0.004	0.298
FF vs FN in ASD	-0.009	0.005	-0.019	0.000	0.058
NN vs NF in TD	-0.007	0.003	-0.013	-0.001	**0.017**
NN vs FF in TD	-0.002	0.003	-0.008	0.004	0.450
NN vs FN in TD	-0.007	0.003	-0.012	-0.001	**0.016**
FF vs NF in TD	-0.005	0.003	-0.011	0.000	0.071
FF vs FN in TD	-0.004	0.003	-0.010	0.002	0.157
Word type (Noun vs Verb)	0.003	0.002	-0.001	0.007	0.155
Duration of target	-0.002	0.001	-0.004	0.000	0.053
Trial number	0.005	0.001	0.003	0.006	**<.001**
ISI	-0.001	0.001	-0.003	0.001	0.248
Participant group (ASD vs TD; Cond. NN)	0.015	0.006	0.003	0.026	**0.012**
Participant group (ASD vs TD; Cond. NF)	0.009	0.006	-0.002	0.020	0.128
Participant group (ASD vs TD; Cond. FF)	0.009	0.006	-0.002	0.021	0.116
Participant group (ASD vs TD; Cond. FN)	0.014	0.006	0.003	0.026	**0.019**
NVIQ	0.002	0.001	-0.001	0.004	0.199
Age	0.006	0.002	0.002	0.010	**<.01**
Gender (Male vs Female)	0.004	0.005	-0.007	0.014	0.489
Condition x Participant Group					
(NN vs NF) x (ASD vs TD)	-0.006	0.005	-0.016	0.004	0.252
(NN vs FF) x (ASD vs TD)	-0.006	0.005	-0.016	0.005	0.289
(NN vs FN) x (ASD vs TD)	-0.001	0.005	-0.011	0.010	0.881
(FF vs NF) x (ASD vs TD)	0.000	0.005	-0.011	0.010	0.941
(FF vs FN) x (ASD vs TD)	0.005	0.005	-0.006	0.015	0.368
N Primes	88				
N Targets	88				
N Subjects	54				
N Datapoints	1628				
Marginal R^2 / Conditional R^2	0.060/0.187				

Note: The baseline is the first argument in the above scheme (x vs y).

Predicted response times from the linear regression models in Table 2.24 and 2.25 are plotted in Figure 2.17 and 2.18 with two figures sharing the same scale on the y-axis.

The points are predicted means and the notches are the predicted 95% confidence intervals. Statistical significance levels should be checked in their corresponding models. Even though in Figure 2.14, similar raw mean facilitation was found in the adults and the children with ASD, the adults exhibited relative facilitation effects at a level similar to the TD children. The raw differences in RTs that were plotted earlier can be a result of generally faster response times by the adults, leaving fewer milliseconds to be improved from the fast response times to primes.

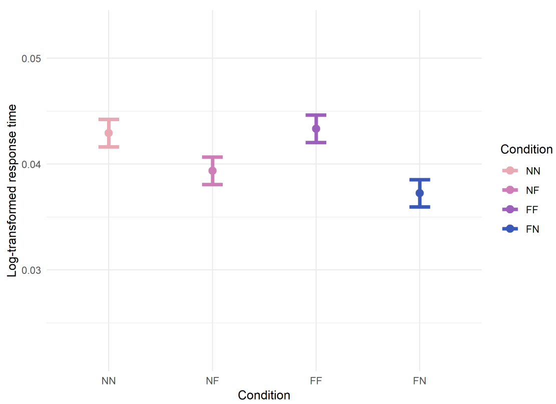


Figure 2.17: Experiment 2: The model's predicted relative facilitation for the adults.

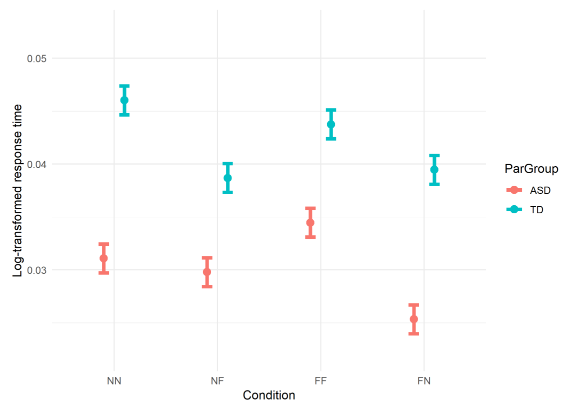


Figure 2.18: Experiment 2: The model's predicted relative facilitation for the children.

2.5.6 Interim discussion and conclusions

Experiment 2 explores the nature of phonological mediation in lexical processing through the underlying representations of tones in Thai. In Experiment 1.2, the accuracy rates of the children with ASD in performance group 2 are the highest in the control condition, while all the other groups of children have the lowest accuracy rates in the control condition. Moreover, while the adults exhibited priming effects in the phonological condition, the TD children and children with ASD did not. The children with ASD's difference in response times between the M and the Ph condition was also found to be significantly greater than the TD children, with significantly faster reaction times in the M condition. The findings pose questions about the nature of the children with ASD's hypo- or hypersensitivity to acoustic stimuli.

Experiment 2 employs lexical stimuli that do or do not differ in their acoustic forms from the primes. Thai disyllabic words with a consonant followed by the vowel [a] as their first syllable may undergo phonological alternations to reflect their stress pattern. Since their first syllables are unstressed, glottal stop deletion and tone neutralization may occur, changing words such as [t^h*áʔ.leː*] to [t^h*á.leː*] or [t^h*a.leː*], all sharing the same lexical meaning 'sea'. While the lexical meaning stays the same, the full form t^h*áʔ.leː* and the immediate form t^h*á.leː* are regarded as being unnatural, isolated, or hyperarticulated (Bennett, 2005; Henderson, 1949; Noss, 1975), as opposed to their natural neutralized-tone counterpart t^h*a.leː*. Experiment 2 is a repetition priming study, including the same words for both primes and targets with or without shared tonal properties. Its experimental conditions include a condition where both the primes and the targets have neutralized tones (NN), a condition where the primes have neutralized tones and the targets have full tones (NF), a condition where both the primes and the targets have full tones (FF), and a condition where the primes have full tones and the targets have neutralized tones (FN). Overall, the NN condition, which involves neutralized-tone forms in both primes and targets, yielded the highest accuracy rates by the children in performance group 1, although accuracy rates do not vary across conditions both for the children in performance group 1 and group 2. As for response times, the relative differences between the prime and the target RTs were calculated to eliminate the effect of response times to the primes. Linear regression models were fitted to the values in order to model the facilitation effects across conditions.

Generally, the FN condition was found to have significantly lower facilitation than both the NN and FF conditions in adults and the NN condition for the TD group. The ASD group, on the other hand, only showed marginal difference between the FF and the FN conditions. These results may be compared to the findings in Chen (2018)'s dissertation. Chen (2018) conducted a priming study on tone sandhi (surface) variant versus underlying tone variant targets in older (greater than or equal to 40 years old) and younger speakers (less than 40 years old) of Taiwan Southern Min. Older participants in her study exhibited significantly higher facilitation from underlying-tone overlap primes than from surface-tone overlap primes in the processing of sandhi variant targets, whereas younger participants did not display such difference in facilitation effects. Chen (2018) discussed that some participants report taking longer time in overanalyzing the underlying-tone variants which normally does not appear in the same context as the one in the experiment. She then concluded that younger participants in her study might have had limited input of the underlying variant that they failed to establish a link between underlying forms and surface forms. In my studies, the adult's facilitation effects in the FN condition are lower than two other highly facilitative conditions, whereas the FN condition yields less facilitation than the most facilitated condition in each group of the children. Such significantly lower facilitation in the FN condition in the adults and the TD children in this study indicates that they are sensitive to the underlying full-tone primes. However, such sensitivity may be due to a longer time of recovery from the unnaturalness of underlying forms or due to the shallower processing of the full-tone primes which results in less facilitation on the processing of the targets.

Similar to the FN condition, the NF condition also involves primes and targets that are not identical to each other. Adults exhibited significantly lower priming effects in the NF condition, compared to the FF condition. Taken together with the results in the FN condition, lower facilitation is generally expected in conditions with mismatched primes and targets in adults. The TD children also had significantly lower facilitation effect in the NF condition than the NN condition, suggesting their sensitivity to the mismatched phonological information. It is worth noting that part of the experimental items in Experiment 1.2 were fillers to this experiment and vice versa, meaning that all of the participants across participant groups and performance groups are exactly the same individuals at the same time point. Recall that in Experiment 1.2, no facilitation was found in the Ph condition, where the underlying forms of the primes rhyme with the targets. The remaining puzzle in Experiment 1.2 is whether such a lack in priming effect was the result of the phonologically mediated link between the neutralized form and its underlying representation or a result of their ability to establish a link between the primes and the targets through rhyming.

For the children with ASD, the NF condition yielded comparable repetition priming effects as the conditions where the primes and the targets were identical, despite its stimuli also having reduced first syllables. This fact supports the idea that the lack of phonological effect in the ASD group in Experiment 1.2 was a result of their inefficiency in establishing a prime-target connection through rhyming. Such a lack of phonological effect in the TD group, on the other hand, could be the result of them being sensitive to the mismatch in the representations between primes and targets and their sensitivity to rhyming.

In terms of individual conditions, while mean facilitation in milliseconds does not seem to differ between the children with ASD and the adults, relative facilitation proportional to reaction times to primes is generally the lowest in the children with ASD. The main results of the experiment are that the children with ASD were significantly less primed in the NN and FN conditions than the TD children, while being similarly facilitated in the NF and FF conditions. Initially, we hypothesized that the children with ASD may be more sensitive to the acoustic differences or similarities between the primes and the targets, which may affect their processing speed. Such a hypothesis predicted that the NN and FF conditions as well as the NF and FN conditions would pattern together in their facilitation effects, owing to the primes and the targets in each pair of conditions being identical or different respectively. The actual results from Experiment 2 seem to suggest that the picture is more complicated than just the acoustic identities of the stimuli. The amount of priming in the ASD group appears to be modulated by the properties of the targets themselves, rather than the connection between the surface forms and the full forms. While the children with ASD performed on par with the TD children in the conditions with full-tone targets, they were significantly less facilitated in the conditions where the targets have neutralized tone.

The question remains as to why they needed more time to process the surface forms, as opposed to the full underlying forms, resulting in their suppressed priming effects in those neutralized tone conditions. Two possible explanations for such a delay appear to be two sides of the same coin. For one, the delay might be the result of the children with ASD's struggle with the processing of the neutralized forms. Lower facilitation may only be manifested when a target is neutralized. In the case where a prime, instead of a target, is neutralized, enough time lapse between prime and target allows the processing of target to not be affected by its neutralized prime. The other explanation might be that they have a shallower processing of the full forms that they reduced the task to surface acoustic matching. Priming effects are, therefore, obtained in the conditions with full targets as they merely require faster, shallower processing than neutralized targets. An implication of this is the possibility that the 'struggle' in processing the neutralized forms as mentioned earlier is not a result of them not processing the neutralized forms but a delay in the time-course because the need for deeper processing. The TD children seem to be able to process the default neutralized forms in a much faster fashion, compared to the children with ASD.

In conclusion, the children with ASD in performance group 1 appear to be taking significantly more time than the TD children to process default neutralized stimuli, despite performing on par with them in conditions with full-form targets. Possible explanations include their shallower processing of less familiar underlying forms or their delay in the deeper processing of the default neutralized forms. Taken together with the results in Experiment 1.2, the enhanced morphological priming effects in the children with ASD, compared to the TD children, do not seem to be phonologically motivated. Otherwise, higher facilitation in the NF condition than the TD children should also be expected. In fact, the children with ASD generally exhibit lower facilitation effects across conditions in Experiment 2. Moreover, the stimuli in Experiment 2 are not synchronically morphologically decomposable. While some of the stimuli are arguably historically complex, the first word in the then compound was reduced to a mere *Ca* structure with barely any phonological trace back to the original word. The significant delay in conditions with neutralized targets found in Experiment 2 is, therefore, arguably not morphologically motivated. Such delay in processing neutralized targets may be attributed to their lexical semantic processing of the neutralized words.

2.5.7 Experiment 3: Effects of talker-token differences on lexical access

Experiment 3 aims to test the effects of non-phonological acoustic sensitivity on lexical access. As with Experiment 2, this experiment is also a repetition priming experiment. While the two versions of the stimuli in Experiment 2 are distinguished by tone neutralization as motivated by stress, this experiment deals with acoustic differences that are not phonologically motivated. In particular, it asks whether the same words spoken by speakers of different genders or different tokens of the same word by the same speaker would affect lexical processing.

While Experiments 1 and 2 found enhanced morphological effects, but impoverished phonological effects for the neutralized-tone targets, in the children with ASD of performance group 1 compared to their TD peers, they leave open the question of whether the delay in the processing of natural surface targets in the children with ASD may be the result of their delay in accessing the lexical meanings of the words. Experiment 3 utilizes the presentation of visual stimuli before auditory stimuli. This makes available lexical concepts before actual auditory lexical processing. Additionally, the results from Experiment 2 reveal no effects of word types (noun versus verb) on a similar repetition priming. All of the stimuli in Experiment 3 are, consequently, nouns.

2.5.7.1 Stimuli

The stimuli are 60 (30 monosyllabic and 30 disyllabic) simplex nouns. General methods can be found in Section 2.5.1. Two tokens per word per speaker were used in this experiment to create 3 pairs for the 3 conditions as summarized in Table 2.26. Subscripts represent token indices. In total, the test items contain 180 pairs distributed over 3 lists (60 pairs per list; 20 pairs per condition). The three conditions include (1) Condition SS, where both the primes and the targets are the exact same sound files, using the same talker and the same token, (2) Condition SD, where both the primes and the targets were two different tokens produced by the same speaker, and (3) Condition DD, where the primes and the targets were produced by two different speakers. Half of the stimuli in each condition was with a female voice and half with a male voice.

Table 2.26: Experiment 3 example prime-target pairs formed from one word: *bâːn* 'house'

Condition	Prime	Target	Pairs per list
Same Talker -	bâːn_1 (Female)	bâːn_1 (Female)	10
Same Token (SS)	bâːn_2 (Male)	bâːn_2 (Male)	10
Same Talker -	bâːn_1 (Female)	bâːn_3 (Female)	10
Different Token (SD)	bâːn_2 (Male)	bâːn_4 (Male)	10
Different Talker -	bâːn_1 (Female)	bâːn_2 (Male)	10
Different Token (DD)	bâːn_2 (Male)	bâːn_1 (Female)	10

All of the stimuli in Experiment 3 are provided in Appendix A.

2.5.7.2 Procedure

In this experiment, participants were presented with pictures and auditory stimuli. Unlike all the previous experiments where the participants made a lexical decision whether an auditory stimulus was an actual word in the language, Experiment 3 employed a picture-sound congruity task (see Coderre 2019; Cantiani 2016; DiStefano et al. 2019). The task was to decide whether a displayed picture matched with the auditory stimulus in a specific trial. Similar to a continuous lexical decision task, this task required participants to make their picture-sound congruity decision in every trial, i.e., once to the prime and once to the target. Whether the auditory primes and targets are matched with their corresponding pictures is counterbalanced across experimental conditions. To ensure enough time for picture identification, the picture was present for 600 ms before the start of the sound file and lasted until after the response. It was then replaced by a central fixation cross until the next trial started. The ISIs were random between 400-600 ms. The proportion between test items and fillers were 40% test items and 60% word fillers. Table 2.19 summarizes the procedure of the task in Experiment 3.

2.5.7.3 Modeling

Section 2.5.2 presented shared data removal and analysis procedures. As shown in the subgrouping criteria in Section 2.5.2.1, only 8 out of 32 children with ASD and 1 out of 59

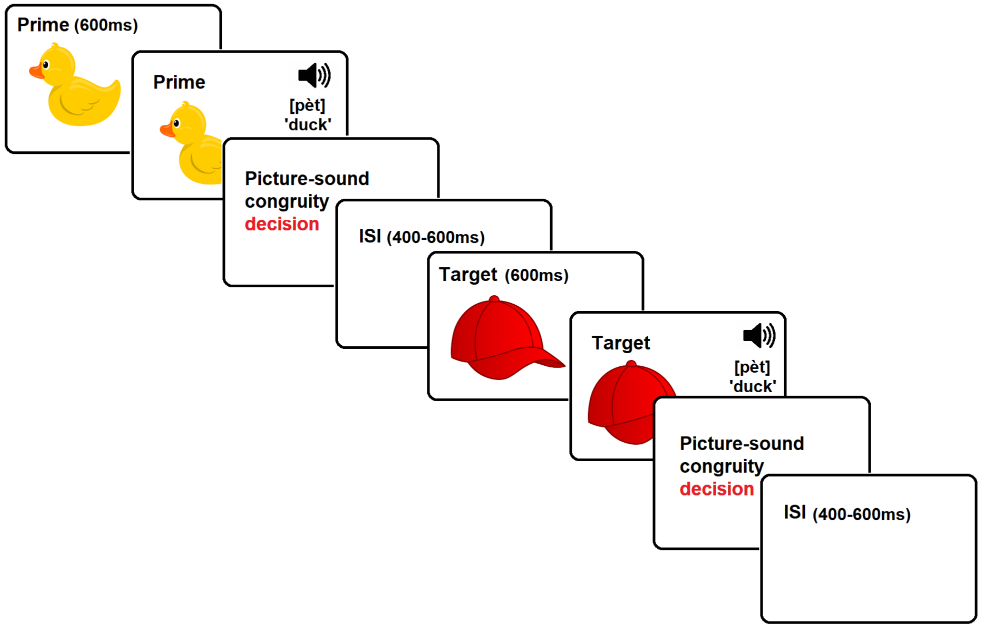


Figure 2.19: Experiment 3: The continuous picture-sound congruity decision task.

TD children were included in performance group 2 in this experiment. Due to the limited number of children in performance group 2 in this study, no logistic regression model was fitted to the target accuracies for this group of children. Only one model of accuracy was fitted to the data of the children in performance group 1. The model consisted of 10 fixed-effects factors, including *condition* (SS, SD, and DD), *z-scored duration of target*, *z-scored trial number*, *z-scored interstimulus interval* (ISI), *prime accuracy*, *log-transformed RTs to primes*, *participant group* (ASD or TD), *z-scored Ravens nonverbal IQ*, *z-scored age*, and *gender*. Also included in the model are the interactions between *condition* and *participant group*, as well as two random effects factors for participants and items. Baseline re-levelling was done through dummy coding.

As previously done in Experiment 2, Experiment 3 also utilizes the same formula, restated in (12), for the relative difference between the prime and the target RTs in each pair of trials to minimize the effects of response times to the primes.

(12) $\frac{log(PrimeRTs)-log(TargetRTs)}{log(PrimeRTs)}$

Models were fitted to relative facilitation, using 9 fixed-effects factors for the child data and 7 factors for the adult data, using the same contrast coding schemes. The factors include *condition*, *target sound-image match*, *prime sound-image match*, *z-scored duration of target*, *z-scored trial number*, *z-scored ISI*, *participant group* (only for the child data), *z-scored NVIQ* (only for the child data), *z-scored age*, and *gender*. Two pairs of interaction were coded between *target sound-image match* and *prime sound-image match* for both the adult and child data and between *condition* and *participant group* in the child data. Factors of participants and items were also added as random effects in the models.

2.5.7.4 Results

2.5.7.4.1 Accuracy

Table 2.27 provides average accuracy per condition per participant group in Experiment 3. There is merely one TD child in performance group 2, hence, no variance in the summary table and figure. An accuracy data visualization for Experiment 3 is presented in Figure 2.20. The accuracy rates are generally very high across conditions for both the children with ASD and the TD children in Group 1. For the children with ASD in Group 2, the SS condition seem to have yielded noticeably lowest accuracy rates, while the SD condition yielded the highest accuracy rates. This general pattern, however, is not supported by a logistic regression model.

Table 2.27: Percentages of accuracy by condition in Experiment 3.

	Accuracy (%)											
	Condition	Adults		Group 1				Group 2				
				ASD		TD		ASD		TD		
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Exp3	SS	99.52	1.00	90.10	10.12	93.19	6.94	47.19	7.00	57.50	NA
	SD	98.63	1.92	88.96	9.52	93.32	6.56	56.25	10.18	57.50	NA
	DD	98.87	1.42	90.63	9.51	94.22	5.68	50.31	8.39	50.00	NA

A logistic regression model, as summarized in Table 2.28, is fitted to the target accuracy of the children in Group 1. Both groups of children did not show any significant difference in accuracy across conditions. However, comparing across participant groups, the TD children performed significantly more accurately than the children with ASD in every condition,

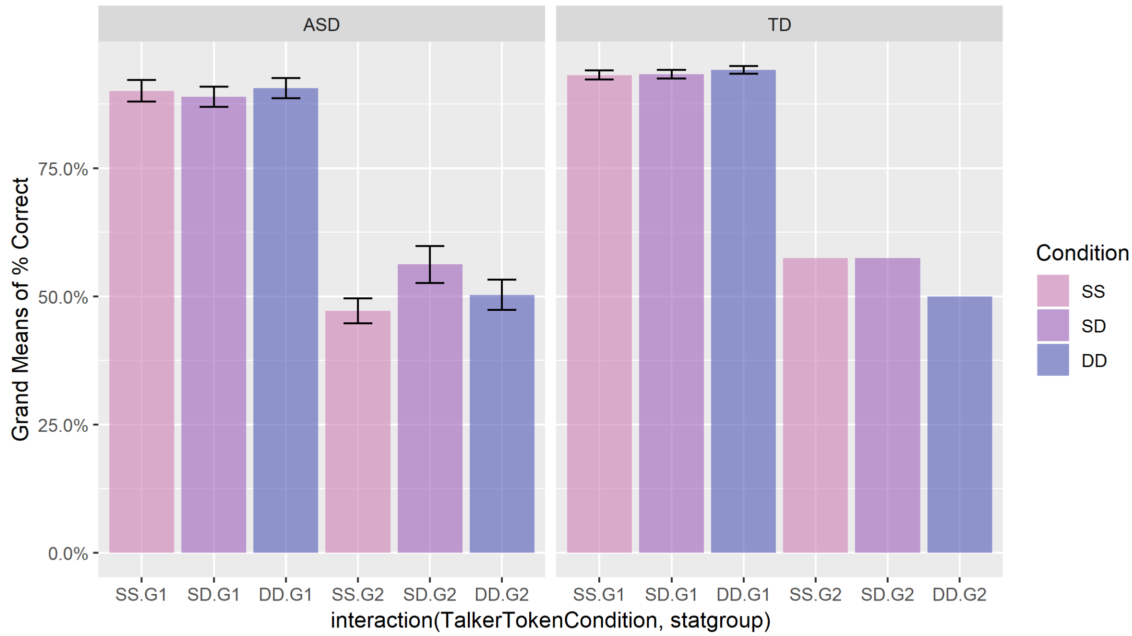


Figure 2.20: Experiment 3 - Mean target accuracy for each condition (SS/SD/DD) by participant groups (ASD/TD) and performance groups (Group 1/Group 2).

with the highest difference in the SD condition (β=1.048, $p<0.001$), followed by the DD condition (β=0.857, $p<0.01$) and the SS condition (β=0.607, $p=0.04$). Other significant predictors, on average for all the children in Group 1, include prime accuracy (β=0.721, $p<0.001$) and the reaction time to the primes (β=0.151, $p<0.01$). Similar to the accuracy model in the repetition priming study in Experiment 2, age (β=0.507, $p<0.001$) but not NVIQ (β=0.152, $p=0.58$) significantly affects target accuracy.

2.5.7.4.2 Response time

Average response times to the primes and the targets are summarized in Table 2.29. As with other experiments in this chapter, faster response times with less variance are found in adults, compared to children. The TD group seems to be also be slower than the children with ASD in processing both the primes and the targets. The raw differences between the mean reaction times to the primes and the targets in milliseconds are plotted in Figure 2.21. Overall, from the raw differences in response times, adults appear to have much less facilitation than both groups of children across the experimental conditions. In general, the

Table 2.28: Experiment 3: Summary of the accuracy model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: SS, ASD)	1.710	0.289	1.144	2.276	**<.001**
Talker-Token condition					
SS vs SD in ASD	-0.311	0.212	-0.727	0.104	0.142
SS vs DD in ASD	0.013	0.223	-0.424	0.450	0.954
SD vs DD in ASD	0.324	0.213	-0.093	0.742	0.128
SS vs SD in TD	0.129	0.167	-0.198	0.456	0.440
SS vs DD in TD	0.262	0.172	-0.074	0.599	0.127
SD vs DD in TD	0.134	0.176	-0.210	0.478	0.446
Duration of target	-0.011	0.074	-0.155	0.134	0.886
Trial number	-0.036	0.076	-0.184	0.112	0.637
ISI	0.003	0.055	-0.104	0.111	0.954
Prime accuracy (Correct vs Incorrect)	0.721	0.165	0.398	1.044	**<.001**
Log-transformed prime RT	0.151	0.050	0.054	0.248	**<.01**
Participant group (ASD vs TD; Cond. SS)	0.607	0.288	0.043	1.172	**0.035**
Participant group (ASD vs TD; Cond. SD)	1.048	0.282	0.495	1.600	**<.001**
Participant group (ASD vs TD; Cond. DD)	0.857	0.294	0.281	1.433	**<.01**
NVIQ	0.067	0.080	-0.090	0.225	0.403
Age	0.507	0.108	0.295	0.718	**<.001**
Gender (Female vs Male)	0.152	0.276	-0.389	0.694	0.581
Condition x Participant Group					
(SS vs SD) x (ASD vs TD)	0.249	0.282	-0.303	0.802	0.376
(SS vs DD) x (ASD vs TD)	0.440	0.270	-0.089	0.969	0.103
(SD vs DD) x (ASD vs TD)	-0.191	0.276	-0.732	0.351	0.490
N Primes	60				
N Targets	60				
N Subjects	82				
N Datapoints	4920				
Marginal R^2 / Conditional R^2	0.084 / 0.234				
Δ Marginal R^2 / Δ Conditional R^2	0.024 / 0.067				

Note: The baseline is the first argument in the above scheme (x vs y).

DD condition yielded the lowest facilitation across the participant groups. It is worth noting that the plot of the differences in raw reaction times may not map with their corresponding models that account for individual variations and other factors.

Figure 2.22 and 2.23 illustrate the distribution of relative facilitation in combined box and density plots for the adults and the children, respectively. The adult data is generally more uniformly distributed, compared to the child data. The plotted values in the two density plots are the values that are fitted in the linear mixed-effects regression models.

Table 2.29: Average response times by participant by condition in Experiment 3.

		Reaction Times (Milliseconds)					
	Condition	Adult		ASD		TD	
		M	*SD*	*M*	*SD*	*M*	*SD*
Prime RTs	SS	1291.58	233.70	1697.74	545.57	1868.94	664.70
	SD	1317.31	257.04	1746.30	550.39	1818.16	669.13
	DD	1290.27	229.62	1713.92	511.07	1853.41	675.47
Target RTs	SS	1189.20	255.74	1490.98	509.63	1585.67	553.44
	SD	1175.86	229.34	1442.21	477.44	1513.31	518.82
	DD	1253.50	235.83	1529.71	493.15	1611.36	568.15

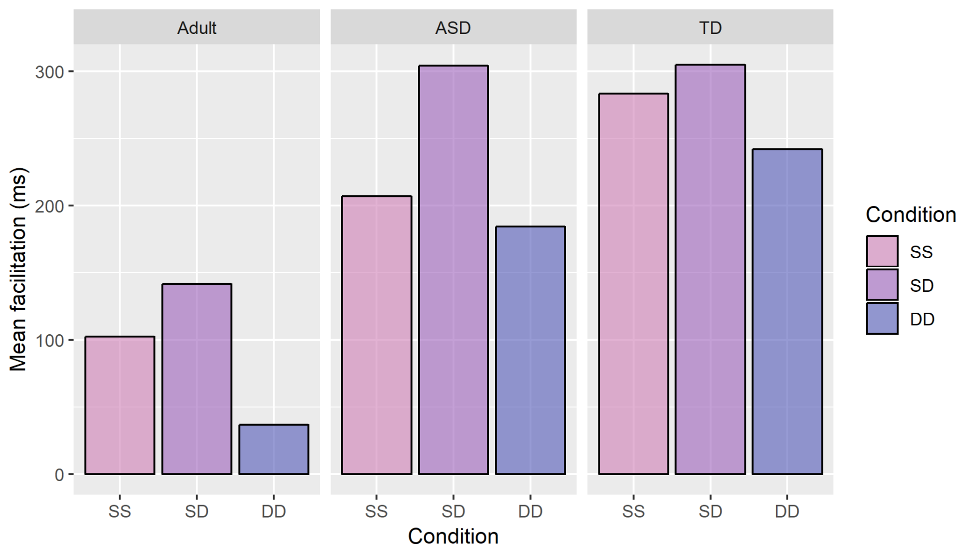


Figure 2.21: Experiment 3: Mean facilitation.

A linear mixed effects model was fitted to the relative facilitation in the adult data and summarized in Table 2.30. The DD condition yielded the least facilitation effects, with significantly less facilitation than both of the other two conditions: the SS condition (β=-0.009, p<0.001) and the SD condition (β=-0.010, p<0.001). The SS and SD conditions did not turn out to be significantly different from each other in their facilitation (β=0.001, p=0.30). As with the previous tasks, trial number significantly increased facilitation (β=0.002, p=0.02). A major difference between this experiment and previous experiments is picture-sound congruity decision task. While in the previous lexical decision tasks, the only responses that were modelled are 'word' responses, involving pressing the same button for all of the cor-

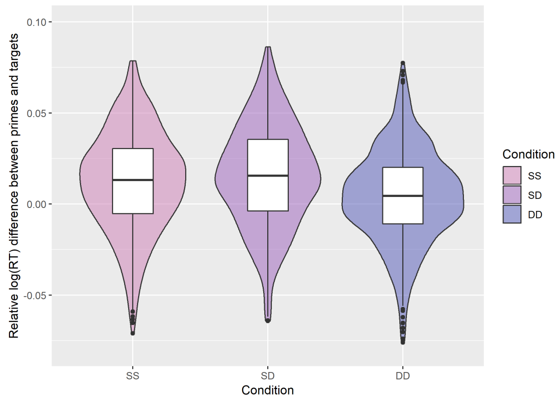


Figure 2.22: Experiment 3: Relative difference between the log-transformed RTs to the primes and the targets by the adults.

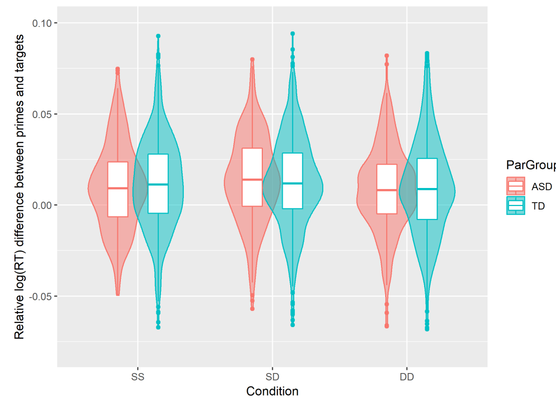


Figure 2.23: Experiment 3: Relative difference between the log-transformed RTs to the primes and the targets by the children in Group 1.

rect trials. This experiment, on the other hand, was counterbalanced by the amount of prime-target pairs that are matched or mismatched with their images across the conditions. Therefore, half of the trials in each condition involve mismatched pictures, with half of those involving hand-switching between the primes and the targets in hitting the correct button for correct responses. The models, therefore, included the factors on whether or not the picture and sound are congruous in targets, primes, and their interaction, i.e. hand-switching. The picture-sound congruities in targets (β=-0.030, p<0.001), primes (β=0.008, p<0.01), and their interaction (β=0.012, p<0.001) displayed highly significant effects on the amount of relative facilitation.

Both groups of children in Group 1 exhibited a pattern similar to the adults. The SS and SD conditions are not significantly different from each other in both the ASD group (β=0.002, p=0.26) and the TD group (β=0.000, p=0.71). Likewise, the DD condition yielded the lowest facilitation effects in both the ASD and the TD group. For the children with ASD, the DD condition is significantly different from the SS condition (β=-0.003, p=0.04) and the SD condition (β=-0.005, p<0.01). The TD children also showed lower facilitation in the DD condition than the SS condition (β=-0.003, p=0.01) and the SD condition (β=-0.002, p=0.03). With such similar patterns, no interaction was found between participant groups and differences between conditions.

Table 2.30: Experiment 3: Summary of the reaction time model for the adults.

Adults:

	Raw prime-target RT difference				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: SS, matched images)	0.019	0.002	0.015	0.022	**<.001**
Talker-Token condition					
SS vs SD	0.001	0.001	-0.001	0.004	0.295
SS vs DD	-0.009	0.001	-0.011	-0.006	**<.001**
SD vs DD	-0.010	0.001	-0.013	-0.008	**<.001**
Target sound-image matched (Yes vs No)	-0.030	0.002	-0.033	-0.027	**<.001**
Prime sound-image matched (Yes vs No)	0.008	0.002	0.005	0.011	**<.01**
Duration of target	0.000	0.001	-0.001	0.002	0.946
Trial number	0.002	0.001	0.000	0.004	**0.016**
ISI	0.000	0.001	-0.001	0.001	0.910
Age	-0.003	0.002	-0.007	0.001	0.201
Gender (Male vs Female)	-0.002	0.001	-0.004	0.000	0.121
Sound-image matched (Target vs Prime) (Yes vs No) x (Yes vs No)	0.024	0.002	0.019	0.028	**<.001**
N Primes	60				
N Targets	60				
N Subjects	31				
N Datapoints	1731				
Marginal R^2 / Conditional R^2	0.316/0.378				

Note: The baseline is the first argument in the above scheme (x vs y).

Unlike repetition priming in Experiment 2, the children with ASD were facilitated to the same extent as the TD children in the SS condition (β=0.001, p=0.61), the SD condition (β=-0.001, p=0.61), and the DD condition (β=0.002, p=0.40). The picture-sound congruities of targets (β=-0.025, p<0.001), primes (β=0.003, p<0.01), and their interaction (β=0.024, p<0.001) also significantly affect the priming effects on average across participant groups and conditions. Trial number also positively affects facilitation (β=0.002, p<0.001). Unlike the previous experiments, neither age (β=0.000, p<0.95) nor NVIQ (β=0.000, p=0.80) are significant predictors for facilitation in Experiment 3.

The predicted response times from the two linear regression models are plotted in Figure 2.24 and 2.25, sharing the same scale on the y-axis. Statistical significance levels should be checked with their corresponding models. The points are the predicted means and the notches are the predicted 95% confidence intervals. The predictions are calculated for all the

Table 2.31: Experiment 3: Summary of the reaction time model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: SS, ASD, matched images)	0.017	0.002	0.013	0.021	**<.001**
Talker-Token condition					
SS vs SD in ASD	0.002	0.002	-0.001	0.005	0.255
SS vs DD in ASD	-0.003	0.002	-0.006	0.000	**0.040**
SD vs DD in ASD	-0.005	0.002	-0.008	-0.002	**<.01**
SS vs SD in TD	0.000	0.001	-0.002	0.002	0.707
SS vs DD in TD	-0.003	0.001	-0.004	-0.001	**0.012**
SD vs DD in TD	-0.002	0.001	-0.004	0.000	**0.034**
Target sound-image matched (Yes vs No)	-0.025	0.001	-0.027	-0.023	**<.001**
Prime sound-image matched (Yes vs No)	0.003	0.001	0.001	0.005	**<.01**
Duration of target	0.000	0.000	-0.001	0.001	0.437
Trial number	0.002	0.000	0.001	0.002	**<.001**
ISI	0.000	0.000	0.000	0.001	0.573
Participant group (ASD vs TD; Cond. SS)	0.001	0.002	-0.003	0.005	0.612
Participant group (ASD vs TD; Cond. SD)	-0.001	0.002	-0.005	0.003	0.611
Participant group (ASD vs TD; Cond. DD)	0.002	0.002	-0.002	0.006	0.397
NVIQ	0.000	0.001	-0.002	0.001	0.798
Age	0.000	0.001	-0.002	0.002	0.952
Gender (Female vs Male)	0.002	0.002	-0.002	0.006	0.289
Condition x Participant Group					
(SS vs SD) x (ASD vs TD)	-0.002	0.002	-0.006	0.001	0.244
(SS vs DD) x (ASD vs TD)	0.001	0.002	-0.003	0.004	0.691
(SD vs DD) x (ASD vs TD)	0.003	0.002	-0.001	0.007	0.121
Sound-image matched (Target vs Prime)					
(Yes vs No) x (Yes vs No)	0.024	0.001	0.022	0.027	**<.001**
N Primes	60				
N Targets	60				
N Subjects	82				
N Datapoints	3801				
Marginal R^2 / Conditional R^2	0.217 / 0.283				

Note: The baseline is the first argument in the above scheme (x vs y).

categorical variables with all the other continuous variables at their mean. In general, adults displayed lower facilitation in this experiment than both groups of children. In accordance with their corresponding models, the DD condition yielded the lowest facilitation across participant groups.

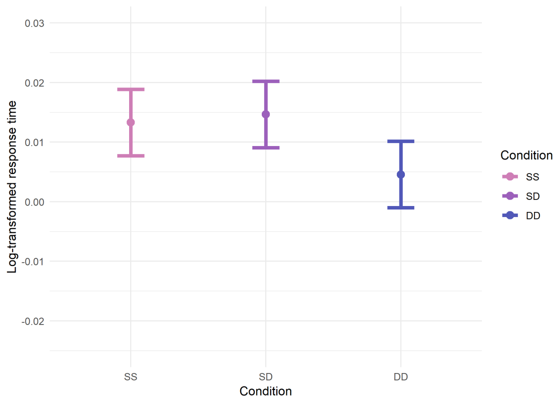


Figure 2.24: Experiment 3: The model's predicted relative facilitation for the adults.

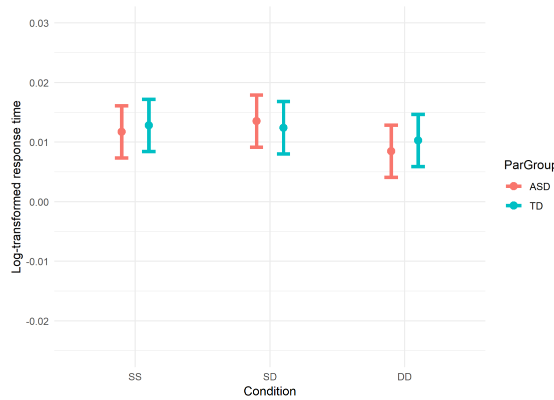


Figure 2.25: Experiment 3: The model's predicted relative facilitation for the children.

2.5.8 Interim discussion and conclusions

Experiment 3 set out to investigate non-phonological acoustic sensitivity and lexical processing. This experiment employed a repetition priming paradigm, with auditory primes and targets being the same lexical words. However, the only *true* repetition of primes and targets is the condition where primes and targets are the same sound files pronounced by the same speaker (Condition SS). Other conditions are not the repetition of the same acoustic signal, i.e., the SD condition involves the same speaker producing two different tokens of the same word, while the DD condition has two different speakers pronounce two different tokens. While Experiment 2 also utilized repetition priming paradigm, it dealt with differences that are not only acoustic but also phonological. The primes in the FN and NF conditions in Experiment 2 differ in their tones from their targets. In contrast, the differences between primes and targets in the SD and DD conditions of Experiment 3 are not phonologically, morphologically, or semantically motivated.

Compared to the previous experiments, more children were included in Group 1, with only 8 children with ASD and 1 TD child in Group 2. This results in no logistic regression model fitted to the data of the children in Group 2. As for the children in Group 1, no difference in accuracy was found across conditions. While voice and token switches do not appear to impact accuracy data, effects of participant groups were found on accuracy in all of the conditions. The TD children performed significantly more accurately than the children with ASD across the board.

Turning to the models on response times, linear mixed-effects regression models were fitted to the relative differences between the prime and target response times proportional to the response time to primes and target duration in order to model the priming effects across conditions. The same pattern of reaction times was observed in adults and both groups of children in Experiment 3. The DD condition yielded the least facilitation, compared to the SS and SD conditions in all of the participant groups. The SS and SD conditions, on the other hand, yielded similar level of priming effects across groups.

A remaining question from Experiment 2 is the nature of the processing of the neutralized targets in the children with ASD. Assuming that underlying full forms induce shallower processing, what type of additional processing in neutralized targets results in their processing delay? While morphological processing might be one possibility, the children with ASD did not seem to be delayed in their morphological processing in Experiment 1.2. In fact, they exhibited enhanced morphological effects compared to their TD peers. Moreover, the stimuli in Experiment 1.2 are synchronically simplex. The children with ASD, therefore, should not require extra time for morphological decomposition, although this fact is arguable.

Major differences, apart from their stimuli's lexical characteristics, between Experiments 2 and 3 exist in their methodology and results. First, even though the same ISI of 400-600 ms was used in both experiments, the time lapse between the auditory primes and targets in Experiment 3 is longer by 600 ms due to the picture presentation. Second, the stimuli in Experiment 2 are purely auditory, whereas the ones in Experiment 3 are both visual and auditory. The major difference between the results of the two experiments is that while the ASD group had significantly lower facilitation in the NN condition than the TD group in Experiment 2, while in the supposedly comparable SS condition of Experiment 3, they displayed the same level of facilitation. These findings suggest that when given enough time and available lexical concepts prior to the auditory targets, the children with ASD can process natural auditory stimuli equally quickly, although less accurately, compared to the TD children.

The next section concludes and discusses the results from all of the experiments in this chapter along with previous observations in the literature on lexical processing and the ASD literature.

2.6 General discussion

This chapter aims to examine the Abstract Representation Difficulty Hypothesis that children with ASD or a subgroup of children with ASD struggle with the activation of abstract lexical representations. Such struggle is hypothesized to be partly due to their hypo- or hyper-attention to acoustic details (Baron-Cohen et al., 2009; Eigsti and Fein, 2013; Jones et al., 2009; Remington and Fairnie, 2017). To explore this hypothesis, the chapter employed three main experiments to test the effects of morphology, lexical semantics, and acoustic manipulations on lexical processing. Experiment 1.1 and 1.2 were designed to determine whether there can be *Independent Morphological Processing* (IMP; Bacovcin et al. 2017) of Thai compounds, i.e., whether morphological processing exists independent of phonological and semantic relations. Experiment 2 explores the extent to which phonological relatedness affects lexical processing. This experiment utilized stimuli with underlying full tones and ones with default natural-sounding neutralized tones, in order to probe the participants' sensitivity to phonological details. Experiment 3 further explored their sensitivity to phonetic details that are not phonologically, morphologically, nor semantically motivated.

All of the experiments in this chapter included TD children and children with ASD, as well as adults. Each experiment involves subgrouping the children into two groups based on their performance. Children who had more than 60% of their data points remaining after the removal of inaccurate and extreme responses were included in Group 1. The data from this group of children were analyzed in both accuracy and response time models. The rest of the children were assigned to Group 2, and only the accuracy data were analyzed from this group. The reason for subgrouping the children was not only to ensure the reliability of the response time analysis but also to deal with the heterogeneity in the children with ASD. The literature has increasingly recognized that children on the autism spectrum are heterogeneous, especially in the linguistic domain. Proposals have been made for the subgrouping children with ASD with the group with language impairments (ALI) and the other with normal or above average linguistic abilities (ALN) (Boucher, 2012; Tager-Flusberg, 2004).

By subgrouping the children into performance groups 1 and 2, the combined individual profile across the experiments may reveal patterns that could be informative as to whether an individual child belongs to the ALI or ALN group. Moreover, the subgrouping criteria were applied to both the TD and children with ASD in the studies. A comparison between the TD and ASD groups within the same performance group can be informative about the nature of the linguistic challenges the children with ASD face as a group.

2.6.1 Major findings

2.6.1.1 Adults

When preceded by morphologically and semantically (MS) related primes, the targets yielded significantly faster reaction times in adults than when the same targets are preceded by primes that are merely semantically related (S) or morphologically related (M). Experiment 1.2 added a control condition (C) and a phonological condition (Ph), and removed the S condition. Experiment 1.2 confirms the results from Experiment 1.1 that the M and MS conditions are significantly different from each other. However, despite the M condition yielding less facilitation than the MS condition, it yielded significant priming effects compared to the C condition. While the Ph condition also showed significant facilitation compared to the C condition, significantly faster reaction times were found in the M condition, compared to the Ph condition.

Proceeding to the effects of phonological details on lexical processing, the results from Experiment 2 indicate that Thai adult speakers are sensitive to the phonological information of full/neutralized tones in lexical processing, despite the primes and the targets being the same lexical word. The adults were the least facilitated in the condition where full-tone forms prime neutralized-tone forms (FN). The FF and NN conditions, which involved exactly the same primes and targets, yielded the two highest facilitation, with the facilitation in the FF condition being significantly higher than the NF condition.

Non-phonological acoustic details, such as different talkers or tokens, were also found to affect the amount of facilitation in the repetition priming paradigm. The adults were observed to have the lowest facilitation when the primes and the targets of the same lexical words were produced by two different speakers of different genders. The primes and the targets pronounced by the same speaker, regardless of whether they are the same token or not, yielded similar priming effects.

2.6.1.2 ASD and TD children

2.6.1.2.1 Performance group 1

In contrast to the adults, neither groups of children displayed any differences in response times across the experimental conditions in Experiment 1.1. However, in terms of accuracy, the children with ASD performed significantly less accurately than the TD children in the MS and S condition, while performing on par with the TD group in the M condition. Unlike Experiment 1.1, while the children with ASD and the TD children performed equally accurately in individual conditions in Experiment 1.2, they exhibited contrasts across conditions. The M and MS conditions both had significantly higher accuracy rates than the C condition for both the ASD and TD groups. In addition, the children with ASD were significantly more accurate in the Ph condition, compared to the C condition. The TD group, on the other hand, performed significantly worse than the children with ASD, with regards to the Ph condition's accuracy, compared to the control condition. Interesting results were also found in the reaction time data for Experiment 1.2. While the adults found facilitation effects in all of the conditions, children in both groups exhibited priming effects for all of the conditions but the Ph condition. Moreover, significant interaction was found between the priming effects of the M condition (C vs M) and participant groups. The children with ASD were significantly more facilitated in the M condition than the TD children. Additionally, the difference in response times to targets of the M and Ph conditions was significantly larger in the ASD group, compared to the TD group.

Phonological effects of tone neutralization appeared to have no effect on accuracy in the repetition priming paradigm for both the ASD and TD groups. On the other hand, the response time data revealed that while the NN condition also elicited significantly higher facilitation than the FN and the NF conditions in the TD group, the children with ASD did not show significant difference across conditions. Additionally, the children with ASD generally exhibited less facilitation than the TD group, with significantly different facilitation in both of the conditions where targets are of natural-sounding neutralized tones (FN and NN).

Experiment 3 divided more participants into Group 1, leaving no accuracy model in Group 2. The accuracy data of Group 1, therefore, showed more variance, with group differences between the children with ASD and the TD children. The children with ASD performed less accurately in all of the conditions than the TD children in this experiment. In terms of response time data, the children in both groups exhibited the same pattern as the adults in this experiment, with both groups being the least facilitated in the conditions where the primes and the targets were pronounced by two different speakers. The children were also equally facilitated in the SS and SD conditions, where the same speakers produced the same or different tokens for primes and targets respectively.

2.6.1.2.2 Performance group 2

Even though the children in Group 2 were only included in the accuracy analysis, intriguing results were obtained from the studies. Accuracy seems to be good measures in relatively more challenging tasks, i.e., non-repetition priming studies in the case of this chapter. Among all the conditions in Experiment 1.1, the MS condition displayed the highest accuracy rates for the TD children, whereas it yielded the lowest accuracy rates for the children with ASD, despite them both being in the same performance group. The pattern was reflected in the interaction between the difference between accuracy rates in the MS and S condition and the participant groups.

Likewise, in Experiment 1.2 where the control condition was the least accurate among all the other groups of children, the children with ASD in Group 2 exhibited their highest accuracy rates in the control condition, which is significantly different from all the other three conditions, and additionally significantly interacting with participant group.

Experiment 2, which targets finer-grained phonological differences between the primes and the targets, did not show clear differences in accuracy rates between conditions in the same way as the first set of experiments did. The task in Experiment 3, which provides visual before auditory stimuli, may have influenced the amount of children in each performance group. Owing to the small number of children in Group 2 of Experiment 3, no definite conclusion may be made in the same regards.

2.6.1.3 Cognitive/developmental factors

Table 2.32 summarizes the effects of age and non-verbal IQ in all of the regression models of child data in this chapter. For the children in Group 1, age generally seems to be a crucial predictor on their performance on these tasks, both in terms of accuracy and response times. For the children in Group 2, on the other hand, NVIQ, rather than age, appears to be affecting their accuracy.

Table 2.32: Effects summary of age and NVIQ in regression models in Chapter 2.

		Exp 1.1		Exp 1.2		Exp 2		Exp 3	
		Age	NVIQ	Age	NVIQ	Age	NVIQ	Age	NVIQ
Group 1	Accuracy	*	**	***	NS	***	NS	***	NS
	RT	***	NS	***	NS	**	NS	NS	NS
Group 2	Accuracy	NS	NS	NS	**	NS	**	-	-

2.6.2 Implications

The evidence from this study supports the IMP hypothesis in the processing of compounds by adult native speakers of Thai. Adults display clear morphological effects that are distinct from phonological and semantic overlap. Contrary to some traditional views in psycholinguistics that claim irregular complex words are represented in the mental lexicon in their full form (hence the idea that semantic transparency is a prerequisite for morphological processing), my studies found facilitation by semantically opaque primes to be significantly more robust than mere phonological facilitation. Our results, therefore, strengthen the idea that morphemes may have their status that is independent of semantic and phonological relatedness.

The results from the children are along the same line as the adults, with one exception that the children do not display phonological effects, likely due to their struggle with rhyming relationships between the primes and the targets. The major finding is the enhanced morphological facilitation effects in the children with ASD of Group 1 compared to the TD group. While the group of children with ASD exhibit enhanced facilitation in the M condition, they do not display enhanced facilitation in the MS condition. This indicates that enhanced morphological effects can appear independent of enhanced semantic effects.

Further investigations into the phonological effects reveal that both adults and children were sensitive to the phonological differences between the primes and the targets in their lexical processing. The adults and the TD children are the least facilitated when neutralized-tone targets are preceded by underlying-tone primes. The children with ASD appear to struggle with targets that are the most natural-sounding surface forms. The results suggest that underlying forms go through a shallower processing than surface forms for children with ASD. Simultaneously, they also hint at the children with ASD's difficulties in lexical semantic processing, requiring extra time compared to the TD children in processing default forms.

When differences between primes and targets are not phonological, morphological, nor semantic, both adults and children do not display acoustic sensitivity to different tokens of the same speaker. They, however, exhibit sensitivity to tokens pronounced by different speakers. The task in this study provides participants with lexical concepts in pictures and more time before the presentation of auditory targets. Given such assistance, children with

ASD are equally facilitated as the TD children, despite having lower accuracy in all of the conditions.

The findings in this chapter provide insights for the heterogeneity in children with ASD. While the children with ASD in Group 1 mostly exhibit similar patterns as the TD children, the children with ASD in Group 2 show hyper-sensitivity to the targets that are most different from, rather than most related to, the primes. Their reversed pattern of accuracy was not only different from the children of Group 1, but also the TD children in the same performance group, suggesting a deviant pattern of struggle that is somewhat specific to their medical condition. Such a deviant pattern does not hold in repetition priming, where there are only slight phonological differences between the primes and the targets, indicating that this group of children with ASD may be attending to larger differences in acoustic details. Moreover, while age boosts the performance of the children in Group 1, non-verbal IQ does so for the children in Group 2, indicating their reliance on cognitive resources at a certain level. The current data highlight the importance of individual or subgroup differences across the autism spectrum.

In sum, this series of studies contribute to our understanding of the Abstract Representation Difficulty Hypothesis. It appears to hold that a subgroup of children with ASD struggles with activating abstract lexical representations. Adding to the hypothesis, my studies suggest that the struggle may not stem from their attention to the similarities in acoustic details but rather their hyper-attention to the noticeable differences in the speech signal. On the other hand, another subgroup of children with ASD with higher performance seems to have intact grammatical representations, with regards to phonological, morphological, and lexical semantic aspects. In fact, this group of children with ASD exhibits enhanced morphological effects, compared to the TD children, that are independent of their phonological and semantic processing. While they display the same pattern of sensitivity to non-phonological acoustic differences as the TD children, they show strong contrasts in their processing of the underlying versus the surface forms, with the surface forms engaging deeper lexical processing. An implication of these results is that they have intact phonological representation, enhanced morphological processing, compared to TD controls, and intact, i.e., deep, but slower lexical semantic processing.

The next chapter probes further into the semantic and pragmatic abilities of children with ASD. It targets the next question on the Pragmatic over Grammatical Deficit Hypothesis to explore how their pragmatic abilities look, compared to their grammatical abilities.

Chapter 3

Presupposition, Implicature, and Deixis

3.1 Introduction

The overall aim of this chapter is to explore the Pragmatic over Grammatical Deficit Hypothesis. The interplay between semantics and pragmatics plays a crucial role in the understanding of a language. By exploring both the linguistically-informed and contextually-informed meaning of an utterance, this chapter provides insights on what aspects of meaning in language are particularly difficult for children with ASD.

The chapter begins with some relevant linguistic concepts and terminology, including semantic and pragmatic inferences, presupposition, implicated presupposition, conversational implicature, and deixis. It then proceeds to provide some background literature on pragmatic deficits and autism. This chapter is divided into two main sections. Section 3.4 presents a pair of experiments on the production and comprehension of Thai personal reference terms. The personal reference system provides connections between both lexically-encoded meaning and different types of inferences. Additionally, it involves deixis, which is a highly contextual aspect of language. Section 3.5 further offers a direct comparison between types of semantic and pragmatic inferences.

3.2 Concepts and terminologies

Semantic entailment and pragmatic inference Meaning in language is not always lexically encoded or grammatically derived. In addition to the literal, truth-conditional meaning, an utterance may also have other contextually influenced meanings. For example, the sentence Kelsy said in (13) may entail its semantic meaning (13a), while also having other pragmatically inferred meanings as in (13b) or (13c).

(13) Tom: "Do you think climate change is a serious problem?"

Kelsy: "Some animals are going extinct."

a. At least one animal is going extinct.

b. Not all animals are going extinct.

c. Yes, I think climate change is a serious problem.

The meaning (13c) arises only by virtue of this particular conversation, but not from any components of Kelsy's sentence themselves. This kind of pragmatic inference is termed *particularized conversational implicatures* (*PCIs*; Grice 1975; Levinson 1983, 2000). In contrast, the meaning such as (13b) can be implicated from the sentence itself through *conversational implicature*. This kind of meaning is referred to as *generalized conversational implicatures* (*GCIs*). Nevertheless, even though this type of meaning is linguistically tied, it is still not a part of the inherent, semantic meaning. This is evident from the fact that the inherent meaning (13a) is not cancelable, as seen in (14a), whereas the pragmatic meaning (13b) is, as in (14b).

(14) a. Some animals are going extinct. #In fact, *none* of them are.

b. Some animals are going extinct. In fact, *all* of them are.

Conversational implicature As seen earlier, conversational implicatures may be distinguished from semantic entailments. Grice (1975) was the first to develop an influential systematic account for conversational implicatures, which have become one of the principal topics in pragmatics. His theory is on how and when conversational implicatures arise. The Co-operative Principle (15) and its associated maxims (16-19) were proposed to determine language users' interpretations of conversations.

(15) The Cooperative Principle: 'Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.'

(16) *Maxim of Quantity:*

a. 'Make your contribution as informative as is required (for the current purposes of the exchange).'

b. 'Do not make your contribution more informative than is required.'

(17) *Maxim of Quality:*

a. 'Do not say what you believe to be false.'

b. 'Do not say that for which you lack adequate evidence.'

(18) *Maxim of Relation:*

a. 'Be relevant.'

(19) *Maxim of Manner:*

a. 'Avoid obscurity of expression.'

b. 'Avoid ambiguity.'

c. 'Be brief. (avoid unnecessary prolixity).'

d. 'Be orderly.' (Grice, 1975, pp. 26-27)

Grice (1975) claimed that speakers of language assume that their interlocutors obey the cooperative principle and its corresponding maxims. These assumptions allow speakers to draw pragmatic inferences, which can go beyond the semantic content. Previously, in Example (13), given Tom's assumption that Kelsy obeyed the Maxim of Relation by giving him a relevant response to his question about climate change, he might then implicate the meaning in (13c) from that assumption, even though her sentence about some animals going extinct has no semantic content that seems directly relevant to his question about climate change. At the same time, Tom might also assume that Kelsy was being as informative as is required, he might then calculate the *scalar implicature* (see §3.5.1.1) that Kelsy was not talking about all animals (13b); otherwise, she would have opted to use a more informative term than 'some', such as 'all', which is stronger on the same lexical scale of quantity.

Lexical presupposition Presuppositions are another important type of inference in language as they allow more than one proposition to be communicated in one single sentence. They also serves as an indication of which proposition is the main assertion and which are merely background information (Sauerland, 2008a). While the extent to which presuppositional inferences are semantically or pragmatically driven is still the subject of considerable debate, two key attributes of presuppositions are typically assumed (Karttunen, 1973; Stalnaker, 1973, 1974). First, presuppositions convey the information that is already known but taken for granted by the speakers. For instance, similar to other change-of-state verbs like 'stop' or 'cease', the linguistic material 'going extinct' in the sentence (20) presupposes that the animals are still in existence. Second, presuppositions are still projected under embedding operators, e.g., those in (21), unlike the literal content that can be canceled by these operators (Chierchia and McConnell-Ginet, 1990; Langendoen and Savin, 1971). While the literal content – that some animals are going extinct – is not anymore conveyed by any of the above sentences in (21), the presuppositions – that the animals are still in existence – remain for all of the sentences.

(20) Some animals are going extinct.

(21) a. Some animals are not going extinct.

b. If some animals are going extinct, it is our fault.

c. Are some animals going extinct?

d. Maybe some animals are going extinct.

e. I believe that some animals are going extinct.

Implicated Presupposition The idea behind implicated presuppositions originates from Heim (1991), who observes that the infelicities of certain expressions cannot be accounted for by either lexical presuppositions or conversational implicatures. She argues that the oddness of the sentence (22) is not a result of the indefinite article *a* having a lexically-inherent non-uniqueness presupposition. While, prior to Heim (1991), Hawkins (1981) proposes that *a* and *the* are scalar alternatives, similar to what we have seen with *some* and *all*, his proposal only predicts that the sentence (22) entails that the victim has more than one father.

(22) # A father of the victim arrived at the scene. (Sauerland, 2008a, pp. 2)

However, Heim (1991) observes that Gricean conversational implicature fails to explain why the definite article *the* should be preferred over the indefinite *a* when they are equally informative in their lexical scale, i.e., they can both convey the quantity of one. The only difference between the two choices lie in their presuppositions. While *the* lexically presupposes the existence and uniqueness of its argument, *a* does not have the uniqueness lexical presupposition. Heim (1991) proposed that the non-uniqueness meaning is implicated from the fact that the speaker did not use the definite article *the*, which has the strongest lexical presuppositions: EXISTENTIAL and UNIQUENESS. In other words, if the speaker believes there to be one (EXISTENTIAL) and unique (UNIQUENESS) father of the victim, the speaker would have used the definite article or the speaker must have been violating the maxim. The use of the indefinite article, therefore, has an implicated presupposition that there is no such unique individual. Through this reasoning, Heim (1991) proposed the MAXIMIZE PRESUPPOSITION maxim (23), extending implicatures to the domain of presuppositions, not just in the domain of truth-conditional content. Her maxim suggests that the form with the strongest lexical presupposition must be chosen whenever its presupposition is felicitous. In other words, an utterance should *lexically* presuppose as much as possible.

(23) *Präsupponiere in deinem Beitrag so viel wie möglich!*
'Make your contribution presuppose as much as possible!' (Heim 1991, pp. 515)

Sauerland (2003) further built up on Heim's maxim, which was written in German with indefinite/definite articles as the only example, and proposed the term *'implicated* *presupposition'* (Sauerland, 2003, 2008a,b). The idea of implicated presupposition is that in the case where the lexical entry with the strongest lexical presuppositions is not chosen, it can be implicated that the left-out presuppositions are not assumed. While it is claimed that implicated presuppositions are pragmatically derived in the same fashion as implicature, they are still backgrounded in the presuppositional domain. This hybrid type of inference between implicature and presupposition is thus interesting in its theoretical stance and in an acquisition point of view.

Deixis Deixis serves as a linguistic hook into the contextual, perspectival aspects of utterances. With regards to the traditional taxonomy, the term 'deixis' covers kinds of references that vary by the context of an utterance based on certain important elements: person (e.g., 'I' and 'you'), time (e.g., 'now' and 'later'), place (e.g., 'here' and 'there'), discourse (e.g., 'this' and 'that'), and social (e.g., honorifics) (Fillmore 1971, 1975; Lyons 1977; Levinson 1983). Deictic information is important for interpreting utterances. Fillmore (1971) gave an illustration of when such information is lacking. If you find a message in (24) from a bottle afloat in the sea, even though the message is understood, such a totally unanchored message cannot be fully interpreted.

(24) 'Meet me here at noon tomorrow with a stick about this big'

Fillmore (1971, pp. 39)

The *deictic center* is the point to which the deictic expression is anchored. By default, the deictic center is assumed to be the speaker, but in certain contexts, it can be *shifted*. While *come* usually describes motion towards the deictic center (Talmy, 1975; Oshima, 2006; Wilkins and Hill, 1995), examples in (25) show the deictic center shifting towards other entities.

(25) a. 'Can I come visit you?'

b. 'John was preparing a meal. Then, the cat came to him.'

(Oshima, 2006)

3.3 Pragmatic deficits and autism

In the ASD literature, pragmatic deficits in ASDs are considered to be closely tied to their deficits in social skills. ASD individuals report that their lack of pragmatic skills cause them anxiety and concerns with regards to socialization. The effects seem to also last into their adulthood (Paul et al., 2014). Owing to the prevalence of pragmatic deficits across the spectrum, this domain has been the focal point of research for the past several decades (Baron-Cohen, 1988; Dewey and Everard, 1974; Kanner, 1943; Kim et al., 2014; Tager-Flusberg, 1981; Volkmar et al., 1987). However, a vast body of literature on pragmatics and autism has focused on either their social/conversational skills or the context-driven, less linguistically-informed side of pragmatics (cf. PCIs). Past literature reported an engagement in conversation with a narrower group of people (McHale et al., 1980), lower rates of conversation initiation (Bernard-Opitz, 1982), less-varied speech acts (Landry and Loveland, 1989), difficulties with turn-taking (Ghaziuddin and Gerstein, 1996), more production of bizarre/inappropriate utterances (Loveland et al., 1990), difficulties engaging in mutual, cooperative conversation (Paul et al., 2009), and so forth. Some anecdotal instances of their pragmatic difficulties are documented in various studies. Dewey and Everard (1974) reported that at a conference, an autistic boy answered the audience questions such as 'Do you have a hobby?' with a simple 'Yes'. Paul and Feldman (1984) found a similar case of a participant merely responding 'Yes.' to the question 'Did you and your sister do anything besides rake leaves over the weekend?'. Loveland et al. (1990) also reported that when asked the question, 'What would you do if someone took something of yours?', a child with autism gave a socially-inappropriate response 'Kill them.'

While the majority of literature on pragmatics and autism based its conclusions – that children with ASD have pragmatic deficits – solely on the socially or contextually-dependent side of pragmatics, first attempts on studying the linguistically-associated side found no difficulties for adolescents with ASD and adults on tasks involving scalar implicature. Pijnacker et al. (2009) asked high-functioning adults (n = 28; 8 female; M age = 26.8) to evaluate the truth values of sentences such as ‘Some sparrows are birds.’ and ‘Zebras have black or white stripes’. These sentences are logically true (cf. the ‘at least one’ meaning in (13a)) but pragmatically infelicitous (cf. the ‘not all’ meaning in (13b)). They found no statistical difference between ASD and TD adults in their proportions of judging the sentences to be false, i.e. basing their judgments on the pragmatically-inferred meaning. Chevallier et al. (2010) found the same results in high-functioning adolescents with ASD (n = 22; all male; M age = 13.3), suggesting that they are just as likely as controls to reject this kind of sentence. Hochstein et al. (2017) also reported similar results in adolescents with ASD (n = 18; 5 female; M age = 14.9), compared to their TD controls, in their scalar implicature task. However, they found that in another task where the participants need to base their answer on another person’s epistemic state, the adolescents with ASD failed to incorporate the information, resulting in them over-computing scalar implicatures in contexts where they are not justified.

We have seen consistent reports that ASD individuals have difficulties with PCI-type pragmatic inferences. The results from these three recent studies pointed to a somewhat puzzling aspect, suggesting that certain less-explored parts of pragmatics in autism may still be intact. Later sections in this chapter explore a broader variety of linguistically-bound pragmatic phenomena to see whether there are additional difficulties caused by any of these areas.

3.4 Personal reference terms

The first pair of experiments[1] was chosen to study the personal reference terms in Thai, a language that is rich in personal reference terms and consists of not only over 50 personal pronouns, but also kin terms, occupational titles, and personal names (Bandhumedha 2011; Cooke 1968; Iwasaki and Ingkapirom 2009). The Thai personal reference system allows us to explore various layers of meaning, including lexically-encoded meaning, presupposition,

[1]Parts of this section have been lightly adapted from Chanchaochai (2017). Experiment 4.2 is a newly-conducted experiment, in addition to Experiment 4.1, which was presented in Chanchaochai (2017).

implicated presupposition, person deixis, and social deixis. The chapter begins with two main topics for the background literature on the semantics and pragmatics of pronouns, the acquisition of implicated presuppositions and pronouns, and on pronouns and autism. The two experiments are then presented and discussed.

3.4.1 Previous literature

3.4.1.1 Semantics and pragmatics of pronouns

Distinctions between personal pronouns can be made along various dimensions. Along the person dimension, the first and second persons are cross-linguistically observed to be different from the third person in various ways, such as their associative plural generalization (See Greenberg 1988; Noyer 1992; Cysouw 2003.) and their bound interpretations (See Heim 1994; Kratzer 2009; Sudo 2012, etc.). While the first and second persons are generally defined as referring to the speaker and the hearer respectively, the third person is described as referring to neither (Lyons 1977). This fact led to different proposed sets of features for first and second person versus third-person pronouns. Sauerland (2008b) proposed that the third person is the most unmarked among the three persons. The verb agreements in Czech (26) is an example of how the first and second persons dominate the third person. Further evidence was presented in Sauerland (2008b) to support that the first person is more marked than the second person as seen in their dominance relationship, e.g., in English (27) and in German (28).

(26) a. bratr a já se uč-íme hrát na klavír
brother and 1.SG self.acc teach-**1PL** play on piano
'My brother and I are learning to play the piano.'

b. tvůj otec a ty jste si podobni
your father and you be.**2PL** self.DAT alike
'Your father and you are alike.' (Corbett 1991, pp. 262)

(27) You and I, **we**, are special. (Sauerland 2008b, pp. 26)

(28) Du und ich sind/*seid etwas besonderes.
you and I be.**1/3PL**/*be.2PL something special

'You and I are something special.' (Corbett 1991, pp. 262)

For languages without inclusive/exclusive distinctions, e.g., English, Sauerland (2008b) proposed that the first person has the most marked feature specifications, containing [participant] and [speaker]. The specification for the second person is only [participant]. For languages with inclusive/exclusive distinctions, including Thai[2], Sauerland (2008b) proposed the features [speaker] and [addressee] instead, leaving exclusive first person pronouns and second person pronouns undetermined in their rank on the markedness scale. In both types of languages, however, the third person lacks a person ϕ-feature altogether.[3] The lexical presupposition is, thus, not triggered by the third person. This is where Sauerland (2008b) adopted Heim's (1991) MAXIMIZE PRESUPPOSITION maxim, suggesting that the form with the strongest lexical presupposition must be chosen whenever its presupposition applies. In other words, the use of third-person pronouns gives rise to another kind of presupposition: an *'implicated presupposition'* (Sauerland, 2003, 2008a,b) that the pronouns do not refer to either of the participants. Otherwise, according to the maxim, the first- and second-person pronouns would have been used. In sum, instead of having a lexical presupposition for the features [speaker] or [addressee], the third person only has an implicated presupposition of being *'anti-participant'*.

Apart from the person dimension, pronouns may contain other descriptive features, such as, gender and number in English, to denote the properties of the referred individual. The relevant descriptive feature for this paper is gender. Sauerland (2008b) proposed that

[2]Cysouw (2013), basing on the data from Noss (1964), did not list Thai as a language with inclusive/exclusive distinctions. Instead, Cysouw (2013) listed Thai as another category having identical 'we' and 'I'. While this may be true for the pronoun *raw*, which can mean both, it is not representative of the entire Thai personal reference system. The forms /raw/ or, with the plural marker, *p^h ûak-raw* have no inclusive/exclusive distinctions, just like English 'we'. However, in Thai, there are also other pronouns that can only mean 'I' and not 'we', such as *c^h án*. Combining this pronoun with the plural marker for pronouns gives *p^h ûak-c^h án* which means 'I and some others, but not you'. This is comparable to *wǒmen* in Mandarin, which was listed as a language with these distinctions. In this paper, it is assumed that Thai is a language with inclusive/exclusive distinctions. Certain pronouns, such as *raw*, might be underspecified for the feature [addressee], resulting in the seeming lack of such distinctions.

[3]Kratzer (2009) had a similar proposal that first and second person pronouns contain the features [1st] and [2nd] respectively, while third-person pronouns only contain the feature [def] as they merely are definite descriptions, i.e., containing no inherent meanings as other persons. The difference in their proposal is that the features [1st] and [2nd] in Kratzer's (2009) proposal pick out an individual, while Sauerland's (2008b) person features are of the type <e,t>. To avoid unnecessary complications, Sauerland's system is employed throughout the paper.

among all the languages with masculine/feminine distinctions in pronouns, the feminine distinction is cross-linguistically more marked than the masculine. This can be seen in the dominance of the masculine gender over the feminine gender on agreement, e.g., in French (29) and Czech (30). In contrast, the human/non-human gender distinction varies in its markedness across languages. For instance, in Luganda, although not fully acceptable in all circumstances, the gender class 8 which agrees with non-human subjects is preferred over, i.e., dominates, the gender class 2 for human, when the subject consists of a mixed group of humans and non-humans (31). While it seems that the non-human gender in Luganda and other languages, especially the Bantu languages, is more marked than the human gender, there are languages, e.g., Tamil (Corbett, 1991), which have a reversed dominance relationship between human/non-human genders.

(29) un père et une mère excellent-s
a.MASC father and a.FEM mother excellent-**MASC**.PL
'an excellent father and mother' (Corbett 1991, pp. 279)

(30) Jan a Věra šl-i do biografu
Jan and Vera go-PST-**MASC**.PL to movies
'Jan and Vera went to the movies.' (Vanek 1977, pp. 31)

(31) a. ? omu-sajja ne em-bwa-ye bi-agwa
1-man and 9-dog-his **8**-fall-PST
'The man and his dog fell down.'

b. * omu-sajja ne em-bwa-ye ba-agwa
1-man and 9-dog-his **2**-fall-PST
'The man and his dog fell down.' (Corbett 1991, pp. 274)

Although Sauerland (2008b) proposed that the [female] gender is crosslinguistically marked, I argue that the fact only holds true in third person. In Thai, there are masculine/feminine distinctions in first- and second-person pronouns as well. The epistemic status of first person male pronoun $p^h\check{o}m$ is restricted such that the referred individuals must only be male, while that of female $c^h\check{a}n$ does not, as illustrated in (32). I, therefore, argue that for *1st* person male pronoun $p^h\check{o}m$ in Thai, the feature *[male]* is marked. For *third person*, the feature *[female]* is marked according to the crosslinguistic trend.

(32) a. *pʰŏm* hĭw
1.MASC hungry
'I am hungry.'

i) ✓referring to a male speaker ii) * referring to a female speaker

b. *cʰăn* hĭw
1 hungry
'I am hungry.'

i) ✓referring to a male speaker ii) ✓referring to a female speaker

As mentioned above, human/non-human gender distinctions vary across languages. Two markedness tests, namely the dominance test and the epistemic status test, were then applied to Thai third person pronouns. The coordination of a human and a non-human subject in (33) shows the dominance of the non-human gender. The 'it'-equivalent pronoun *man* is chosen to be a resumptive pronoun for the entire coordination. Note that when this pronoun is used to refer to a person, it is implied that the speaker does not respect them. The third-person human pronoun *kʰáw*, on the other hand, cannot be used to refer to a coordination where one of the components is non-human. The epistemic status test in (34) confirms that the non-human gender is less marked, as reference to a human is not ruled out as impossible by the use of the pronoun *man*. It is then concluded that the [human] feature in Thai is marked, while the [non-human] feature is not, giving rise to an implicated presupposition.

(33) a. * câw-kʰɔ̌ːŋ kàp mǎ: *kʰáw* dɤːn ma: dûaj-kan
owner and dog 3.**HUM** walk DEI together

b. câw-kʰɔ̌ːŋ kàp mǎ: *man* dɤːn ma: dûaj-kan
owner and dog 3.**NH** walk DEI together
'The owner and the dog walked (towards the speaker) together.'

c. * mǎ: kàp câw-kʰɔːŋ *kʰáw* dɤːn ma: dûaj-kan
dog and owner 3.**HUM** walk DEI together

d. mǎ: kàp câw-kʰɔːŋ *man* dɤːn ma: dûaj-kan
dog and owner 3.**NH** walk DEI together
'The dog and the owner walked (towards the speaker) together.'

(34) a. *man* kam-laŋ kin k^hâːw jùː
3.**NH** PROG eat rice PROG
'It is having a meal.'

i) ✓referring to an animal ii) ✓referring to a person

b. *kháw* kam-laŋ kin k^hâːw jùː
3.**HUM** PROG eat rice PROG
'He/she is having a meal.'

i) * referring to an animal ii) ✓referring to a person

Personal pronouns are also inherently deictic, meaning that they have varied referents depending on the extralinguistic contexts of who the speakers and the addressees are in a particular speech event (Fillmore 1971, 1975; Lyons 1977; Levinson 1983). In addition to involving person deixis, personal pronouns may also be socially deictic, i.e., the choice of a pronoun points to the social status of the participants in the context. This aspect is closely related to their politeness distinctions. Typologically, second person pronouns in 71 languages out of 207 investigated languages encode politeness distinctions in some way (Helmbrecht, 2013). Among these languages, 49 of them encode a binary politeness distinction (e.g., German du/Sie, Russian ty/vy, French tu/vous, etc.), while 15 encode multiple politeness distinctions (e.g., Marathi). The rarest type of politeness distinctions, found in merely 7 languages, is when second person pronouns are avoided for politeness. These languages are all spoken in East and Southeast Asia, including, Burmese, Indonesian, Japanese, Khmer, Korean, Thai, and Vietnamese. Southeast Asian languages, instead, employ other kinds of personal reference terms to politely address the hearer.

Thai is a language with a highly complex personal reference system. Personal reference system in Thai involves not only personal pronouns, but also kin terms, occupational titles, and personal names (Bandhumedha 2011; Iwasaki and Ingkapirom 2009, among others). According to the list by Cooke (1968), personal pronouns alone comprise 27 first-person pronouns, 22 second-person pronouns, and 8 third-person pronouns. The other three categories combined consist of a large number of items. Choosing pronouns among these abundant choices requires considering different factors, such as age, sex, and societal status. Kin terms, for instance, can be used in an amicable fashion to refer to people *outside of one's family*, depending on the referent's age and relationship with the speaker.

Certain personal reference terms in Thai can refer to more than one person with different pragmatic effects. For instance, in child-directed speech, a female adult can use the male first-person pronoun *pʰǒm* to refer to a hearer who is a boy. As established earlier, the male first-person pronoun *pʰǒm* is not applicable for a female speaker to use to refer to herself. By using the male first person pronoun while speaking to a boy, it reverses the features between speakers and hearers; instead of the speaker being male, the hearer is male. This kind of person syncretism is derived from deictic-center shifting, which changes the deictic center from the speaker to the hearer, as seen in abundant cases of other terms in Thai. For example, talking to their younger child, parents can refer to their older child as *pʰîː* 'older sibling'. This is a case where parents shift the deictic center to their younger child who would refer to their older child using that term. Had the parents themselves been the deictic center, the older child would be referred to as *lûːk* 'child'. Since such use of personal reference terms involves stylistic usages, this paper assumes that for certain terms where deictic-center shifting is possible, their features are not underspecified nor unmarked. Thus, their meaning should not be derived through an implicated presupposition.

3.4.1.2 The acquisition of implicated presuppositions and pronouns.

The acquisition of implicated presuppositions has received much less attention than other pragmatic inferences, with some exceptions such as Yatsushiro (2008) and Legendre et al. (2011). Yatsushiro (2008) investigated the acquisition of lexical presupposition, implicated presupposition, and scalar implicature. She examined the German universal quantifier *jeder* 'every', which both lexically presupposes existence and implicates a presupposition of anti-uniqueness. Consider the sentences in (35): since the definite determiner *the* lexically presupposes both existence and uniqueness, its use is felicitous. On the other hand, the universal quantifier *every* has an implicated presupposition of anti-uniqueness. Our encyclopedic knowledge that one can only have one biological father makes the sentence infelicitous.

(35) a. # I interviewed every biological father of the victim.

b. I interviewed the biological father of the victim. (Yatsushiro 2008, pp. 667)

Yatsushiro (2008) conducted an experiment with 120 German-speaking children and 21 adult controls. The task is to choose the felicitous sentence(s) from a choice of two sentences for describing the picture that is shown. For instance, sentences in (36) were presented as choices for describing the picture of a girl playing soccer.

(36) a. Das Mädchen hier spielt Fussball
the girl here plays soccer
'The girl here is playing soccer.'

b. Jedes Mädchen hier spielt Fussball
every girl here plays soccer
'Every girl here is playing soccer.' (Yatsushiro 2008, pp. 671)

The results show that 6-year-old children accepted (36b) significantly more than other groups of children and adults. This suggests that they have acquired lexical presuppositions, but have not fully acquired implicated presuppositions of anti-uniqueness. Yatsushiro (2008) then argued that implicated presuppositions are acquired later than lexical presuppositions, while having their acquisition path of implicated presuppositions more similar to that of scalar implicatures.

Legendre et al. (2011) examined the acquisition of pronouns in French by testing the comprehension of 3 singular and 3 plural French pronouns by sixteen 30-month-old toddlers. They found that the comprehension of third-person *elle* was at chance level, in contrast with a good performance on first-person *je* and second-person *tu*. All the plural pronouns seem to yield below-chance performance across all persons. They concluded that the results support Heim's (1991) theory of presuppositions and Sauerland's (2008b) markedness scale. The result is also in accordance with Yatsushiro's (2008) claim that implicated presuppositions are acquired later than lexical presuppositions.

3.4.1.3 Pronouns and autism

Pragmatics and discourse are generally accepted in the autism literature to be central to language deficits in autism (for reviews, see Lord and Paul 1997; Tager-Flusberg 1999; Wilkinson 1998). More recent studies (e.g., Eigsti et al. 2011; Tager-Flusberg and Joseph 2003) have found more fundamental impairments in other areas of language. Current hypotheses (See Walenski et al. 2006; Boucher 2012; Boucher et al. 2008) propose that the grammatical domains of language are impaired in ASD, while the lexical domains are still intact. Further research on language and autism is needed to support or challenge such a claim.

Among pragmatic deficits, difficulties in personal pronoun use have been observed since the beginning of the study of autism by Kanner (1943). Such difficulties with pronouns in ASD were also reported in many of the later studies (see, for instance, Bartak and Rutter 1974; Charney 1980; Chiat 1982; Fay 1979; Loveland 1984). Mizuno et al. (2011) explored the neural basis of the personal pronouns *I* and *you*, in comparison with names which denote fixed identity in adults with high-functioning autism. The results show slower and less accurate responses when the task involves personal pronouns rather than names. Moreover, for questions containing the second person pronoun, this study detected an underconnectivity between right anterior insula, primarily involved in self-awareness and self-consciousness, and precuneus, essentially involved in spatial attention. The underconnectivity did not, however, appear with the questions containing first person pronouns.

Interestingly, errors in pronoun usage in autism are not restricted to deixis and the reversal of person features (37), but also involve errors in case markings (38). This leads to further questions about where the difficulties actually lie when it comes to the processing of pronouns in autism.

(37) a. "You want candy."

b. "Hurt yourself."

c. "Help you please." (Tager-Flusberg 1994, pp. 185)

(38) a. "My get it."

b. "Me cool off."

c. "Do down me arm." (Tager-Flusberg 1994, pp. 184-5)

As for Thai personal reference terms and autism, Chanchaochai (2013) observed three children with ASD over a three-month period and found that personal reference terms with lower deictic levels, including kin terms, occupational titles, and personal names, were preferred over the ones with higher deictic levels like pronouns. Person deixis avoidance is thus another phenomenon that may play a role in the production of Thai personal reference terms in autism.

3.4.2 Experiment 4: Production and comprehension of personal reference terms

3.4.2.1 Shared methods

3.4.2.1.1 Stimuli

The main design of the first two experiments adapts the Fishing Task (Girouard et al. 1997; Legendre et al. 2011). In Experiment 4.1, done in 2016, the speech context comprises five participants, including the experimenter (E), the child (C; tested individually), and 20-inch-tall cardboard figures of a boy (B), a girl (G), and a monkey (M; see Figure 3.1.). The blank space, held by each of the cardboard figures, was left for attaching 58 cards with pictures of different objects using a reusable adhesive. Based on the results from 2016, Experiment 4.2 in 2017 left out the monkey figure, while retaining other details.

Tested personal reference terms For the comprehension task of Experiment 4.1, all of the personal reference terms applicable to the context of the experiment were chosen. The test phase included 8 personal reference terms: 1 first-person, 4 second-persons (3 pronouns for each child depending on the child's gender, i.e., *nǔː* for girls and *p*^{h}*ǒm* for boys as highlighted in Table 3.1), and 3 third-persons. The selected terms are personal pronouns, except for two terms: *p*^{h}*îː* 'older sibling' and *nɔ́ːŋ* 'younger sibling', which are

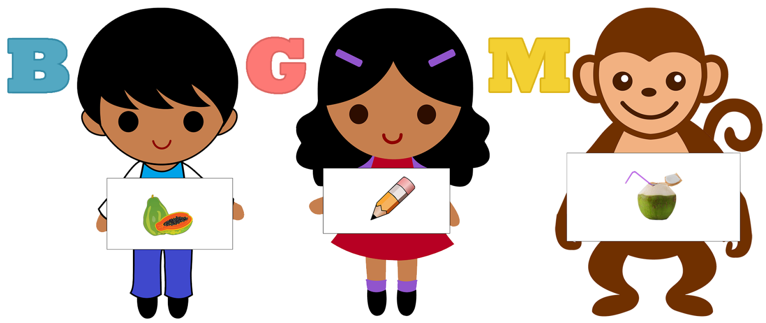


Figure 3.1: Extra *participants* in Experiment 4.1 (Boy, Girl, and Monkey) and Experiment 4.2 (Boy and Girl)

kin terms. The order of the pronouns in question was pseudo-randomized such that the possible answers of each phase do not refer to all the speech participants, so that they do not leave later referents predictable. The randomization methods make the amount of trials per each pronoun different. Each targeted pronoun was, however, repeated at least twice. Experiment 4.2 left out the second-person kin term *nɔ́ːŋ* younger sibling and the third-person non-human pronoun *man*. The first-person pronoun *k^hâː* was instead added in an attempt to compare it with the unambiguously second-person pronoun *k^hun* in the formal register. The pronoun *k^hâː* is unambiguously first person but is outdated and not widely used, except in storytelling. Both the pronouns *k^hâː* and the newly-added pronoun *k^hâː* are, therefore, **not** pragmatically appropriate to the context of the experiment.

Based on the literature discussed in Section 3.4.1.1, tentative semantic denotations for the personal reference terms that were used in the experiment are provided in Table 3.1. The denotations of each pronoun are merely semi-formal so as to clearly illustrate their possible feature bundles to the readers. This table summarizes all the possible denotations of each personal reference term whose target is restricted to only one referent by the context of the experiment. For instance, the first term in the table *p^hîː* 'older sibling' can be used to refer to either the speaker or the addressee as long as the referent is the older one in the situation. Therefore, in the setting of this experiment, when I, the experimenter, used this term to talk to a child, this term always referred to me, the older participant. Likewise, if the child used this term in this situation, it would still refer to me, the older experimenter.

Table 3.1: Tested personal reference terms in Experiments 4.1 (p^h*îː*, *nǔː*/p^h*ǒm*, k^h*un*, *nɔ́ːŋ*, k^h*ǎw*, t^h*ɤː*, and *man*) and 4.2 (k^hâː, p^h*îː*, *nǔː*/p^h*ǒm*, k^h*un*, k^h*ǎw*, and t^h*ɤː*). Stimuli differences between two experiments are marked with asterisks.

Participant					
Term	**Person**		**Gender**	**Social-deictic** [4]	**Target**
k^hâː*	speaker	{1st}	-	outdated/story-telling	E
p^hiː	participant	{1st, 2nd}	-	older sibling	E
nǔː	participant	{1st, 2nd}	-	younger participant	C
p^hǒm	speaker	{1st}	male	-	C
	addressee	{2nd}	male	younger participant	
k^hun	addressee	{2nd}	-	formal	C
nɔ́ːŋ*	participant	{1st, 2nd}	-	younger sibling	C
Anti-participant					
Term	**Person**		**Gender/ Social-deictic**	**Implicated Presup**	**Target**
k^hǎw [5]	-		human	anti-participant, non-feminine	B
t^hɤː	addressee	{2nd}	peer	-	G
	-		human, female	anti-participant	
man*	-		-	anti-participant, non-human	M

This is different from the pronouns p^h*ǒm* and t^h*ɤː*, which have more complex dimensions while being used as different persons. In Section 3.4.1.1, I proposed that deictic-center shifting does not involve unmarked person features. Thus, even though the pronoun p^h*ǒm* is technically a first-person pronoun for men of any age, it is also marked with 2nd as a separate entity since it can be used only in child-directed speech, where deictic-center shifting is employed. As for the pronoun t^h*ɤː*, it is generally a second-person pronoun when the addressee is of an equivalent age or social status. The addressee can be younger or in a lower social status as well but that is only used in an unfriendly and distant (almost degrading) sense. Since the experimenter is not the children's peer and also ended each sentence with a polite final particle, the second person reading should not be applicable in this context.

[4]Social-deictic features are normally listed in the encyclopedic (non-linguistic) knowledge. It may be possible that in certain languages, some social descriptive features are encoded in the grammar. It is beyond the scope of this paper to discuss the claim. The social descriptive features are only included for the reader's understanding of these pronouns.

[5]Its reduced form k^háw (more frequently used) are underspecified for gender. Only the full form was

3.4.2.1.2 Procedure

In the beginning of each block, the children were first asked to name pictures of commonly known animals and objects. The pictures were then distributed across participants. Before the production task, no pronouns were used so as to avoid priming the children. In the test phase, each participant in the production task or each term in the comprehension task was randomly selected as the expected target at least twice. A different set of 5 objects was changed after every 3 trials. Below are the instructions in the order as they appeared in the experiment.

Preparatory Phase:

E: 'What's (your) name?'[6]

E: 'What is this?' (Repeat for 5 objects per block.)

Production Task:

Test Phase:
E: 'Who is holding *X*?' (Twice for each target.)
C: '___ (is holding *X*.)'

Comprehension Task:

Familiarization Phase:

E: 'What is $Y_{\{the\ boy/girl/monkey/child's\ name\}}$ holding?'

C: '(Y is holding) X.'

Test Phase:
E: 'What is $Y_{\{tested\ pronoun\}}$ holding?'
C: '(Y is holding) ___.'

tested.

[6] Thai is a pro-drop language so pronouns can be avoided here.

3.4.2.2 Experiment 4.1

3.4.2.2.1 Results

Overall accuracy One ASD child was withdrawn from the experiment because he did not answer any of the questions. His results were excluded from the calculations. An answer was marked as accurate when it referred to the right referent. The accuracy rate for production is near ceiling for both the ASD (94.6%) and the TD (90.6%) groups with children with ASD performing significantly more accurately (Mann-Whitney U=97595, p=0.04). The accuracy rate for comprehension dropped for both groups (60.4% for ASD; 82.3% for TD) with a much sharper drop for ASD (Figure 3.2). The comprehension task accuracy thus yields a highly significant difference between participant groups (Mann-Whitney U=658640, p<0.001).

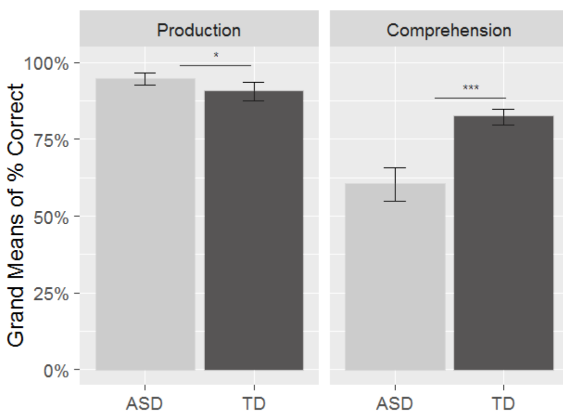


Figure 3.2: Experiment 4.1: Overall accuracy across tasks.

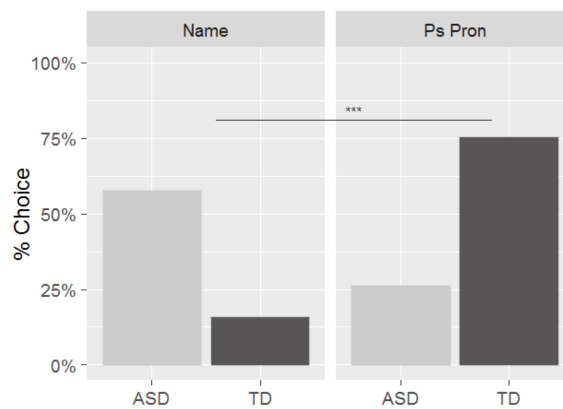


Figure 3.3: Experiment 4.1: Choices of terms the children used to refer to themselves.

Production The most common personal reference terms that the children in both groups used to refer to themselves are personal names and personal pronouns. However, they were found in a reversed preferred pattern (Figure 3.3). In the ASD group, personal names were used 57.4% of the time versus 25.9% for personal pronouns, compared to 15.7% versus 75.2%, respectively, for the TD group. The proportion of counts for the two most commonly-chosen categories for self-reference showed a very significant difference across participant groups (Fisher's Exact, p<0.001). The choice for referring to the experimenter and all other third-persons was not significantly different across groups (Fisher's Exact, p=0.23 and p=0.19 respectively).

Comprehension Overall, third person yields the poorest performance for the ASD group (See Figure 3.4). As for the TD group, only the male third person yields poorer performance among the third persons. The only form where children with ASD outperformed TD children is the formal second-person pronoun $k^h un$ with a non-ambiguous referent. A fixed effects logistic regression model (Accuracy $\sim$ Group + Gender + zAge + zNVIQ) was run on the comprehension task. It reveals that the accuracy is significantly different across participant groups (z=10.736, p<0.001), age (z=12.294, p<0.001), and NVIQ (z=10.167, p<0.001). The gender of the participants is not a significant factor for their performance (z=-0.015, p=0.99).

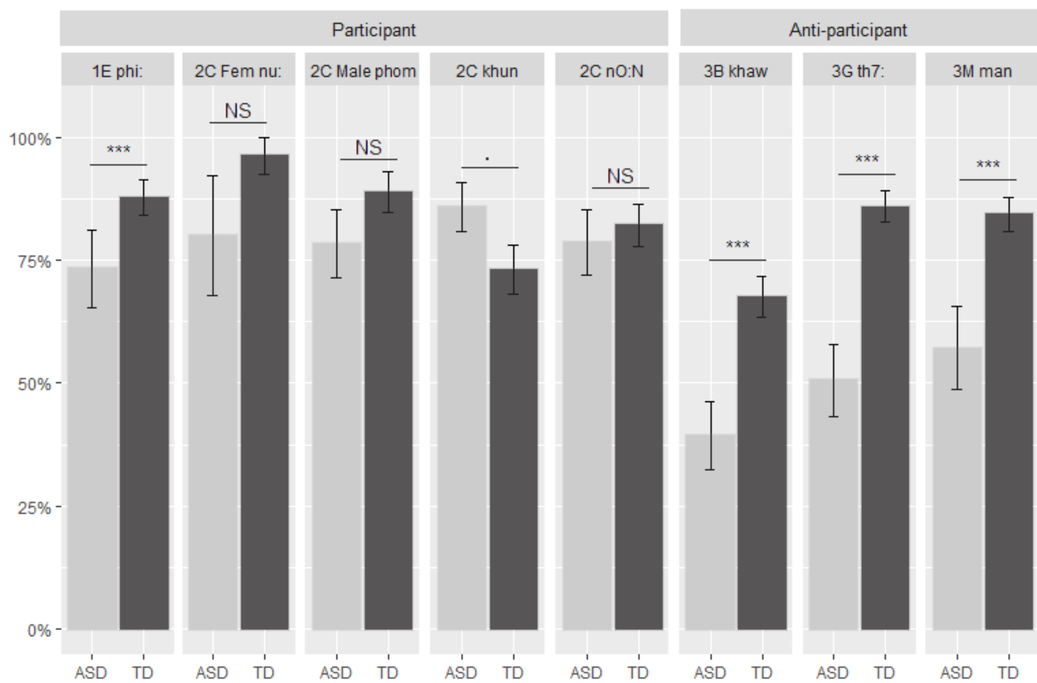


Figure 3.4: Experiment 4.1: Accuracy in comprehension task by item

3.4.2.2.2 Error analysis

This section explores the pattern of errors in the comprehension task. Figure 3.5 shows the percentages of errors among all trials. This is to examine the choices the children opted for, instead of the expected referents.

Experimenter-Targeted: Instead of choosing the experimenter as the target for the pronoun *pʰîː* 'older sibling', a subgroup of both ASD and TD children mistook the term for referring to the cardboard figures (Figure 3.5a). The children with ASD made more mistakes answering that they themselves were the referent to the term 'older sibling', while in fact, they were not older (ASD 8%; TD 1.5%).

Child-Targeted: A similar pattern was observed in the comprehension of the term *nɔ́ːŋ* 'younger sibling' where the children chose the cardboard figures as the referent, instead of choosing themselves (Figure 3.5e). Some children with ASD also chose the experimenter as the referent for the terms *nǔː* (1st/2nd younger female) (10%; Figure 3.5b), *pʰǒm* (1st male deictic-center shifted) (8.7%; Figure 3.5c), *kʰun* (2nd formal) (1.8%; Figure 3.5d), and *nɔ́ːŋ* 'younger sibling' (1.8%; Figure 3.5e). As for the TD children, regardless of the number of errors they made in the comprehension of the formal second person pronoun *kʰun*, the experimenter was never one of the wrong targets for any of the tested second person pronouns.

Boy-Targeted: The majority of mistakes made by both ASD and TD were related to gender, where they chose the cardboard girl figure instead (ASD 25.9%; TD 20.5%). With regards to the person feature, the children with ASD chose more non-third-person targets than the TD group (24.1% versus 6%; see Figure 3.5f).

Girl-Targeted: The pronoun used for targeting the girl is *tʰɤː*. As noted earlier, this pronoun is generally used to refer to a second person, with underspecified gender. Although the usage as a second person is very common, it is only used among people of the same age or status. It is highly likely that the participants were referred to by their peers using this pronoun. If the speaker of the pronoun is an older person, the addressee and the speaker must be close to each other (stylistic use), otherwise, the term would sound very unfriendly and pragmatically inappropriate. The results seem to show that this social dimension of the pronoun was largely ignored by the children with ASD, choosing themselves as the target 31% of the time (Figure 3.5g).

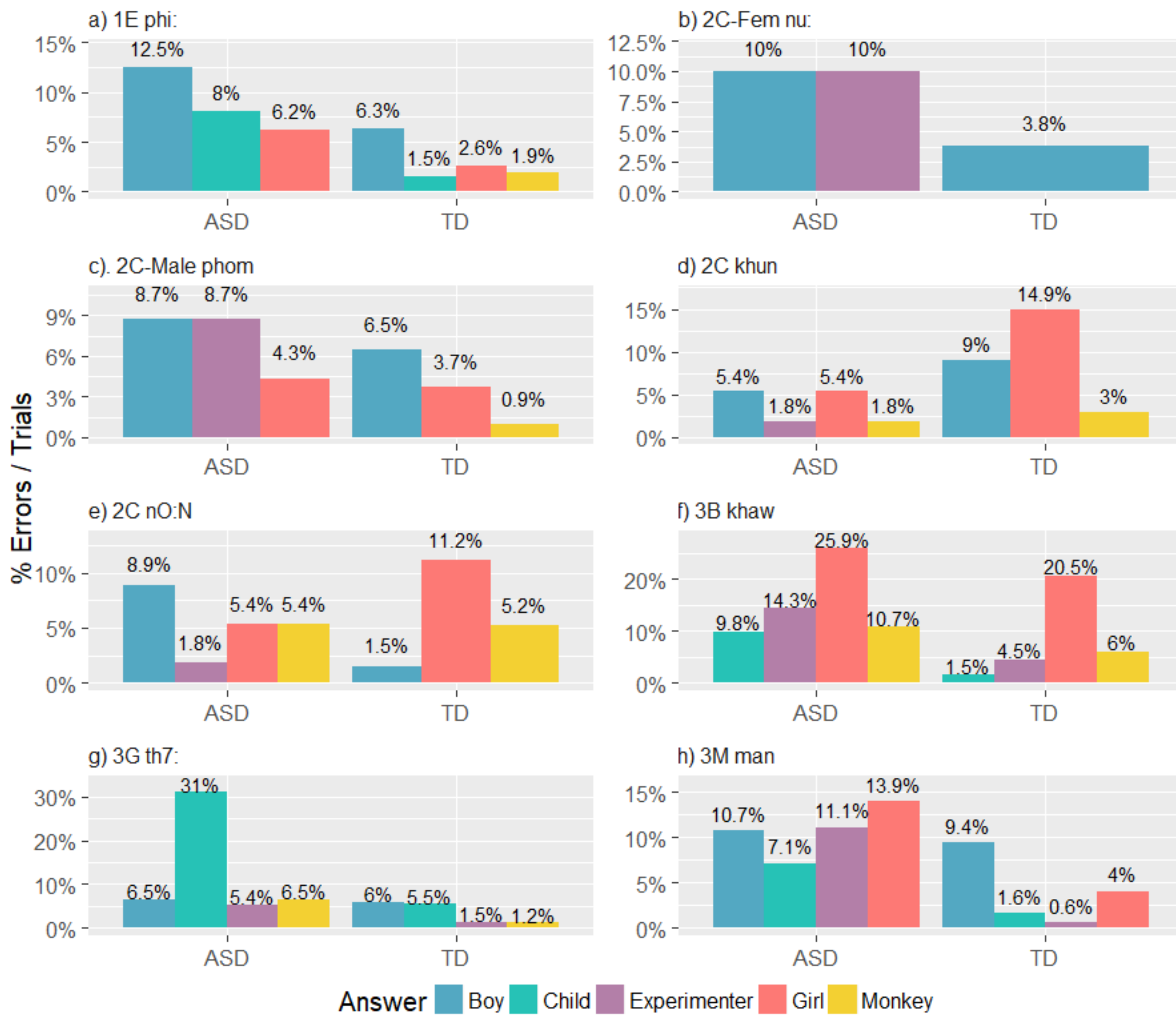


Figure 3.5: Experiment 4.1: Errors in comprehension task by item

Monkey-Targeted: The errors for *man* covered all four other choices (Figure 3.5h). The children with ASD made mistakes with regards to person features, choosing the experimenter or themselves (11.1% and 7.1%, respectively) at a much higher rate than the TD children (0.6% and 1.6%).

3.4.2.3 Experiment 4.2

Experiment 4.2 mainly adopted the same methods used in Experiment 4.1, with three main changes. First, the monkey was left out from the experiment, along with third-person non-human pronoun *man*. Second, the second-person kin term *nɔ́ːŋ* younger sibling was removed. Third, a new unambiguously first-person pronoun k^h*âː* was added to directly compare with the results obtained from the unambiguously second-person pronoun k^h*un* in the formal register. While this newly-added pronoun k^h*âː* is unambiguously first person, it is also pragmatically marked because of it being outdated and not widely used, except in storytelling.

3.4.2.3.1 Results

Overall accuracy Four children with ASD were withdrawn from the experiment because they either did not answer the questions or scored less than 50% in the production task. The children in both groups have near-ceiling accuracy rates (97.3% for ASD; 99.38% for TD) in the production task, while having lower accuracy rates in the comprehension task (58.18% for ASD; 65.97% for TD). The TD group scored significantly higher in both the production task (Mann-Whitney U=52656, p=0.02) and the comprehension task (Mann-Whitney U=658640, p<0.001).

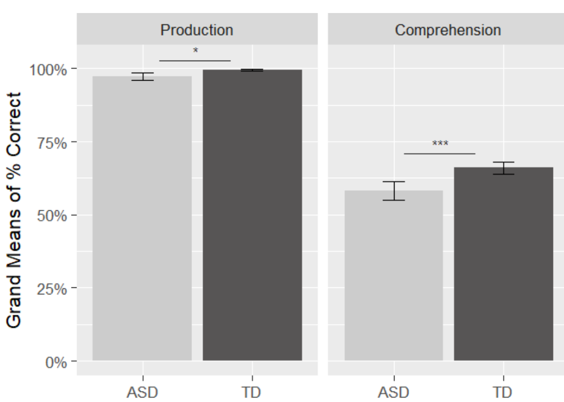


Figure 3.6: Experiment 4.2: Overall accuracy across tasks.

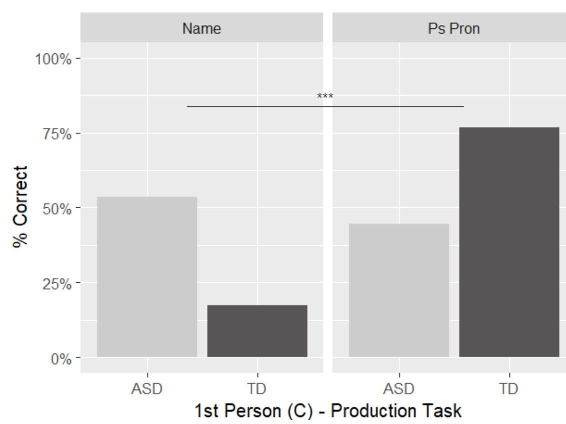


Figure 3.7: Experiment 4.2: Choices of terms the children used to refer to themselves.

Production The results in the production task of Experiment 4.1 are replicated. The ASD group preferred to use personal names to personal pronouns (53.6% vs 44.6%) for self-reference, while the revered pattern was found in the TD group (17.5% vs 76.7%; see Figure 3.7.). The difference in the proportion of counts was highly significant (Fisher's Exact, p<0.001). The choice for referring to the experimenter and all other third-persons was not significantly different across groups (Fisher's Exact, p=0.39 and p=0.23 respectively).

Comprehension As predicted, the newly-added pronoun k^h*âː* is difficult for both groups of participants. Third person pronouns still yield poor performance for the ASD group (See Figure 3.8). As for the TD group, the male third person still yields the poorest performance. In this experiment, the TD performance on the female third person pronoun t^h*ɤː* is lower than the TD performance in Experiment 4.1, although they still scored significantly higher than the ASD group. Consistent with Experiment 4.1, the only form where children with ASD significantly outperformed TD children is the formal second-person pronoun k^h*un* with a non-ambiguous referent. Similar results were obtained from a fixed effects logistic regression model of the comprehension task (Accuracy ∼ Group + Gender + zAge + zNVIQ). Participant groups (z=2.88, p=0.004), age (z=4.814, p<0.001), and NVIQ (z=2.526, p=0.012) were found to be a significant factor predicting their accuracy, while the gender of the participants was not (z=-1.319, p=0.187).

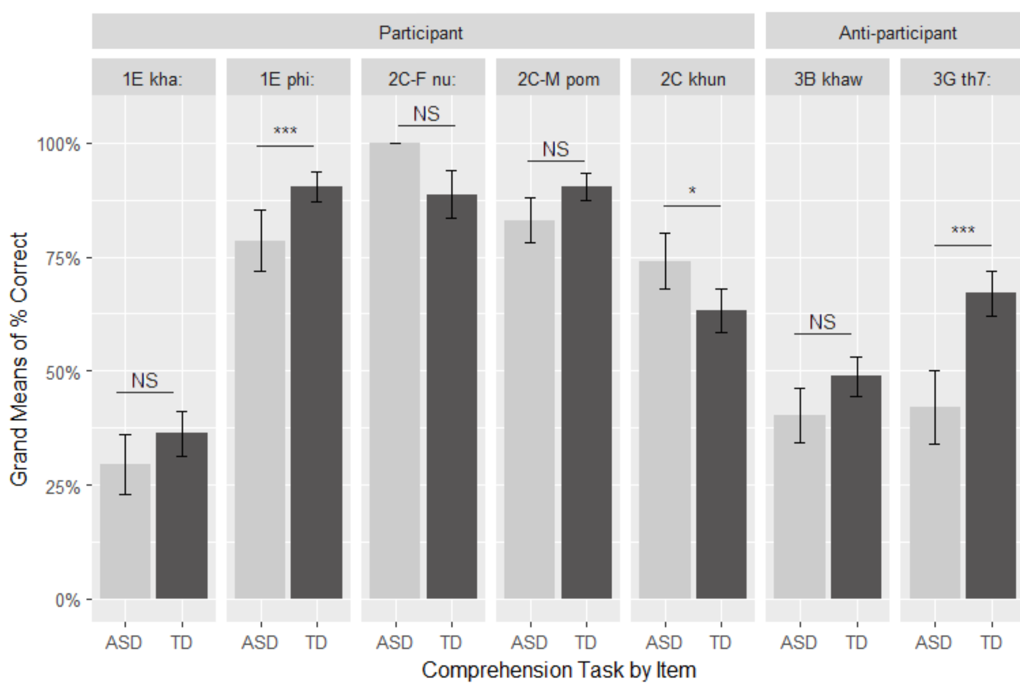


Figure 3.8: Experiment 4.2: Accuracy in comprehension task by item

3.4.2.3.2 Error analysis

Similar pattern of errors was found in this experiment as seen in Figure 3.9. As for the newly added pronoun $k^h\hat{a}ː$, the children in both groups seem to be at chance level in choosing whether it refers to the first, second, or third person. Both groups made the most errors thinking that the pronoun is child-targeted, instead of experiment-targeted (ASD 37.5%; TD 36.2%). The children with ASD mistook it as referring to the third person for 33% of the trials, while the TD chose the third person 27.4% of the time.

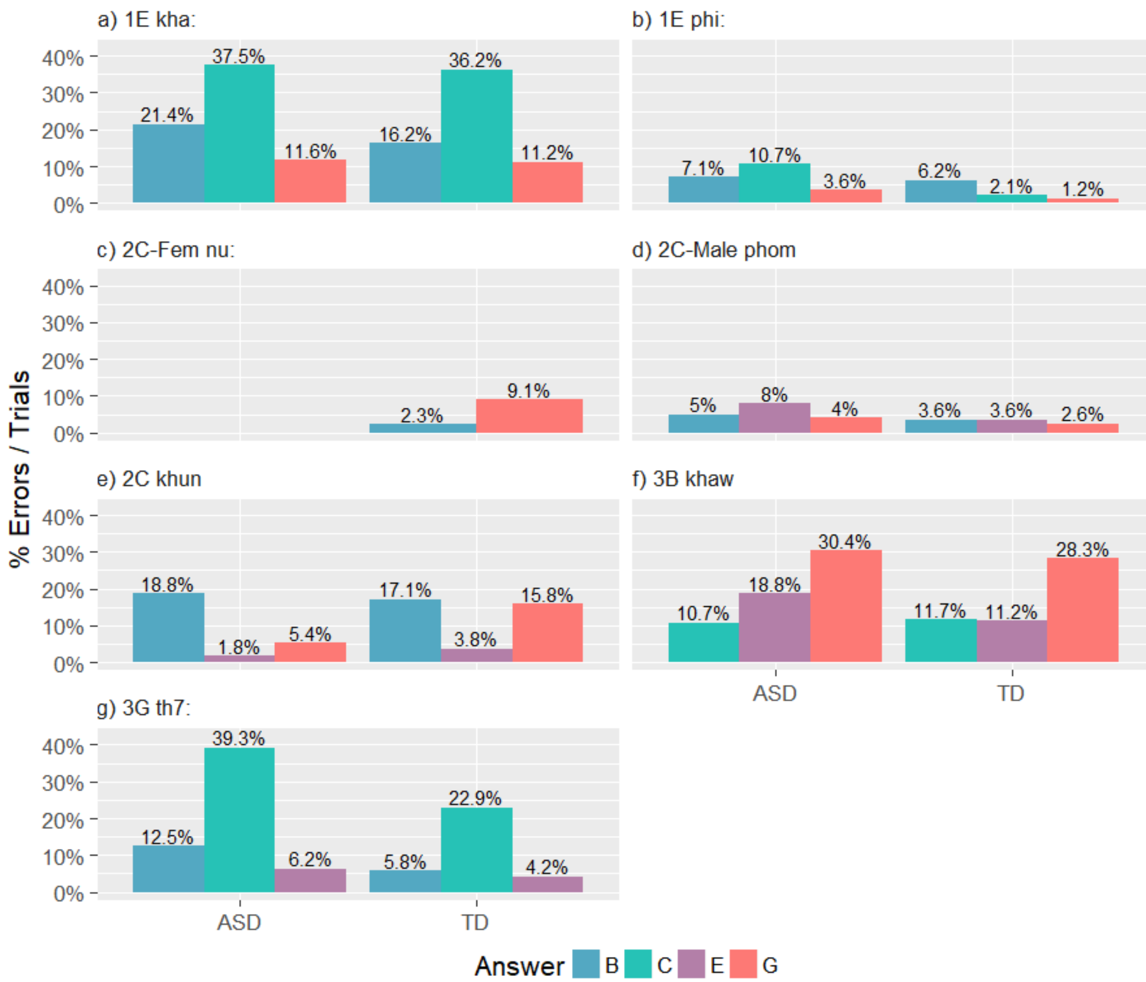


Figure 3.9: Experiment 4.2: Errors in comprehension task by item

3.4.3 Interim conclusion and discussion

The performance on production and comprehension was asymmetrical in both participant groups, with the children with ASD performing significantly more poorly than the TD children in the comprehension tasks in both of the experiments. Lexical presuppositions seemed to be easier to comprehend than implicated presuppositions for both groups of children, as seen from the generally higher accuracy in pronouns with marked person ϕ-feature. Even though their overall accuracy is lower than TD children, children with ASD are, to a large extent, able to comprehend the lexical presupposition suggested by the person ϕ-feature, when the person feature is not underspecified. This was suggested by the fact that *k^h^un* (2nd formal) is the only pronoun on which the ASD group significantly outperformed the TD group. The TD group's performance, on the other hand, seems to be suppressed by the social awkwardness of using the formal pronoun to refer to a child, while the children with ASD solely paid attention to the person ϕ-feature as they largely ignored the social deictic dimension of the formal second-person pronouns.

Experiment 4.2 attempted to explore the same kind of effects in k^h*un* (2nd formal) on the first person by adding the pragmatically-inappropriate but unambiguous pronoun k^h*âː* (1st outdated/story-telling). The results showed that unlike the pronoun k^h*un*, the performance of both groups k^h*âː* (1st outdated/story-telling) was at chance level. This indicates that this pronoun may either not yet be acquired by the children or that some children may have been confused by the pronoun being used in this particular context.

A similar result was found in the errors in the comprehension of the pronoun t^h*ɤː*, targeting the cardboard girl figure. The children with ASD made significantly more mistakes than the TD children even though the [female] feature is marked, suggesting that person ϕ-features are the most prominent cue for them, not gender or social descriptive features. This is in accordance with the overall results that the children with ASD could correctly detect the marked person feature of a pronoun but failed to take into account the social descriptive features (that the term is mostly used among peers) or to recognize the social relationship in a particular context (that the experimenter is not his/her peer).

However, given the freedom of production, children with ASD avoid person deixis by choosing fixed referential terms (names) rather than terms with a higher level of person deixis (i.e., pronouns) to refer to themselves. To refer to the experimenter, both of the groups mainly chose to use either kin terms or occupational titles. Recall that Thai is among the seven languages that omit second-person pronouns for politeness. If a relationship between the speaker and the addressee is known, the term denoting that relationship, rather than a second-person pronoun, should be used. As for the terms used for cardboard figures, children in both groups chose to use common nouns, rather than any personal reference terms. This can be explained by the fact that the use of pronouns also presupposes salience (Roberts 2004). The children preferred the full form over the pronouns because the referent was not salient or not as salient as other possible referents in the context. If the experiment had been conducted in English, the same results should still be expected, as can be seen in the examples below where a weakly familiar referent does not guarantee salience (39). It is, therefore, not possible to conclude that the choice of less deictic terms for the second- and third-person referents in the experiment is the case of person deixis avoidance or not.

(39) a. * In Amsterdam, if a bicyclist isn't very careful, it'll be stolen.

b. In Amsterdam, if a bicyclist isn't very careful, her bicycle will be stolen.

(Roberts, 2004, pp.517)

In terms of implicated presuppositions across populations, challenges arise in the resolution of implicated presuppositions when certain ϕ-features are unspecified. For the ASD group, person unmarkedness alone could decrease their performance, as can be seen in the lower performance in all the third-person forms. The further pragmatic inference that has to be made for the gender unmarkedness of male pronouns had an additive decreasing effect for the ASD group. The implicated presupposition from the unmarked non-human feature seemed to be easier than that from the unmarked masculine feature across participant groups. The TD group's performance was affected the most in male third-person pronouns, compared to other third-person forms. This suggests either that the TD group may only be affected when two implicated presuppositions (from person and gender unmarkedness) appear simultaneously or that the gender unmarkedness is particularly difficult for them. Such performance on different kinds of implicated presuppositions and deixis might correspond to the order of acquisition.

It is worth noting that in Experiment 4.2, the TD's group performance on the female third-person pronoun t^hɤː was poorer than in Experiment 4.1. This may be explained by the removal of the monkey figure in Experiment 4.2. Having three distinct words targeting at the gender feature in Experiment 4.1 highlighted the [female] feature of the pronoun t^hɤː, providing the TD children more clues towards selecting the intended referent. Despite the lower performance in Experiment 4.2, their accuracy rates on this pronoun remain significantly higher than the ASD group's performance.

As for the case where adult native speakers of Thai seem to, prima facie, reverse 'I' and 'you' while talking to young children, pronouns with deictic-center shifting seemed to yield similar results to kin terms and other first and second person pronouns. This supports the hypothesis that person syncretism as a result of deictic-center shifting is not the same as that which involves person underspecification.

3.5 Presupposition and implicature

This section aims to investigate the adult and children's interpretation of negated quantificational sentences in order to directly compare their sensitivity to lexical presupposition, implicated presupposition, and scalar implicature. The section begins with some theoretical background on quantification, scalar implicature, and semantic and pragmatic inferences of the quantifier '*every*'. It then provides further background on previous experimental studies on the topic, before proceeding to reporting the conducted experiment.

3.5.1 Theoretical background

3.5.1.1 Quantification: Entailment and scalar implicature

Human languages have various ways of expressing number and quantity. Many terms in languages refer to numeral amounts (24, 33, 90, etc.), rough estimates (a few, a lot), existence (a, some, any), empty sets (no, none), universals (all, every), and comparisons of quantities (more, most). Quantifiers, such as *every*, *some*, *all*, and *no*, allow us to make generalizations about a group of individuals (Lidz, 2016). Quantifiers require a representation of a relation between two sets. For example, the sentence (40) expresses a relation between the set of plates of food and the set of entities that deserves chili peppers. In compositional semantics, quantifiers express relations between two functions of type <e,t>, which relate individual entities of type <e> and truth-values of type <t>. The semantic values for quantifiers do not vary by the evaluation world. In (41), a lexical entry for a universal quantifier (41a) and one for an existential quantifier (41b) are provided. (Heim and Kratzer, 1998; von Fintel and Heim, 2011)

(40) Every plate of food deserves chili peppers.

(41) a. $[\![\text{every}]\!]^{w,g} = \lambda P_{<e,t>}.\lambda Q_{<e,t>}.\forall x_{<e>} : P(x) = 1 \rightarrow Q(x) = 1.$

b. $[\![\text{some}]\!]^{w,g} = \lambda P_{<e,t>}.\lambda Q_{<e,t>}.\exists x_{<e>} : P(x) = 1 \ \& \ Q(x) = 1.$

Quantifiers have many mathematical properties of their relational meanings, including their *monotonicity* properties. Within the domain D, whose subsets are A, B, and C, the monotonicity properties of determiners can be formally described as in (42).

(42) a. A determiner is left upward monotone if for all A, B, C:

$A \subseteq B$ and $<A, C> \in R_{Det}$ then $<B, C> \in R_{Det}$

b. A determiner is left downward monotone if for all A, B, C:

$A \subseteq B$ and $<B, C> \in R_{Det}$ then $<A, C> \in R_{Det}$

In other words, for a determiner that is upward monotone (upward-entailing), if its relation holds for A, then such relation also holds for a superset of A (i.e., B in (42a)). In contrast, for a determiner that is downward monotone (downward-entailing), if its relation holds for B, then such relation also holds for a subset of B (i.e., A in (42b)). The following sentences in (43a) and (43b) suggest that the determiner *some* is upward monotone, while *every* is downward monotone by the formal definitions that were given earlier.

(43) a. Upward monotonicity of *some*:

Some wild animal loves papaya salad $\models$ Some animal loves papaya salad

Every wild animal loves papaya salad $\not\models$ Every animal loves papaya salad

b. Downward monotonicity of *every*:

Some animal loves papaya salad $\not\models$ Some wild animal loves papaya salad

Every animal loves papaya salad $\models$ Every wild animal loves papaya salad

Lexical *scales*, first proposed by Horn (1972), are ordered sets of scalar alternatives. Orderings on scales express scalar relations between scalar alternatives within the same set, based on their semantic strength defined by entailment. A given lexical item outranks, i.e., is stronger than, its alternate on the same scale if and only if a statement with its presence unidirectionally entails the corresponding statement containing its alternate. Below are examples of scales, with each term outranking the term to its right on the same scale.

(44)	<all, most, many, some>	<always, usually, often, sometimes>
	<and, or>	<... , 6, 5, 4, 3, 2, I>
	<must, should, may>	<necessary, (logically) possible>
	<certain, probable/likely, possible>	<obligatory, permitted>
	<boiling, hot, warm>	<freezing, cold, cool, (lukewarm)>
	<beautiful, pretty, attractive>	<hideous, ugly, unattractive, plain>
	<adore, love, like>	<loathe, hate, dislike>
	<excellent, good, OK>	<{terrible/awful}, bad, mediocre>

(Horn, 1989, pp. 232)

With such lexical scales, quantifiers may also involve *scalar implicatures*. Scalar implicatures are a subset of generalized conversational implicatures, whose derivations are generally accounted for by the Gricean Maxim of Quantity of the Cooperative Principle, as described in Section 3.2. Assuming that a speaker obeys the Maxim of Quantity, i.e., being as informative as is required and not being more informative than is required, a speaker chooses to use a weaker term on the scale because the stronger term is overinformative, i.e., not applicable to the amount on the scale in the actual situation they are describing. Therefore, without explicitly being said, scalar implicatures can be inferred from an utterance.

Consider the following instances. Scalar implicatures may hold in the case of numbers on numeric scales, where the situations that are compatible with an utterance described with a larger number are a superset of the situations that are compatible with an utterance with a smaller number. The utterances in (45a), thus, implicates the proposition in (45b). Similarly, assuming that *some* and *all* are scalar alternatives, the use of the expression *some*, which is ordered lower on the scale of quantity than the expression *all*, implicates that the use of *all* is not applicable, as seen that the utterance (46a) typically implicates (46b).

(45) a. Four graduate students are having Thai food.

b. Not more than four graduate students are having Thai food.

(46) a. Some graduate students have finished writing their term paper.

b. Not all graduate students have finished writing their term paper.

While scalar implicatures operate on lexical scales, the nature of their operation is similar to implicated presuppositions, as seen in the previous sections. As Heim (1991) stated, scalar implicatures and implicated presuppositions operate partially using the same mechanism. In addition to entailments and scalar implicatures, the next section describes other inferences that can be made from the universal quantifier under investigation in the next experiment.

3.5.1.2 Semantic and pragmatic inferences of the quantifier '*every*'

Assuming that you know the fact that a human being has no tail, one tongue, and two legs, the following utterances in (47) may sound strange to you.

(47) a. #Every tail of mine is long and curly.

b. #Every tongue of mine is pink.

c. #Every leg of mine is muscular.

Yatsushiro (2008) viewed that such oddness of those sentences are due to the fact that they violate the three presuppositions of the universal quantifier '*every*' in (48).

(48) a. Existential presupposition: There exists at least one member in a set of the first argument of '*every*'.

b. Anti-uniqueness presupposition: There exists more than one member in a set of the first argument of '*every*'.

c. Anti-duality presupposition: There exists more than two members in a set of the first argument of '*every*'

One widely-discussed property of presupposition is its ability to project outside of certain environments, e.g., negation (49a), question (49b), antecedent of a conditional (49c), and modal scope (49d). Thus, the following linguistic environments did not improve its acceptability.

(49) a. #Not every tail of mine is long and curly.

b. #Is every tail of mine long and curly?

c. #If every tail of mine is long and curly, I would be very proud!

d. #Maybe every tail of mine is long and curly.

While Existential presupposition is a part of the lexical meaning of the quantifier '*every*', the other two are implicated presuppositions, whereby there is an expression with a stronger presupposition, e.g., '*the*' for (48b) and '*both*' for (48c), for a speaker to use.

Speakers are required to choose the term that has the strongest presupposition, abiding by the pragmatic maxim of MAXIMIZE PRESUPPOSITION (Heim, 1991). Hence, it is more felicitous to say the following sentences in (50a-50b) than the previous (47b-47c).

(50) a. My tongue/The tongue of mine is pink.

b. Both of my legs are muscular.

The Thai universal quantifier '*tʰúk*' follows the same principle with the violation of the three presuppositions resulting in sentences sounding strange (51a-51c; 53a-53d) and the alternatives with stronger presupposition being more felicitous (52a-52b).

(51) a. # hǎːŋ tʰúk hǎːŋ kʰɔ̌ːŋ cʰán jaːw lɛ́ʔ pen-kliːaw
tail every CLS of 1SG long and spiral
'Every tail of mine is long and curly.'

b. # lín tʰúk lín kʰɔ̌ːŋ cʰán sǐː-cʰom-pʰuː
tongue every CLS of 1SG pink
'Every tongue of mine is pink.'

c. # kʰǎː tʰúk kʰâːŋ kʰɔ̌ːŋ cʰán miː klâːm
leg every CLS of 1SG have muscle
'Every leg of mine is muscular.'

(52) a. lín kʰɔ̌ːŋ cʰán sǐː-cʰom-pʰuː
tongue of 1SG pink
'My tongue is pink.'

b. kʰǎː tʰáŋ-sɔ̌ːŋ kʰâːŋ kʰɔ̌ːŋ cʰán miː klâːm
leg both CLS of 1SG have muscle
'Both of my legs are muscular.'

(53) a. # hǎːŋ mâj tʰúk hǎːŋ kʰɔ̌ːŋ cʰán jaːw lɛ́ʔ pen-kliːaw
tail not every CLS of 1SG long and spiral
'Not every tail of mine is long and curly.'

b. # hǎːŋ tʰúk hǎːŋ kʰɔ̌ːŋ cʰán jaːw lɛ́ʔ pen-kliːaw rɯ́ʔ-plàːw
tail every CLS of 1SG long and spiral Q
'Is every tail of mine long and curly?'

c. # t^hâ: hǎːŋ t^húk hǎːŋ k^hɔ̌ːŋ c^hán jaːw lɛ́ʔ pen-kliːaw c^hán càʔ p^huːm-caj
if tail every CLS of 1SG long and spiral 1SG will proud
mâːk
very
'If every tail of mine is long and curly, I would be very proud!'

d. # hǎːŋ t^húk hǎːŋ k^hɔ̌ːŋ c^hán ʔàːt-càʔ jaːw lɛ́ʔ pen-kliːaw
tail every CLS of 1SG may long and spiral
'Maybe every tail of mine is long and curly.'

3.5.2 Previous experimental studies

3.5.2.1 Quantifiers in child language

Many studies have investigated children's comprehension of concepts related to quantification, including approximation, numbers, sets, and quantifiers (see Lidz (2016) and Smits (2010) for a comprehensive review). Attention to the topic in various fields originated from the studies by Inhelder and Piaget (1958, 1959, 1964), presenting the data suggesting that children's interpretation of quantifiers may be different from adults'. They observed that when asked whether all the circles are blue, while being shown a picture in which the only blue things are non-circles, some children will answer "no". Their explanation was that while adults base their responses based on the application of the universal quantifier *all* to the set of circles, not the set of things that are blue, children apply the term to both the set of circles and the set of things that are blue.

The results of these studies have triggered interest from researchers in different areas, probing into how children's interpretation of quantified expressions is different from adults'. Several experimental studies on quantifiers in the field of semantics focus on the acquisition of scalar implicatures and presuppositions. Early studies suggest that children favor a logical, literal meaning interpretation of quantified expressions and disjunction over a pragmatically implicated meaning. Brain & Rumain (1981) reported that adults tend to prefer an exclusive interpretation of disjunction (*either p or q*), whereas 7-to-9-year-old children tends to favor an inclusive interpretation (*p or q and perhaps both*). Smith (1980) similarly observed a more logical reasoning in children, having found that 4-to-7-year-old children interpreted the quantifier *some* as being compatible with the meaning *all*.

The first detailed study to explore children's acquisition of scalar implicatures was the study by Noveck (2001). Noveck (2001) modified and expanded Smith (1980)'s study to French. He recruited 8-year-olds (n = 32; M age = 8;2), 10-year-olds (n = 30; M age = 10;7), and 15 adult native speakers of French to participate in the study. The task was simply for the participants to indicate whether they agreed or disagreed with the sentences, examples of which are presented in (54-56). While children and adults had similar interpretations of instances in the bizarre (54) and the factually existential (55) conditions, children in both groups were significantly more accepting of sentences such as (56a). Consider that sentences such as (56a) are logically, truth-conditionally true, i.e., it is true that there exist giraffes with long necks, but pragmatically infelicitous due to their underinformativeness. The fact is, therefore, congruous with the results in the earlier studies, providing a strong case for children preferring more logical responses than adults.

(54) Bizarre:

a. Some fruits have computers.

b. All birds have telephones.

(55) Factually existential:

a. Some flowers are yellow.

b. All birds live in cages.

(56) Factually universal:

a. Some giraffes have long necks.

b. All elephants have trunks.

(Noveck, 2001, pp. 187)

Some subsequent studies yielded similar results as Noveck (2001) (see Chierchia et al. 2001; Gualmini et al. 2001; Foppolo et al. 2012; a.o.), with one major note that the children's dispreference for calculating scalar implicatures may not arise from their genuine inability to do so but may be due to experimental settings. Papafragou and Musolino (2003) found that 5-year-old Greek-speaking children were highly significantly more likely than adults to judge pragmatically infelicitous descriptions as being true. However, when they adjusted the experimental procedures and provided some training to another group of 5-year-olds, they observed a significantly higher rejection rates than those in the first version of experiment, although the children still did not reach the adult-like levels.

As laid out in the previous section, the universal quantifier ‘every’ may also involve inferences from lexical and implicated presuppositions. The most directly relevant study, comparing the acquisition of scalar implicatures, lexical presuppositions, and implicated presuppositions was by Yatsushiro (2008) (refer to Section 3.4.1.2 earlier for a detailed review of studies on the acquisition of implicated presuppositions). Yatsushiro (2008) reported that 6-year-old German-speaking children were more likely than adults to accept an equivalent sentence of ‘every girl here is playing soccer’ even when the picture they were shown depicted only one girl playing soccer. This suggests that children may base their felicity judgement merely on the lexical EXISTENTIAL presupposition. The results support that lexical presuppositions are acquired earlier than implicated presuppositions of ANTI-UNIQUENESS, which asks for more than one member in the set. Moreover, Yatsushiro (2008) found further, although less concrete, evidence for her hypothesis that the acquisition of implicated presuppositions and scalar implicatures pattern together in their path. For one thing, the expected response rates increase between 6-year-olds and 7-year-olds only in the case of implicated presuppositions and scalar implicatures, but not for lexical presupposition. Additionally, some children accepted both the sentence ‘the girl here is playing soccer’ and the sentence ‘every girl here is playing soccer’ as viable alternatives for the picture with only one girl playing soccer, only significantly in the ANTI-UNIQUENESS implicated presupposition condition and the scalar implicature condition, but not in the lexical presupposition condition.

3.5.2.2 Quantifiers and autism

First attempts at studying the linguistically-associated side found no difficulties for adolescents with ASD and adults on tasks involving scalar implicature. Pijnacker et al. (2009) found no statistical difference between high-functioning ASD (n = 28; Age M = 26.8, range = 19-40) and TD controls (n = 28; Age M = 26.3, range = 19-39) in their responses in judging underinformative *some* sentences such as (57) and underinformative disjunction sentences such as (58) to be false.

(57) 'Some sparrows are birds.'

(58) 'Zebras have black or white stripes'.

(TRUE = logical; FALSE = pragmatic; Pijnacker et al. 2009, pp. 611-612)

Chevallier et al. (2010) followed up on Pijnacker et al. (2009), using spoken language stimuli with added stress on the disjunction as in (59). Additionally, they recruited younger adolescents with ASD than the study by Pijnacker et al. (2009) (n = 22; Age M = 13;4, range = 11;1-15;11) and TD controls (n = 22; Age M = 13;10, range = 10;10-16;03). They predicted that adolescents with ASD would accept fewer pragmatically inferred disjunction as being correct than the TD group. However, Contrary to their prediction, they replicated the unexpected results in Pijnacker et al. (2009), showing no significant difference between participant groups.

(59) There is a sun OR a train. (Chevallier et al., 2010, pp. 1108)

Hochstein et al. (2017) also reported similar results in adolescents with ASD (n = 18; Age M = 14.9, range = 1218), compared to neurotypical adults (n = 17; Age M = 22.6; range = 1841). However, they found that adolescents with ASD over-computed scalar implicatures in a different task where the participants need to base their answer on another person's epistemic state. This suggests that scalar implicature may generally not be impaired in adolescents with ASD potentially because it does not essentially involve epistemic reasoning, which proves to be more difficult for ASD individuals.

In sum, scalar implicatures appear to be intact in the ASD group. However, most of the studies on such topic were based on adolescents with ASD. It is, therefore, interesting to recruit children with ASD to perform in similar tasks. Moreover, while Yatsushiro (2008) found some evidence for GCIs like scalar implicatures to have a similar path of acquisition as implicated presuppositions, further investigations are needed in directly comparing the two mechanisms in both TD and children with ASD.

3.5.3 Experiment 5: Presupposition and implicature

Experiment 5 is a study on the negated universal quantifier *not every*. A study on this quantifier allows for a more direct comparison between scalar implicature and the two types of presupposition within one paradigm. Similar to the universal quantifier *every*, the negated quantifier *not every* also yields an EXISTENTIAL presupposition and an ANTI-UNIQUENESS implicated presupposition. Additionally, the literal *not all* meaning is also present. Given that if there is no intersection between restrictor and nuclear scope, cf. subject and predicate, other quantifiers, such as *no* or *none*, that are scalar alternatives to *not every*, would have been used to obey with the Maxim of Quantity, the meaning that there has to be a restrictor-nuclear scope intersection is then derived from the use of *not every* through scalar implicature. The four types of meanings (60) for 'not every', derived from different mechanisms, are provided with Example (61) below.

(60) 'Not every'

a. $\exists_{Ps}$ (DOM): Existential presupposition for the domain

b. $\exists_{Imp}$ (RESTR $\cap$ SCOPE): Restrictor-nuclear scope intersection implicature

c. >1 IMPPS (DOM): Anti-uniqueness implicated presupposition

d. $\neg\forall$: Literal *Not All* meaning

(61) 'Not every zebra is holding an ice cream.'

a. $\exists_{Ps}$ (DOM): There is a zebra

b. $\exists_{Imp}$ (RESTR $\cap$ SCOPE): There is a zebra holding an ice cream.

c. >1 ImpPs (Dom): There is more than one zebra.

d. ¬∀: It is not true that every zebra is holding an ice cream.

Based on the previous literature on scalar implicature and autism (Pijnacker et al., 2009; Chevallier et al., 2010; Hochstein et al., 2017), it is expected that children with autism would be able to reject the literal meaning and base their judgement on scalar implicatures, which belong in the category of linguistically-informed inferences, to the same extent as their TD peers. However, significant difference in their scalar implicature calculation rates between the two groups of children and adults is still expected. The second question of this experiment is on how children would perform on implicated presuppositions, compared to scalar implicatures. The hypothesis for this question may not be as clear as one for the first question, owing to the smaller number of experimental studies on implicated presuppositions in children. While Yatsushiro (2008) predicted that the inferences derived by implicated presupposition and scalar implicature would yield similar results in children, this study on personal reference terms seem to suggest that number or type of implicated presuppositions matter. In the previous experiment, person implicated presupposition was enough to cause difficulty on the children with ASD's comprehension of third-person pronouns. The TD children, on the other hand, were affected when not only person but also gender implicated presuppositions were present. It is, therefore, interesting to compare how children perform with regards to scalar implicatures, lexical presuppositions, and implicated presuppositions from quantifiers.

3.5.3.1 Methods and design

This study adapted the Covered Box paradigm (Huang et al., 2013). In each trial, a *context* picture was first shown on a screen to the participants (see the top picture in Figure 3.10), with an auditory description in (62). The context picture depicts a group of animals doing the same thing, corresponding with the auditory context sentence. After the sentence ended, the screen was shifted to presenting two pictures, one visible and one covered with a black box, hidden from their view (see the bottom picture in Figure 3.10 for illustration). Note that in the visible pictures, the number of animals by type matched between the context screen and the test screen. Another description was then auditorily presented with the scheme provided in (63). The participants were instructed to choose either the visible picture or the covered box to map with the auditory description. Before proceeding to the critical trials, four practice trials were presented to familiarize the participants with the task. In the practice trials, the black box was removed to reveal the picture behind the box. In the critical trials, on the other hand, no picture behind the covered box was revealed. It is, therefore, solely dependent on each participant's imagination of what picture that could be. The participants made their choice by selecting the picture that they thought was a good match with the sentence in (63).

(62) naj klùm níː sàt tʰúk tuːa *y* jùː ...
in group this animal every CLS *y* CONT ...
'In this group, every animal is *doing y...*'

(63) ... tɛ̀ː-wâː naj klùm níː *x* mâj tʰúk tuːa *y* jùː
... but in group this *x* not every CLS *y* CONT
'but in this group, not every *x* is *doing y*'

The conditions were manipulated with regards to the compatibility between the visible picture and the readings under investigation. To test how each of the four meanings, presented earlier in (60-61), plays a role in the participants' interpretation of the quantifier *Not Every*, four experimental conditions were created. All of the critical experimental conditions are consistent with the literal *Not All* ($\neg\forall$) reading. They differ, however, in their consistency with the other three readings. The *AllMet* condition (See Table 3.2) is compatible with all of the readings, with the visible picture showing 2 out of 3 target animals, i.e., '*not every*' of them, doing the described action. In the critical *AllViolated* condition, on the other hand, the visible picture showed no mentioned animal to begin with, making it incompatible with the three readings: the domain existential presupposition reading ($\exists_{Ps}$ (Dom)), the restrictor-nuclear scope intersection implicature ($\exists_{Imp}$ (Restr $\cap$ Scope)), and the anti-uniqueness implicated presupposition (>1 ImpPs (Dom)) readings. The visible picture in

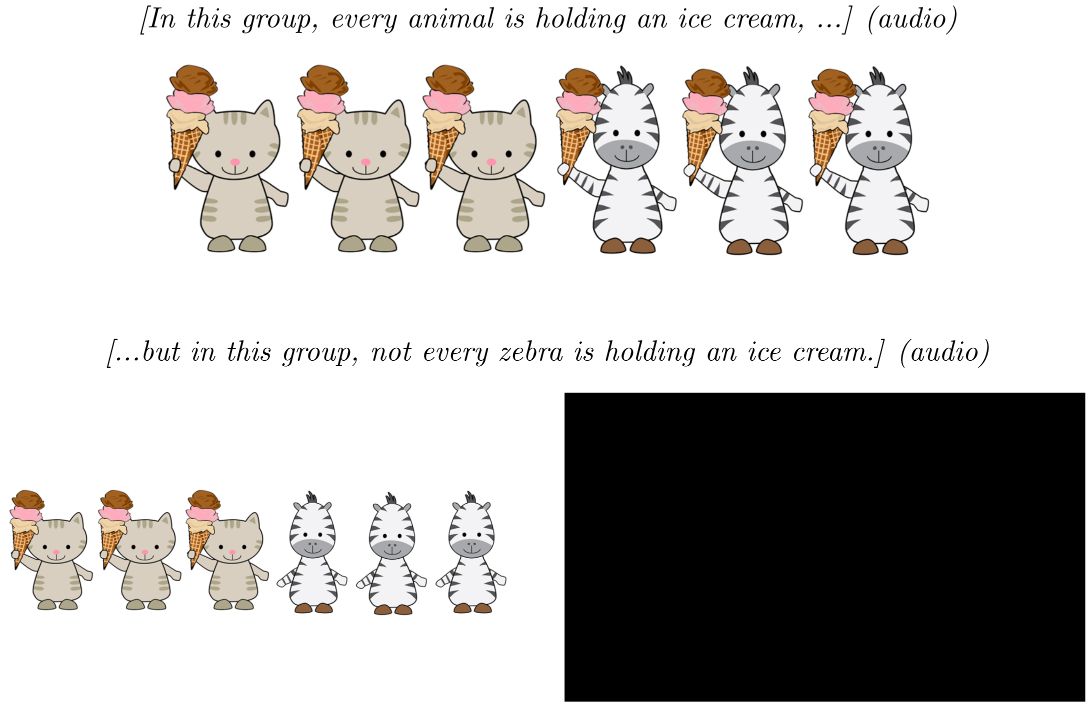


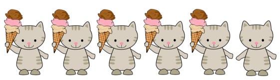
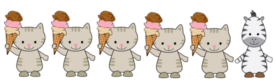
Figure 3.10: Example context screen (top) and test screen (bottom) in Experiment 5.

the critical *ImpViolated* condition showed three of the target animals, auditorily described in the sentence, but none of them was doing the action that was mentioned. Therefore, the condition is consistent with all but one reading, which is the restrictor-nuclear scope intersection implicature reading. In the critical *ImpImpPsViolated* condition, the visible picture was manipulated such that only one target animal was depicted and it was not doing the described action. This condition is then not compatible with the restrictor-nuclear scope intersection implicature (target animal not doing described action) and the anti-uniqueness implicated presupposition (not more than one target animal depicted) readings.

Table 3.2 presents example visible pictures for each experimental condition. It additionally summarizes predictions of compatibility with the interpretations under investigation for each condition. The study consisted of 64 critical trials (16 trials per condition). In addition, 48 filler trials with the quantifier *some* (3 conditions; 16 trials per condition; see Figure 3.11) were included to control for participants' understanding of the task. Those trials were counterbalanced and pseudo-randomized across 4 experimental lists. Each list, therefore, contained 16 critical trials and 12 filler trials, presented with an even distribution of trial types in each of the four blocks. Experimental lists were counterbalanced between participants.

Table 3.2: Predictions for compatibility of readings in Experiment 5 conditions

[...but in this group, not every zebra is holding an ice cream.] (audio)

	$\exists_{Ps}$ (Dom)	$\exists_{Imp}$ (Restr $\cap$ Scope)	>1 ImpPs (Dom)	$\neg\forall$
AllViolated 	*	*	*	✓
ImpViolated 	✓	*	✓	✓
ImpImpPsViolated 	✓	*	*	✓
AllMet 	✓	✓	✓	✓

Note: ✓indicates a visible picture selection; * indicated a covered box selection.

3.5.3.2 Procedure and subgroups of participants

The child data were collected offline with the details described in the first chapter. An additional collection of adult data was done online using PennController (Zehr and Schwarz, 2018). The adult participants are native speakers of Thai, demographically mixed, recruited through personal contacts and word-of-mouth. They accessed the experiment online using their personal computer. The consent form was shown at the beginning of the experiment. Participants provided consent by their completion of the experiment. In the online version, participants were instructed to press *F* on their keyboard to select the visible picture or *J* to select the covered box. In the offline version, the participants indicated their choices by pointing. The only difference between the online and offline version of the task is that in the online version, before the experimental trials, there was a line of text on the screen

[...but in this group, only some animals are wearing glasses.] (audio)

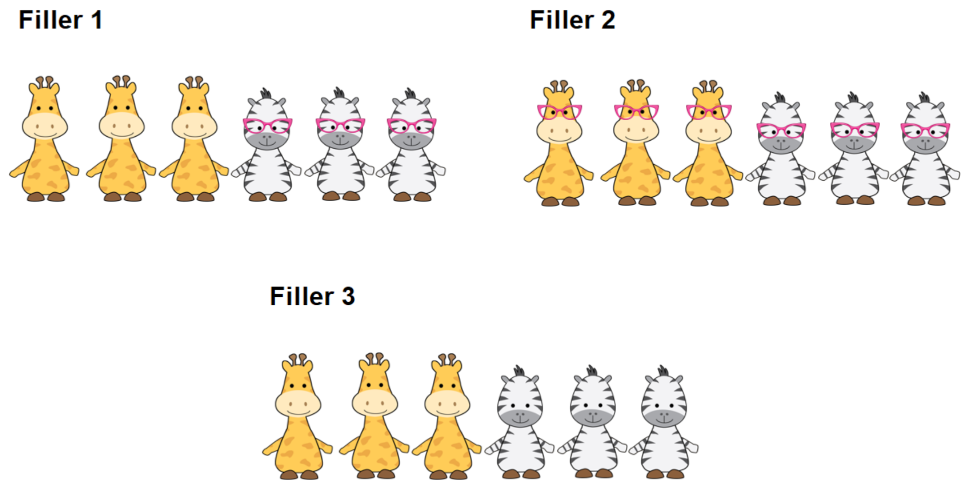


Figure 3.11: Fillers in Experiment 5.

emphasizing that their task is to match the sound with the second set of pictures on the screen in each trial.

A set of criteria, provided in (64) was established to ensure objective measures on whether a participant was performing the task. Participants who failed to meet the criteria were removed from the statistical analyses. The two conditions that the criteria are based on are not controversial in their interpretation with respect to their corresponding auditory sentences. These criteria were also used to subgroup children into Group 1 and Group 2 based on their performance.

(64) *Inclusion criteria:*

a. Accuracy score over 50% in the *AllMet* condition

b. Accuracy score over 50% in the *Filler 3* condition

c. Accuracy score over 50% on average between *AllMet* and *Filler 3*

Three adult participants did not meet the criteria and, therefore, were excluded from the statistical analysis. A higher proportion of children in each participant group was included in the performance group 2 for this task. Table 3.3 provides demographic details for each of the participant groups.

Table 3.3: Experiment 5: Participant information

	Adults		ASD		TD	
	Included	Excluded	Group 1	Group 2	Group 1	Group 2
N (Female N)	37 (15)	3 (1)	19 (2)	13 (1)	32 (7)	28 (4)
M Age	32.43	37	10;0	9;1	8;5	7;5
M NVIQ	NA	NA	99.79	89.24	120.71	111.97

3.5.3.3 Predictions

This experiment aimed at exploring the acquisition of presuppositions, implicated presuppositions, and scalar implicature. The readings associated with '*not every*' are laid out in (61) to gauge which reading is available for the participants' interpretation of the negated quantifier. These readings are associated with a predicted response pattern across the experimental conditions, summarized in Table 3.2. The compatibility with each reading was assessed to create unique contrasts across conditions. The $\exists_{Ps}$ (DOM) presupposition reading (61a) predicts a contrast between the *ImpImpPsViolated* (choice of visible picture) and the *AllViolated* (covered) conditions. The $\exists_{Imp}$ (RESTR $\cap$ SCOPE) scalar implicature reading (61b) predicts a contrast between the *AllMet* (visible) and the *ImpViolated* (covered) conditions. The >1 IMPPS (DOM) implicated presupposition reading (61c) predicts a contrast between the *ImpViolated* (visible) and the *ImpImpPsViolated* (covered) conditions. Additionally, the pure literal $\neg\forall$ reading (61d) predicts a contrast between different groups of participants if they accept the *AllViolated* visible picture to a different extent.

3.5.3.4 Modeling

Covered box rates were modelled separately for adults and children in the performance group 1. The child model contained 5 fixed effects factors, including *condition* (AllViolated, ImpViolated, ImpImpPsViolated, and AllMet), *participant group*, *z-scored Ravens nonverbal IQ*, *z-scored age*, and *gender*. The model additionally include interactions between *condition* and *participant group*. The adult model contained 3 fixed factors, including *condition*, *z-*

scored age, and *gender* and no interaction. Both models had a random effects factor for individual participants. Dummy coding was employed for baseline re-levelling.

Additionally, to compare the results between children and adults, one additional model was fitted to the covered box rates, using 3 fixed effects factors of *condition*, *participant group*, and *gender*. Interactions between *condition* and *participant group* were included, with a random effects factor for individual subjects. This model has to drop 2 fixed effects factors of age and NVIQ because no NVIQ data were collected for adults and age correlates with participant groups.

Mixed effects logistic regression models were run using the lme4 package (Version 1.1.12; Bates et al. 2015) with the extension lmerTest package (Version 2.0.32; For obtaining p-values; Kuznetsova et al. 2016) in the R software (Version 3.3.1; R Core Team 2016) and MuMIn package (Version 1.43.6; For obtaining r-squared; Barton 2019).

3.5.3.5 Results

A mixed effects logistic regression model were fitted to the covered box responses of the adult participants, as summarized in Table 3.4. *Covered* responses were chosen significantly more in the *AllViolated* condition, compared to the other three conditions, including the *ImpViolated* condition (β=-1.238, p=0.02), the *ImpImpPsViolated* condition (β=-1.866, $p<0.001$), and the *AllMet* condition (β=-9.048, $p<0.001$). At the same time, the participants chose the visible picture to a significantly higher extent in the *AllMet* condition than the other conditions: the *ImpViolated* condition (β=-7.810, $p<0.001$) and the *ImpImpPsViolated* condition (β=-7.182, $p<0.001$). The *ImpViolated* and the *ImpImpPsViolated* conditions turned out to not differ from each other in their covered box rates (β=-0.628, p=0.119). Additionally, on average of all conditions, female participants were found to accept the visible picture to a significantly higher rate than men (β=1.304, p=0.05)

According to the mixed effects logistic regression model on the Group 1 child data, summarized in Table 3.5, children with ASD and the TD children in Group 1 displayed the same pattern of significance contrasts between conditions as adults. In particular, the

Table 3.4: Experiment 5: Summary of the accuracy model for the adults.

Adults

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: AllViolated)	4.331	0.597	3.160	5.501	**<.001**
Condition					
AllViolated vs ImpViolated	-1.238	0.530	-2.278	-0.198	**0.020**
AllViolated vs ImpImpPsViolated	-1.866	0.521	-2.886	-0.846	**<.001**
AllViolated vs AllMet	-9.048	0.940	-10.890	-7.207	**<.001**
ImpViolated vs ImpImpPsViolated	-0.628	0.403	-1.417	0.162	0.119
ImpViolated vs AllMet	-7.810	0.850	-9.475	-6.145	**<.001**
ImpImpPsViolated vs AllMet	-7.182	0.813	-8.776	-5.589	**<.001**
Age	0.353	0.320	-0.274	0.979	0.270
Gender (Female vs Male)	1.304	0.667	-0.002	2.611	**0.050**
N Critical items	16				
N Subjects	37				
N Datapoints	592				
Marginal R^2 / Conditional R^2	0.701 / 0.823				
Δ Marginal R^2 / Δ Conditional R^2	0.657 / 0.771				

Note: The baseline is the first argument in the above scheme (x vs y).

children with ASD selected the covered box significantly more in the *AllViolated* condition, compared to the other three conditions, including the *ImpViolated* condition (β=-1.731, p<0.001), the *ImpImpPsViolated* condition (β=-2.411, p<0.001), and the *AllMet* condition (β=-3.960, p<0.001). The visible picture was also chosen significantly more in the *AllMet* condition than the *ImpViolated* condition (β=-2.228, p<0.001) and the *ImpImpPsViolated* condition (β=-1.549, p=0.001). The *ImpViolated* and the *ImpImpPsViolated* conditions appeared to be similar in their covered box rates (β=-0.679, p=0.082).

Similarly, the TD children exhibited significantly stronger preference for the covered box in the *AllViolated* condition than the *ImpViolated* condition (β=-2.614, p<0.001), the *ImpImpPsViolated* condition (β=-2.932, p<0.001), and the *AllMet* condition (β=-5.041, p<0.001). The *AllMet* condition, on the other hand, significantly differed in its responses from the *ImpViolated* condition (β=-2.428, p<0.001) and the *ImpImpPsViolated* condition (β=-2.109, p=0.001). The *ImpViolated* and the *ImpImpPsViolated* conditions also did not differ in the TD group (β=-0.319, p=0.290).

Additionally, group difference between the children with ASD and the TD children lies in their covered box rates in the *AllViolated* condition, with the children with ASD choosing significantly fewer covered responses (β=1.561, p=0.02). Moreover, on average for all the children in the performance group 1, age (β=0.682, p<0.01), but not NVIQ (β=0.076, p=0.59), significantly increases their covered responses.

Table 3.5: Experiment 5: Summary of the accuracy model for the children in Group 1.

Performance group: Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: AllViolated, ASD)	1.200	0.493	0.234	2.165	**0.015**
Condition					
AllViolated vs ImpViolated in ASD	-1.731	0.412	-2.538	-0.925	**<.001**
AllViolated vs ImpImpPsViolated in ASD	-2.411	0.431	-3.255	-1.567	**<.001**
AllViolated vs AllMet in ASD	-3.960	0.528	-4.995	-2.925	**<.001**
ImpViolated vs ImpImpPsViolated in ASD	-0.679	0.390	-1.444	0.086	0.082
ImpViolated vs AllMet in ASD	-2.228	0.485	-3.179	-1.277	**<.001**
ImpImpPsViolated vs AllMet in ASD	-1.549	0.486	-2.501	-0.597	**0.001**
AllViolated vs ImpViolated in TD	-2.614	0.402	-3.402	-1.825	**<.001**
AllViolated vs ImpImpPsViolated in TD	-2.932	0.409	-3.733	-2.131	**<.001**
AllViolated vs AllMet in TD	-5.041	0.482	-5.986	-4.096	**<.001**
ImpViolated vs ImpImpPsViolated in TD	-0.319	0.301	-0.908	0.271	0.290
ImpViolated vs AllMet in TD	-2.428	0.370	-3.152	-1.703	**<.001**
ImpImpPsViolated vs AllMet in TD	-2.109	0.365	-2.824	-1.394	**<.001**
Participant group (ASD vs TD; AllViolated)	1.561	0.644	0.299	2.823	**0.015**
Participant group (ASD vs TD; ImpViolated)	0.679	0.579	-0.456	1.814	0.241
Participant group (ASD vs TD; ImpImpPsViolated)	1.039	0.587	-0.111	2.190	0.076
Participant group (ASD vs TD; AllMet)	0.480	0.674	-0.842	1.801	0.477
NVIQ	0.076	0.141	-0.201	0.352	0.591
Age	0.682	0.231	0.230	1.134	**<.01**
Gender (Female vs Male)	0.423	0.556	-0.668	1.513	0.447
Condition x Participant Group					
(AllViolated vs ImpViolated) x (ASD vs TD)	-0.882	0.568	-1.994	0.230	0.120
(AllViolated vs ImpImpPsViolated) x (ASD vs TD)	-0.522	0.582	-1.662	0.619	0.370
(AllViolated vs AllMet) x (ASD vs TD)	-1.081	0.693	-2.440	0.278	0.119
(ImpViolated vs ImpImpPsViolated) x (ASD vs TD)	0.361	0.492	-0.604	1.326	0.464
(ImpViolated vs AllMet) x (ASD vs TD)	-0.199	0.605	-1.385	0.987	0.742
(ImpImpPsViolated vs AllMet) x (ASD vs TD)	-0.560	0.605	-1.745	0.626	0.355
N Critical items	16				
N Subjects	51				
N Datapoints	816				
Marginal R^2 / Conditional R^2	0.391 / 0.604				
Δ Marginal R^2 / Δ Conditional R^2	0.359 / 0.554				

Note: The baseline is the first argument in the above scheme (x vs y).

Figure 3.12 and 3.13 plotted mean covered response rates in adults and children, respectively. Significance levels from the two models presented above are also summarized in the two figures. In general, the overall patterns of covered box rates are the same across all participant groups. However, one noticeable difference is that while covered box rates in the *ImpViolated* and the *ImpImpPsViolated* for the adults averaged at 88.5% and 83.1% respectively, the children's covered box rates in the two conditions are noticeably lower, with an average at 43.4% and 31.6% in the ASD group and at 50% and 44.9% in the TD group.

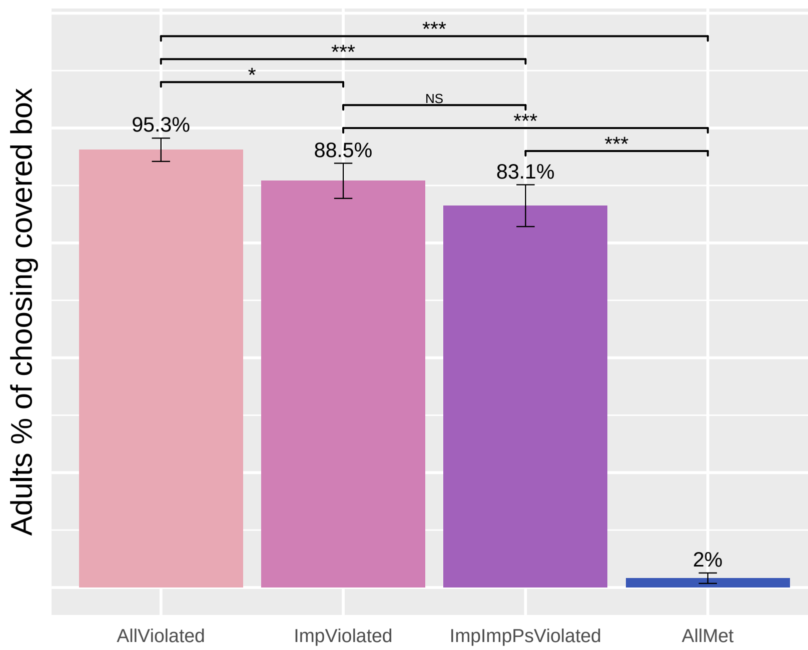


Figure 3.12: Experiment 5: Adults' accuracy by condition

To further compare between the adult and child data, a logistic mixed effects model was fitted to their data, dropping the fixed effects of NVIQ and age. The model is summarized in Table 3.6, showing only differences between adults and children in only the relevant pairs of conditions. In general, adults were significantly more likely than both groups of children to choose a covered box in all of the conditions, except in the *AllMet* condition, where children chose a covered box significantly more than adults. Comparing the differences between (1) the *AllViolated* and the *ImpImpPsViolated* conditions (compared to ASD: β=-0.59, p=0.374; to TD: β=-1.123, p=0.08) and (2) the *ImpViolated* and the *ImpImpPsViolated* conditions (compared to ASD: β=-0.073, p=0.90; to TD: β=0.298, p=0.55), adults did not differ from either group of children. However, adults differ from both groups of children in

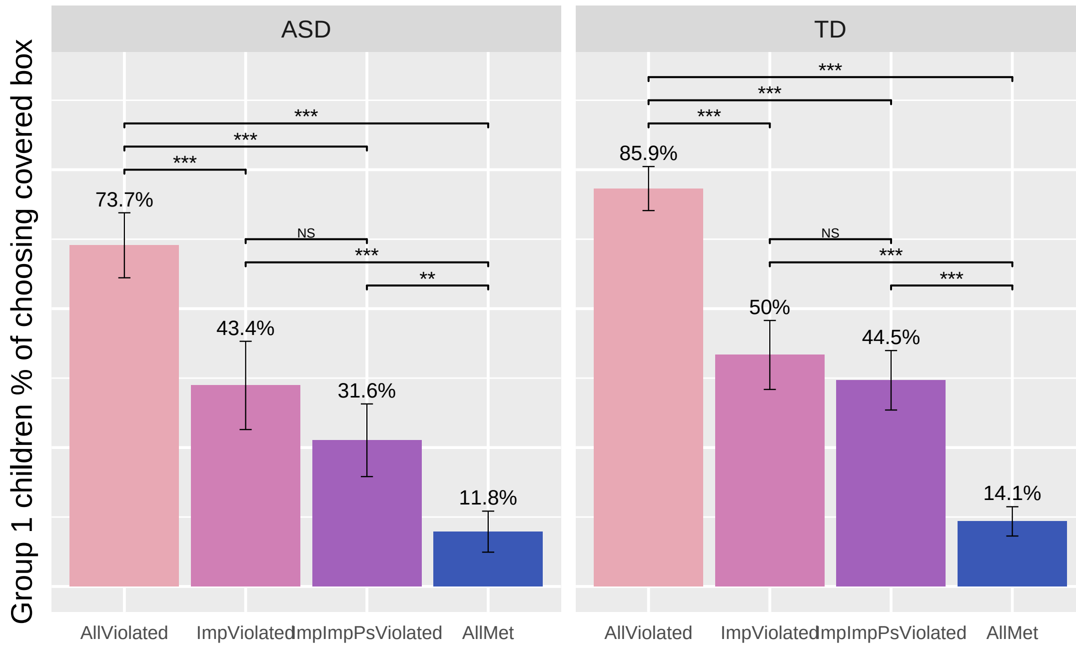


Figure 3.13: Experiment 5: Group 1 children's accuracy by condition

their differences between the covered box rates in the *ImpViolated* and the *AllMet* conditions (compared to ASD: β=5.428, p<0.001; to TD: β=5.269, p<0.001).

No logistic regression model was run on the data of the children in the performance group 2. The pattern is, however, plotted in Figure 3.14. In general, the children in this group seemed to misunderstand or not fully comprehend the task, resulting in similar pattern of responses across conditions.

3.5.3.6 Interim conclusion and discussion

Experiment 5 aimed at directly comparing the acquisitions of scalar implicatures, lexical presuppositions, and implicated presuppositions in one paradigm. In particular, it investigated the meanings that can be obtained from the negated universal quantifier '*not every*' through different mechanisms, including the EXISTENTIAL lexical presupposition, the restrictor-nuclear scope intersection implicature, ANTI-UNIQUENESS implicated presuppositions, and the literal, logical truth. The study adapted the Covered Box paradigm (Huang et al., 2013), where two alternatives of a visible picture and a picture that is covered from

Table 3.6: Experiment 5: Summary of the accuracy model comparing the adults and the children in Group 1.

Adults vs Children in Group 1

	Accuracy				
Fixed Effects	*Estimates (Betas)*	*SE*	*Lower CI*	*Upper CI*	*p-values*
Intercept (Baseline: AllViolated, Adults)	4.216	0.550	3.137	5.294	**<.001**
Participant group (Adults vs ASD; AllViolated)	-2.538	0.718	-3.946	-1.131	**<.001**
Participant group (Adults vs ASD; ImpViolated)	-3.060	0.627	-4.289	-1.832	**<.001**
Participant group (Adults vs ASD; ImpImpPsViolated)	-3.133	0.613	-4.334	-1.931	**<.001**
Participant group (Adults vs ASD; AllMet)	2.367	0.868	0.667	4.068	**0.006**
Participant group (Adults vs TD; AllViolated)	-1.434	0.677	-2.760	-0.108	**0.034**
Participant group (Adults vs TD; ImpViolated)	-2.854	0.555	-3.942	-1.767	**<.001**
Participant group (Adults vs TD; ImpImpPsViolated)	-2.557	0.528	-3.592	-1.521	**<.001**
Participant group (Adults vs TD; AllMet)	2.414	0.779	0.887	3.941	**0.002**
Gender (Female vs Male)	0.755	0.451	-0.130	1.639	0.095
Condition x Participant Group					
(AllViolated vs ImpImpPsViolated) x (Adults vs ASD)	-0.594	0.668	-1.904	0.715	0.374
(ImpViolated vs ImpImpPsViolated) x (Adults vs ASD)	-0.073	0.561	-1.172	1.027	0.897
(ImpViolated vs AllMet) x (Adults vs ASD)	5.428	0.894	3.675	7.180	**<.001**
(AllViolated vs ImpImpPsViolated) x (Adults vs TD)	-1.123	0.649	-2.394	0.149	0.084
(ImpViolated vs ImpImpPsViolated) x (Adults vs TD)	0.298	0.500	-0.682	1.278	0.551
(ImpViolated vs AllMet) x (Adults vs TD)	5.269	0.830	3.642	6.895	**<.001**
N Critical items	16				
N Subjects	88				
N Datapoints	1408				
Marginal R^2 / Conditional R^2	0.570 / 0.747				
Δ Marginal R^2 / Δ Conditional R^2	0.540 / 0.707				

Note: The baseline is the first argument in the above scheme (x vs y). The results comparing conditions for each participant group as well as differences between ASD and TD children should be checked in their independent models.

sight were simultaneously presented. The participants were asked to select the picture that matched with the audio description in the scheme of '*...but in this group, not every x is doing y*', e.g., '*not every zebra is holding an ice cream*'.

If participants interpret the sentence by its literal meaning: 'It is not true that every zebra is holding an ice cream.' alone, lower rates of choosing covered box, i.e., rejecting the visible picture, in the *AllViolated* condition, where no zebra is present in the visible picture, are expected. By comparing between the covered box response rates in the *AllViolated* condition and those in the *ImpImpPsViolated* condition, where one zebra is present but not doing the action, differences are expected if participants base their answer on the EXISTENTIAL lexical presupposition. If participants are sensitive to the ANTI-UNIQUENESS implicated presuppositions, differences between the covered box response rates in the *ImpImpPsViolated* condition and those in the *ImpViolated* condition, where there is indeed more than

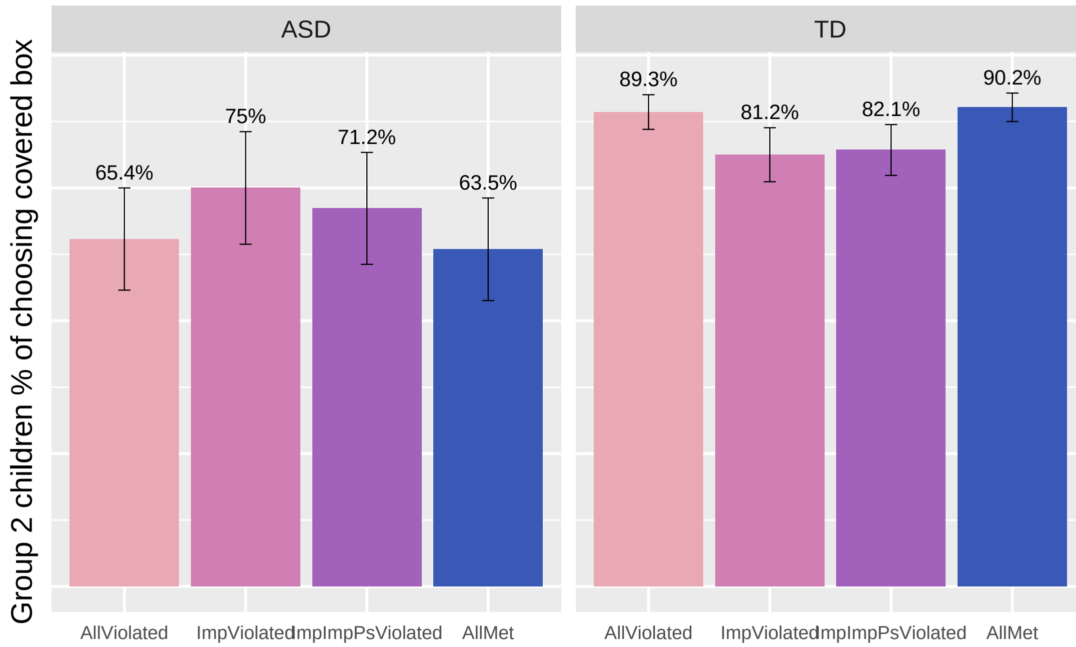


Figure 3.14: Experiment 5: Group 2 children's accuracy by condition

one zebra but none is doing the action, should be detected. It is worth noting, however, that the difference between the *ImpImpPsViolated* and the *ImpViolated* conditions would be due to an *additive* and not pure effects from implicated presuppositions alone, as scalar implicatures are also violated in the condition. Lastly, difference in covered box response rates between the *ImpViolated* condition and the *AllMet* condition, where 2 out of 3 zebras are holding an ice cream, is predicted if participants compute the scalar implicature that the set of zebras and the set of entities holding an ice cream should intersect.

The adult data provide empirical evidence that they were accessing the meanings from the EXISTENTIAL lexical presupposition and the restrictor-nuclear scope intersection implicature, as suggested from their significant differences in covered box rates between (1) the *AllViolated* and the *ImpImpPsViolated* conditions and (2) the *ImpViolated* and the *AllMet* conditions, respectively. The adults, however, did not display their sensitivity to the ANTI-UNIQUENESS implicated presuppositions, showing no differences between the *ImpImpPsViolated* and the *ImpViolated* conditions.

The pattern in the child data was the same as adults, with signs of them computing lexical presuppositions and scalar implicatures, but not implicated presuppositions. Overall, age was a significant factor in predicting their responses, with older children choosing more covered boxes. Comparing between the children with ASD and the TD children, children with ASD chose covered boxes significantly less in the *AllViolated* condition, compared to the TD children. Other pairs of conditions did not yield significant differences between the two groups of children. This suggests that access of the literal, logical meaning is the most indicative of group differences in children, with children with ASD basing their interpretation on literal meanings to a higher extent than TD children. In contrast, children with ASD are on par with TD children in accessing the meaning derived from lexical presuppositions, implicated presuppositions, and scalar implicatures.

A comparison between adults' and children's behavior reveals several significant differences. For one thing, adults had significantly higher covered box rates in the *AllViolated*, the *ImpViolated*, and the *ImpImpPsViolated* conditions, while having signifcantly lower covered box rates in the *AllMet* condition than both groups of children, suggesting that they were, in general, more likely to produce expected results. Secondly, adults were significantly less likely to accept the visible picture in the *AllViolated* condition than both children with ASD and TD children, indicating the children's higher tendency to rely on the logical meaning rather than pragmatically inferred meaning, compared to adults. Moreover, a significant interaction between condition and participant group was obtained where the effects of scalar implicatures were predicted. Specifically, adults significantly chose more covered boxes in the *ImpViolated* condition than in the *AllMet* condition to a higher extent than children in both groups. This suggests that children are less likely to derive scalar implicatures, compared to adults.

3.6 General discussion

This chapter aims at investigating the Pragmatic over Grammatical Hypothesis that children with ASD struggle more with pragmatic than grammatical aspects of language. The experiments in this chapter were designed to directly compare between the children's performance on linguistically encoded information and contextually-informed meaning in utterances. Experiment 4.1 and 4.2 probe into children's production and comprehension of Thai personal reference terms, which encode both morpho-semantic information and pragmatically inferred meaning. Since Thai personal reference system is sensitive to the relationships between interlocutors, data were only collected with children to avoid the lack of comparability with adult data. Experiment 5 explores further into the children's ability to access different types of meanings, including literal meaning and meanings that are derived from lexical presuppositions, implicated presuppositions, and scalar implicatures.

3.6.1 Major findings

3.6.1.1 Personal reference terms

Production and comprehension tasks consistently yield asymmetrical performance across both experiments on personal reference terms. Children in both groups were observed to have significant more accuracy in production tasks than comprehension tasks in Experiment 4.1. The same results were replicated in Experiment 4.2, despite the two experiments being administered to different groups of individuals. With regards to the difference between the two groups of participants, both experiments acquired the same results that children with ASD avoided terms with higher person deictic level by choosing to refer to themselves with personal names rather than pronouns, when they had freedom of choice in production.

As for the comprehension task of Experiment 4.1, TD children generally made fewer and different types of errors, compared to children with ASD. Children with ASD were shown to generally be able to detect the person ϕ-features, but they seemed to struggle the most with the pragmatic aspects of personal reference terms that involve implicated presuppositions and person and social deixis. Even though person ϕ-features seem to be detected by children with ASD, gender ϕ-features, such as those marked on the female third-person pronoun *tʰɤː*, proved to be a less prominent cue for them. Additionally, a small group of children with ASD had difficulties even with marked person ϕ-features, resulting in the pronoun-reversal type of errors. TD children were found to be the least accurate in their comprehension of the male third-person pronoun k^h*ǎw*, indicating that either number or type of implicated presuppositions from person and/or gender unmarked features affects their performance. As for deictic-center-shifted pronouns, they yielded similar results to kin terms and pronouns with marked person ϕ-features, suggesting essential difference between their acquisition and the acquisition of pronouns with person underspecification.

Experiment 4.2 largely replicated the results from Experiment 4.1. Children with ASD still outperformed TD children in their comprehension of the second-person formal pronoun k^h*un*, where its ϕ-feature is marked but the social-deictic information was unusual. Third-person pronouns still appeared to yield low accuracy rates across the two participant groups, with male third-person pronoun being especially difficult. The outdated first-person pronoun k^h*âː* that was added in Experiment 4.2 appeared to not have been acquired by both groups of children, yielding the lowest accuracy rates among all the personal reference terms.

3.6.1.2 Presuppositions and implicatures

The significant difference in the adults' covered box response rates in the *AllViolated* and the *ImpImpPsViolated* conditions provides empirical evidence that adults access the derived meaning from EXISTENTIAL lexical presupposition. They also appear to compute scalar implicature, as seen in the difference between the *ImpViolated* condition and the *AllMet* condition. However, no significant additive effects were obtained from the ANTI-UNIQUENESS implicated presuppostion in this experiment. While high proportions of children were excluded from the main statistical analyses (41.94% exclusion for ASD; 40% for TD) due to them not fully comprehending the task, the children in the performance group 1 display the same pattern as adults. The statistical analysis of the child data provides evidence for both children with ASD and TD children in Group 1 accessing the meaning derived from lexical presupposition and scalar implicature. The most indicative of group difference between children with ASD and TD children is their acceptance of literal meaning in the *AllViolated* condition, of which the visible picture conforms to only the literal meaning.

The children with ASD significantly chose visible pictures more than the TD children, who mostly preferred covered boxes.

Overall, the differences between adults and children are that adults rely less on the literal, logical meaning than both children with ASD and TD children, preferring covered boxes in the *AllViolated* condition to a higher extent than children. Adults and both groups of children, however, are not different in their likelihood to derive lexical presuppositions nor implicated presuppositions. However, the results show significant difference between adults and children in calculating scalar implicatures.

3.6.2 Implications

The results from the studies in this chapter support the Pragmatic over Grammatical Deficit Hypothesis that pragmatics is particularly challenging for children with ASD, compared to the grammatical aspects of language. One major caution, however, is that while grammar seems to be relatively intact, compared to pragmatics, a subgroup of children with ASD still does not perform well in that respect. In Experiment 4.1 and 4.2, while generally, children with ASD were observed to be sensitive to the grammatically encoded person ϕ-features, some children in the group made mistakes in reminiscence of pronoun reversals. These grammatical mistakes with regards to ϕ-features may hint at more fundamental language deficits. Children with ASD who made such mistakes after a certain age may belong to the ALI subgroup. A large proportion of children who participated in Experiment 5 fails to fully comprehend the task. Such non-uniformity that was observed in the data suggests that despite pragmatic deficits being more prominent even in higher-functioning children, grammatical deficits may still be present for some subgroup of children with ASD.

The high consistency between the results of Experiment 4.1 and 4.2 indicates that deixis proves to be difficult for children with ASD. While grammatical ϕ-features are detected, unusual social-deictic information does not deter children with ASD from seconding their choice. Given freedom of choice in production tasks, children with ASD prefer to avoid highly deictic personal reference terms. Such replicated results strongly support person deixis avoidance in ASD, as also previously observed in a small group of children with ASD (Chanchaochai, 2013).

Overall, the results in the current studies are very consistent with previous literature in many aspects. Firstly, previous experimental studies on scalar implicature in child language found significantly higher preference for logical responses to scalar implicature in children than adults (Chierchia et al., 2001; Gualmini et al., 2001; Foppolo et al., 2012; Noveck, 2001; Papafragou and Musolino, 2003). The current study also observed that children rely more on logical, literal meaning to a higher extent compared to adults.

Secondly, studies on scalar implicatures in adolescents with ASD suggest that their scalar implicatures are intact (Chevallier et al., 2010; Hochstein et al., 2017; Pijnacker et al., 2009). The results in this chapter provide further empirical evidence that not only do adolescents with ASD perform on par with TD adolescents, *children* with ASD are also age-appropriate in their performance on deriving scalar implicatures. Additionally, this study adds that even though the children with ASD's ability to compute scalar implicature is on par with TD children, they still tend to give more logical, literal responses, compared to their peers, as seen in their significantly lower covered box rates in the *AllViolated* condition.

Thirdly, the current results are in accordance with Yatsushiro (2008)'s claim that lexical presuppositions are acquired earlier than scalar implicatures and perhaps than certain types of implicated presuppositions, similar to Legendre et al. (2011). The current study adds the observation to the literature that types of implicated presupposition matter in the acquisition pattern. In Experiment 4.1 and 4.2, the implicated presuppositions of non-human seem to be relatively easier than those of masculine gender for children in both groups. Moreover, the third-person male pronoun, which lack both their person ϕ-feature and their masculine gender feature, yield the lowest accuracy rates by both groups. Experiment 5 lends further insights that types, rather than the number of, implicated presuppositions attributes to the interpretation of a given term. This is evident from the fact that even though implicated presuppositions seem to affect the accuracy rates in comprehending certain personal reference terms in Experiment 4.1 and 4.2, implicated presuppositions do not seem to have an additive effect on covered box response rates in any group of the participants in Experiment 5.

The proposal that different types of implicated presuppositions may affect participants' performance differently is a plausible proposal, considering that rates of deriving scalar implicatures were also previously observed to differ by scalar terms. Papafragou and Musolino (2003) improved success rates in children deriving scalar implicatures when the task involved number terms, such as <three, two>, rather than scalar terms, such as <all, some>. Moreover, the results in Experiment 4.1 and 4.2 show that marked person ϕ-features are noticeable to children with ASD, while marked gender ϕ-features are challenging for them to detect. This suggests a similar conclusion that types of ϕ-feature may also be represented differently. These observations raise interesting theoretical issues on types of implicated presupposition and lexical ϕ-feature and their pattern of acquisition.

In addition to the contributions that are in line with previous literature, it is important to note that these studies are the first to explore implicated presuppositions in children with ASD. The results from these experiments indicates their struggles in comprehending implicated presuppositions in the domain of personal reference terms. However, since implicated presuppositions were not evident in adults nor TD children in their interpretation of the negated quantifier '*not every*', the absence of evidence for implicated presuppositions in children with ASD is, therefore, not deviant from other participant groups.

Chapter 4

Language Profiles and Cognitive/Developmental Factors

4.1 Introduction

This chapter aims at exploring the effects or correlations between different cognitive and developmental factors and the children's performance on the linguistic tasks. This is to investigate the Cognitive Factor Hypothesis: that a developmental factor such as age similarly correlates with the performance of children with ASD and TD children on their linguistic tasks, whereas cognitive factors may correlate more with the performance of children with ASD than TD children. The hypothesis is based on two alternative explanations: that more cognitive resources and effort may be required for children with ASD to equally perform on linguistic task as TD children or that children with ASD's cognitive systems compensate for certain language impairment (Livingston and Happé, 2017; Ullman and Pullman, 2015). The secondary aim of this chapter is to explore individual differences in the group of children with ASD, which may give rise to patterns of different subgroups of autism based on their performance across linguistic tasks.

This chapter begins with a summary of experiments and cognitive measures that the children participated in. It proceeds to the correlation analyses between cognitive measures, age, and performance across experiments. A summary of individual language profiles is then presented before the chapter concludes.

4.2 Experiments and cognitive measures

This chapter includes the data from Fall 2017 because the data from Summer 2016 were restricted to two experiments, whereas the data from Fall 2017 covered all of the five experiments and two cognitive measures. The complete list of experiments and cognitive measures that were administered is provided below.

1. <u>Experiment 1.2:</u> Processing of compounds (Conditions MS, M, Ph, and C)
2. <u>Experiment 2:</u> Effects of Thai stress and tones on lexical processing
3. <u>Experiment 3:</u> Effects of talker/token differences on lexical processing
4. <u>Experiment 4.2:</u> Personal Reference Terms (Participants E, C, B, and G)
5. <u>Experiment 5:</u> Implicated presuppositions and implicatures (NotEvery)
6. <u>Cognitive measures:</u>
    (a) Non-verbal intelligence quotient (NVIQ)
    (b) Non-verbal visual-spatial working memory test

The Ravens Standardized Progressive Matrices (Raven et al., 2000) were administered to the participants to measure their non-verbal intelligence quotient (NVIQ). Non-verbal working memory (NVWM) scores were obtained by administering the Corsi Block-Tapping Task (Corsi, 1972; Kessels et al., 2000) in the Psychology Experiment Building Language (PEBL) Test Battery, Version 2.0 (Mueller and Piper, 2014). The participants were instructed to remember the sequences in which square targets were lit and reproduce the sequences by clicking on the targets in the same order as they appeared. Figure 4.1 shows a screenshot of the Corsi Block-Tapping Task that was presented to the children. A total of 9 square blocks were on the screen. Up to 9 block spans were lit up in a random order. Two trials of the same span length were included in each block. Participants had to get at least one trial correct in order to proceed to the next block with one longer block span. The memory span of each participant obtained from the PEBL program was included as one of the cognitive measures in this chapter.

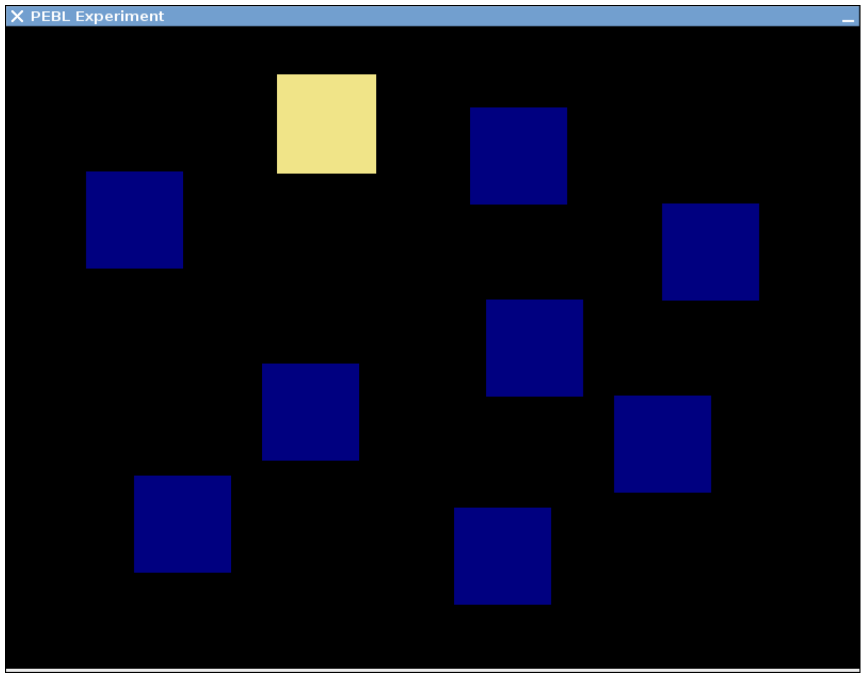


Figure 4.1: The Corsi Block-Tapping Task.

4.3 Correlation analyses

To test the hypotheses stated above, Pearson correlation analyses were done between age, cognitive measures, and the participants' performance on each task were tested. The first section provides the correlation analyses among developmental and cognitive measures themselves. The next sections continue to explore the correlations between developmental/cognitive measures and task performance. The section ends with correlation analyses of performance between tasks.

4.3.1 Age and Cognitive measures

A result of the Pearson correlation showed no significant correlations between age and NVIQ in either the group of children with ASD (r=-0.21, p=0.25) or TD children (r=-0.09, p=0.50). A linear regression model confirmed no effects of age on NVIQ (β=-0.018, p=0.22). Participant group is not a significant factor in predicting NVIQ (β=6.058, p=0.78). Additionally, No interaction was found between participant groups and age effects on NVIQ (β=1.470, p=0.52).

While there was no correlations between age and NVIQ in either groups of children, age and non-verbal working memory significantly positively correlate in the TD group (r=0.72, p<0.001) but not in the group of children with ASD (r=0.30, p=0.10). A linear regression model also showed interaction between age and participant groups in affecting NVWM, with more effects of age on NVWM in TD children than children with ASD (β=0.265, p=0.05). Figure 4.2 presents such correlations, showing steep improvement in NVWM with age in the TD group.

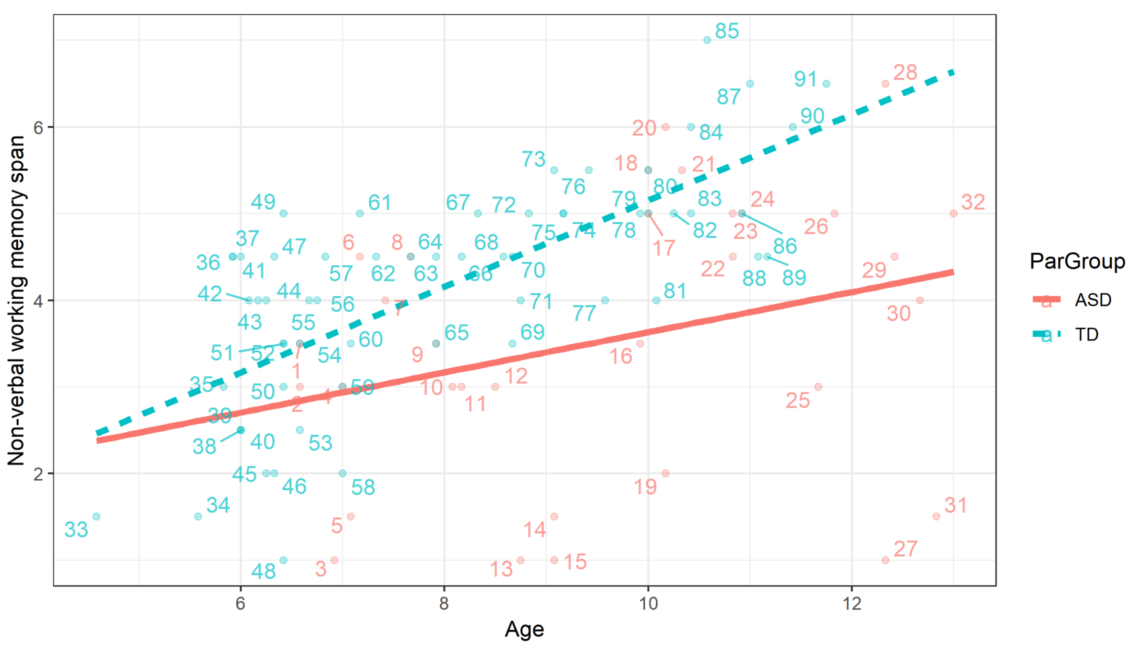


Figure 4.2: Scatter plot and regression line showing individual participant's age and non-verbal working memory span with their participant groups and ID number.

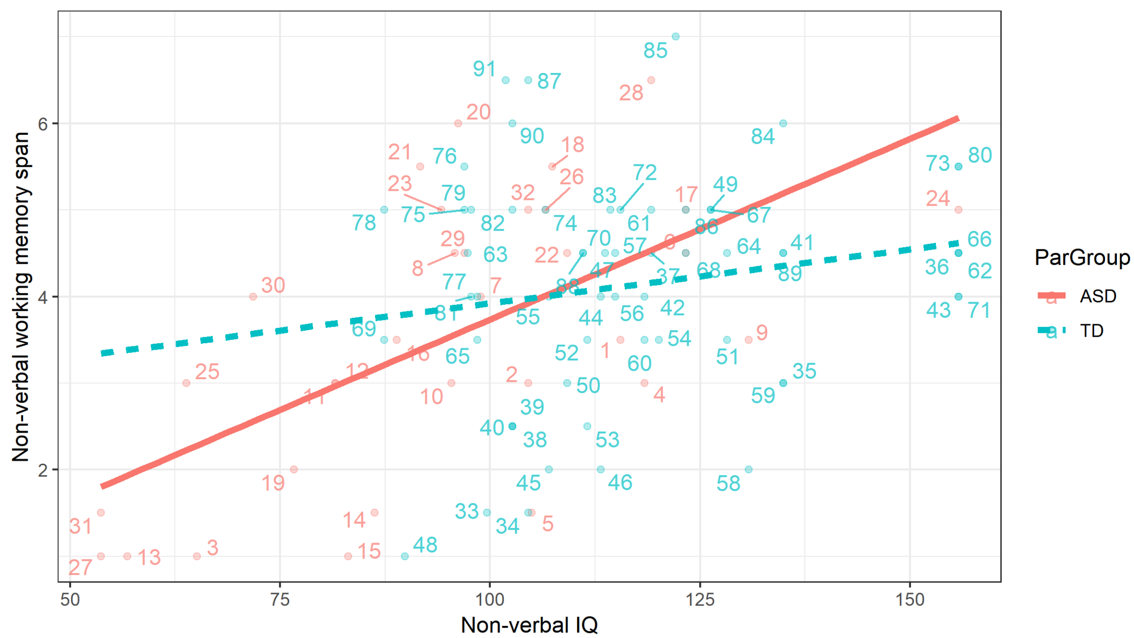


Figure 4.3: Scatter plot and regression line showing individual participant's non-verbal IQ and non-verbal working memory span with their participant groups and ID number.

In contrast, while age and NVWM did not correlate in the group of children with ASD, their NVIQ and NVWM highly positively correlate (r=0.61, p<0.001). On the other hand, such correlation between NVIQ and NVWM was not found in the TD group (r=0.18, p=0.17). An interaction result from a linear regression model also supported that NVIQ affects NVWM to a significantly lower extent in the TD group than in the group of children with ASD (β=-0.029, p=0.03). Figure 4.3 shows higher NVWM as NVIQ increases in the group of children with ASD, compared to TD children. A linear regression model revealed that age affects the performance on this task

4.3.2 Age and performance across experiments

This section investigates the effects of age, a developmental factor, on the children's performance on different tasks. Specifically, it investigates whether age correlates with or affects the subgrouping criteria used for each task or certain results that were found to be significantly different between participant groups. Age was found to negatively correlate with the percentages of excluded data points in Experiment 1.2 and 2 (same data set) in both the group of children with ASD (r=-0.40, p=0.03) and the TD group (r=-0.56, p<0.001). A linear regression model revealed that age affects the performance on this task

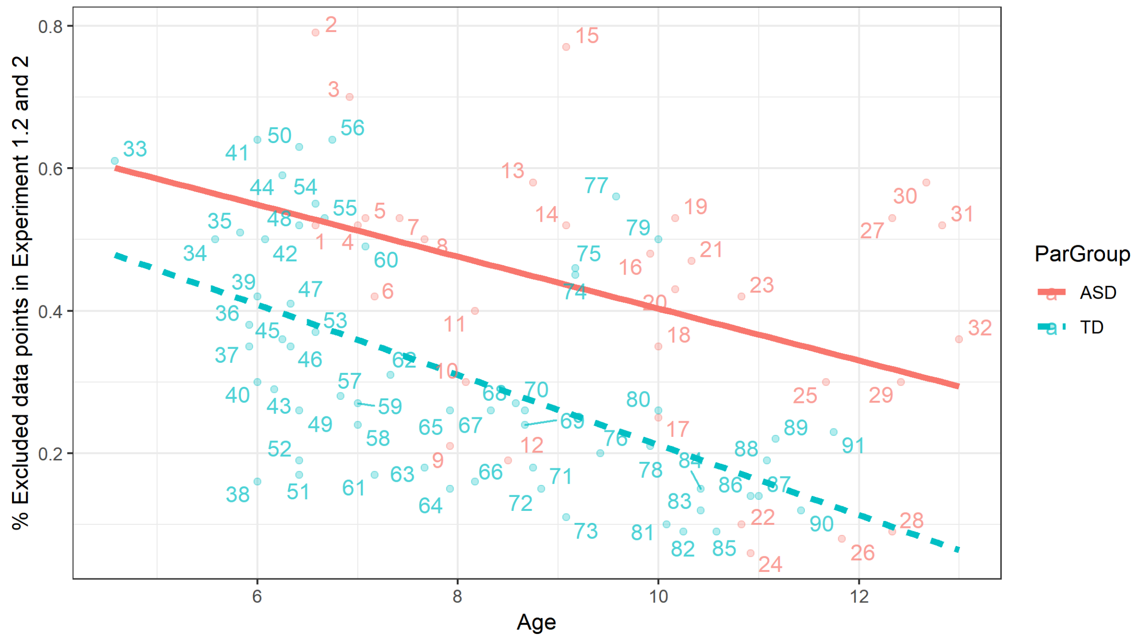


Figure 4.4: Scatter plot and regression line showing individual participant's age and percentages of excluded data points in Experiment 1.2 and 2 with their participant groups and ID number.

similarly in both groups of children (β=-0.013, p=0.45), with older children having less excluded data points, and hence more of them belonging to Group 1. Figure 4.4 presents such correlations in both groups of children. In Experiment 3, age also appeared to negatively correlate with the percentages of excluded data points of the TD children (r=-0.48, p<0.001) but not of children with ASD (r=-0.01, p=0.94). However, a linear regression model did not reveal any interaction between age and participant groups effects on the performance in Experiment 3 (β=-0.021, p=0.20).

Because only four participants were excluded in Experiment 4.2, two other continuous variables were included in the correlation analyses. The two variables were shown to be indicative of participant group effects in the previous chapter. A Pearson correlation analysis showed that age positively correlates with both groups of children's choice of using a personal pronoun to refer to themselves, rather than personal names or other terms (ASD: r=0.37,

p=0.04; TD: r=0.45, p<0.001). A linear regression showed no difference between the effects of age on the use of first-person pronouns across participant groups (β=-0.021, p=0.65), with older participants of both groups being equally more likely to choose to use personal pronouns than younger children.

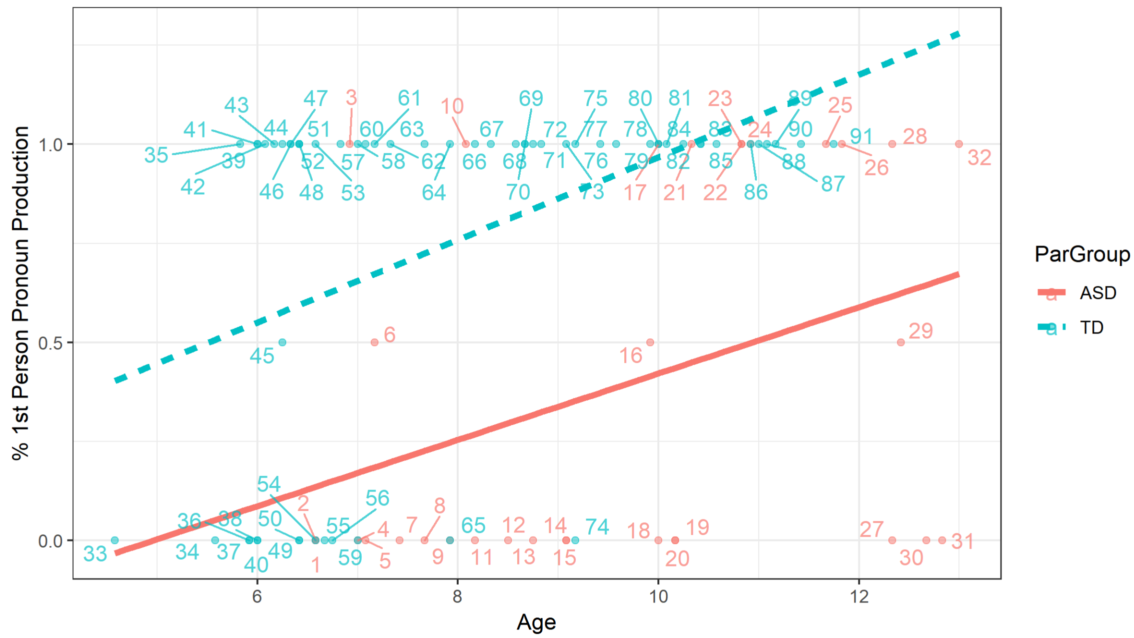


Figure 4.5: Scatter plot and regression line showing individual participant's age and percentages of children using first-person pronouns to refer to themselves.

Figure 4.5 shows that even though age affects their use of personal pronouns to a similar extent, no TD children of age 10 or older preferred choices other than personal pronouns in referring to themselves. All of the children were also fairly consistent with their choice of personal reference terms across their two trials of first person production, hence most choices being either 0% or 100% of personal pronoun use. Further correlation analysis were done on their accuracy rates in comprehending the second-person pronoun $k^h un$ in the formal register, which were shown in the previous chapter to differ across participant groups. In both the groups of children with ASD and TD children, no correlations were found between age and their accuracy rates (ASD: r=0.06, p=0.74; TD: r=-0.01, p=0.97). A linear regression model also revealed no interaction between the age effects on their accuracy rates across participant groups (β=-0.011, p=0.79).

As for Experiment 5, age of both groups of children showed no significant correlation with their accuracy rates in the *AllMet* and the *Filler 3* conditions, which were used as measures for task comprehension and exclusion criteria (ASD: r=0.31, p=0.09; TD: r=0.18, p=0.17). A linear regression model supported that the effects of age on their accuracy rates in the two conditions of Experiment 5 do not differ across participant groups (β=-0.008, p=0.75). As seen in the previous chapter, the *AllViolated* condition yielded significantly different results between children with ASD and TD children. The covered box rates in the *AllViolated* condition of Experiment 5 were, therefore, included in the correlation analyses. The results from the correlation analyses showed no correlation between age and their covered box rates in the *AllViolated* condition in the TD group (r=0.18, p=0.17). On the other hand, in the group of children with ASD, the covered box rates positively correlate with the age of the children (r=0.46, p<0.01), as shown in Figure 4.6. Such difference in correlations was, however, not supported by a linear regression model, only showing no significance in the interaction between the effects of age and participant groups on their covered box rates, with age having less effects in the TD group (β=-0.05, p=0.08).

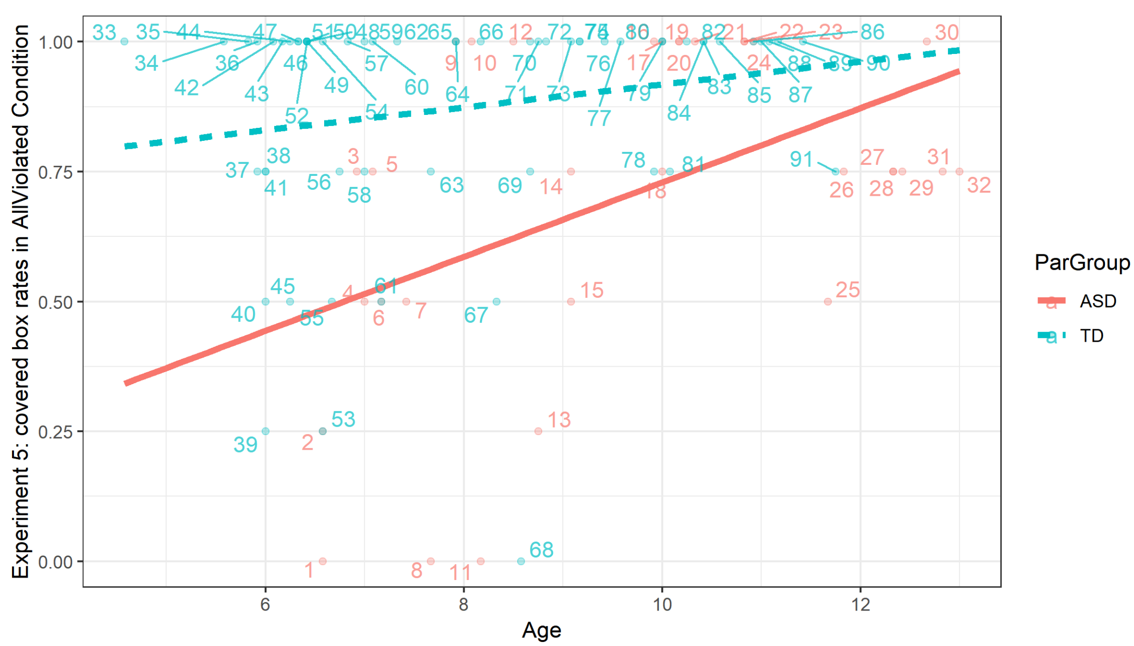


Figure 4.6: Scatter plot and regression line showing individual participant's age and covered box rates in the *AllViolated* condition of Experiment 5.

In sum, age effects were present in all of the experiments. Nevertheless, the effect of age on the task performance were not found to significantly differ across the participant groups in all of the experiments.

4.3.3 Cognitive measures and performance across experiments

This section explores the correlations between cognitive measures, namely non-verbal intelligence quotient (NVIQ) and non-verbal working memory (NVWM) on the children's performance across the experiments, in the same aspects as what we have seen in the previous section with the effects of age.

4.3.3.1 Non-verbal intelligence quotient

NVIQ displayed a negative correlation with the percentages of excluded data points in Experiment 1.2 and 2 in the group of children with ASD (r=-0.40, p=0.03), but not in the TD group (r=-0.56, p<0.001). A linear regression model, however, did not show significant interaction between the effects of NVIQ and participant groups on the percentages of excluded data points in Experiment 1.2 and 2 (β=0.003, p=0.11).

On the other hand, NVIQ highly correlates with the percentages of excluded data points in Experiment 3 in the group of children with ASD (r=-0.52, p<0.01), but not in the TD group (r=0.01, p=0.97). A linear regression model supported the correlations with a highly significant interaction effect between NVIQ and participant groups on the performance in Experiment 3 (β=0.005, p<0.001). Figure 4.7 showed a sharp contrast between the correlations of NVIQ and task performance in Experiment 3 between the group of children with ASD and the TD group. While NVIQ showed no correlation on the performance of TD children, higher NVIQ in children with ASD assisted them in completing the task with higher accuracy and fewer items with extreme reaction times.

As for the production and comprehension of personal reference terms, no correlations were found between NVIQ and the production of first-person pronouns (ASD: r=0.26, p=0.15; TD: r=0.09, p=0.49) nor the comprehension of the second-person pronoun $k^h un$

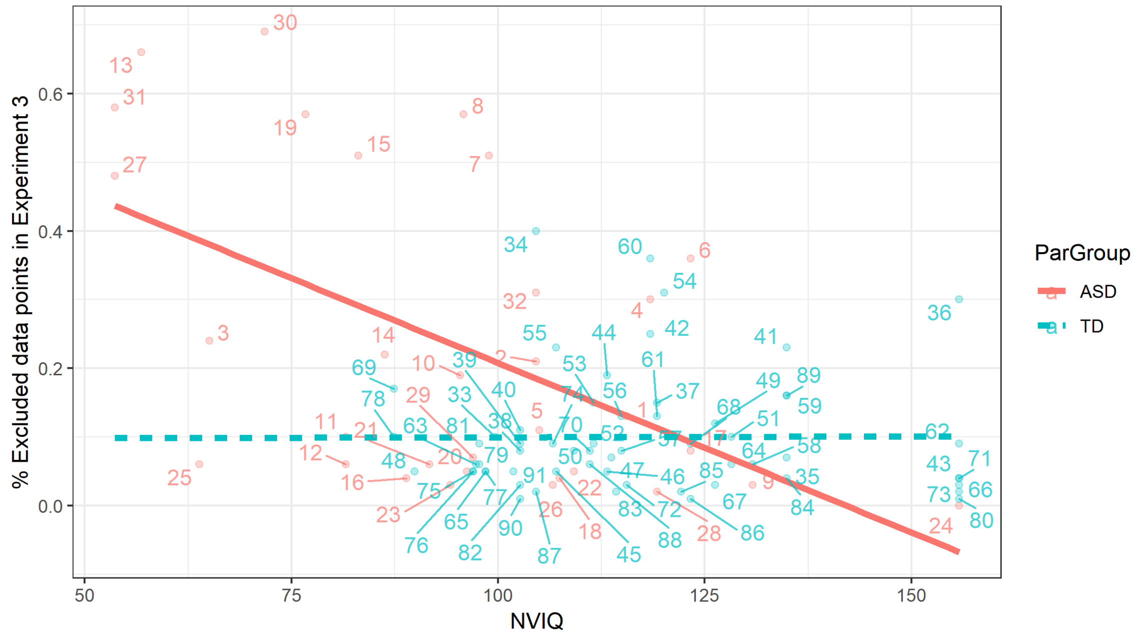


Figure 4.7: Scatter plot and regression line showing individual participant's NVIQ and percentages of excluded data points in Experiment 3 with their participant groups and ID number.

in the formal register (ASD: r=0.09, p=0.64; TD: r=0.55, p=0.68) in both groups of participants. Linear regression models also yielded no interactional effects between NVIQ and participant groups on either the production of first-person pronouns (β=-0.003, p=0.50) or the comprehension of the formal second-person pronoun (β=-0.000, p=0.97).

In Experiment 5, NVIQ positively correlates with the accuracy rates in the *AllMet* and the *Filler 3* conditions for children in ASD (r=0.43, p=0.02), but not in TD children (r=0.24, p=0.06). Such group difference in correlations, however, were not supported by a linear regression model, finding no interaction between NVIQ and participant groups on the accuracy rates in the two conditions of Experiment 5 (β=-0.001, p=0.78). Similarly, no correlations were observed between NVIQ and the covered box rates in the *AllViolated* condition in either the group of children with ASD (r=0.11, p=0.56) or the TD group (r=0.18, p=0.17). A linear regression model supported that the effects of NVIQ on their covered box rates do not differ across participant groups (β=0.001, p=0.78).

All in all, the correlations between NVIQ and task performance were observed in Experiment 1.2, 2, 3, and 5 but not in Experiment 4.2. Additionally, NVIQ was also found to differ in its effects on the children's performance in Experiment 3 across participant groups. Higher NVIQ in children with ASD positively affects their task performance, while it does not do so in the TD child data.

4.3.3.2 Non-verbal working memory

A negative correlation was observed between NVWM and the percentages of excluded data points in Experiment 1.2 and 2 for both groups of children (ASD: r=-0.60, p<0.001; TD: r=-0.46, p<0.001). With the correlations present in both groups, a linear regression model showed no significant interaction between the effects of NVWM and participant groups (β=0.012, p=0.60).

Additionally for both groups of children, NVWM negatively correlates with the percentages of excluded data points in Experiment 3 (ASD: r=-0.50, p<0.01; TD: r=-0.33, p=0.01). A linear regression model further displayed a significant interaction effect between NVWM and participant groups on the performance in Experiment 3 (β=0.046, p=0.02), with a stronger effects of NVWM on the task performance in the group of children with ASD than the TD group. See Figure 4.8 for the correlations.

While it was shown earlier that NVIQ did not affect the production of first-person pronouns, NVWM positively correlates with the percentages of first-person pronoun production in both groups of children (ASD: r=0.45, p=0.01; TD: r=0.33, p=0.01). No interaction between NVWM and participant groups was found in modelling the first-person pronoun production in Experiment 4.2 (β=-0.017, p=0.79). Similar to NVIQ, NVWM also does not correlate with the comprehension of the second-person pronoun k^hun in both groups of participants (ASD: r=0.15, p=0.42; TD: r=-0.03, p=0.80). Linear regression models yielded no interaction between NVWM and participant groups on the comprehension of the pronoun (β=-0.040, p=0.46).

Similar to NVIQ and Experiment 5, NVWM positively correlates with the accuracy rates in the *AllMet* and the *Filler 3* conditions for children in ASD (r=0.54, p=0.001),

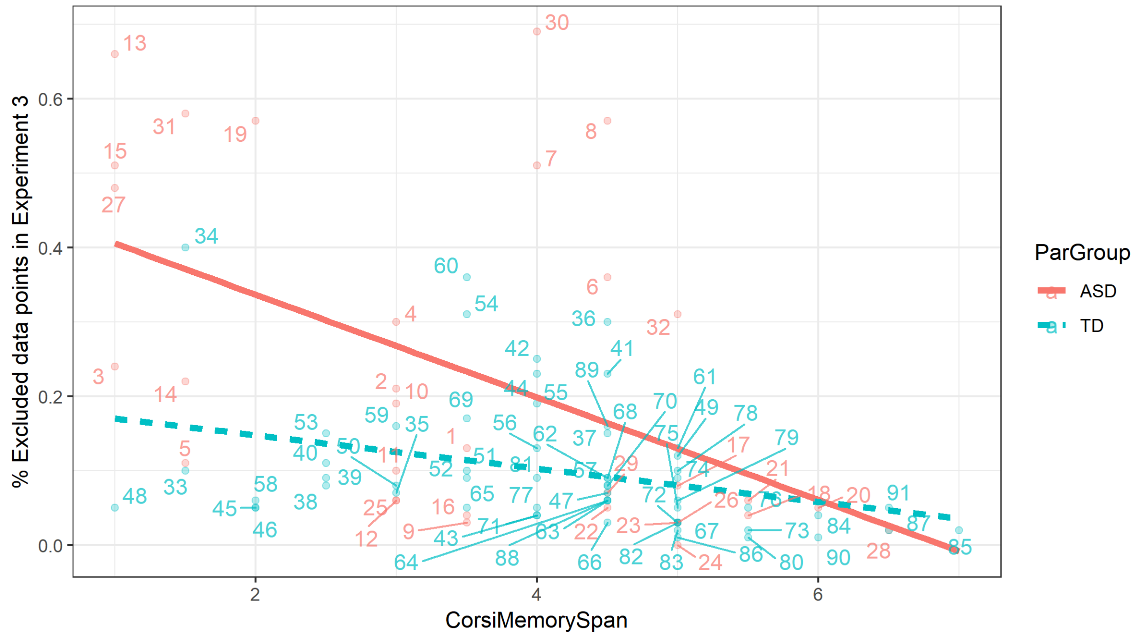


Figure 4.8: Scatter plot and regression line showing individual participant's NVWM and percentages of excluded data points in Experiment 3 with their participant groups and ID number.

but not for TD children (r=0.13, p=0.33). No interaction between NVIQ and participant groups on the accuracy rates in the two conditions was, nonetheless, found in a linear regression model (β=-0.049, p=0.17). No correlations were observed between NVWM and the covered box rates in the *AllViolated* condition in either the group of children with ASD (r=0.23, p=0.20) or the TD group (r=0.19, p=0.15). Accordingly, the effects of NVIQ on their covered box rates in a linear regression model do not differ across participant groups (β=-0.012, p=0.75).

To summarize, the correlations between NVWM and task performance were found in some aspects of all of the experiments. Similar to NVIQ, NVWM was observed to affect the performance in Experiment 3 to a higher extent in the group of children with ASD than the TD group.

4.3.3.3 Between-experiment performance

TD Children: The performance across experiments appeared to correlate. The percentages of excluded data points in Experiment 1.2 and 2 positively correlate with those in Experiment 3 (r=0.52, p<0.001), while negatively correlate with the percentages of first-person pronoun production in Experiment 4.1 (r=-0.38, p<0.001) and whether or not they belong to Group 1 in Experiment 5 (r=-0.27, p=0.04). Excluded data points in Experiment 3 also negatively correlate with their first-person pronoun production in Experiment 4.1 (r=-0.41, p<0.001). Additionally, Experiment 4.2 first-person pronoun production and the accuracy rates for the *AllMet* and *Filler 3* conditions in Experiment 5 correlate (r=0.28, p=0.03). The accuracy rates in comprehending of the formal second-person pronoun $k^h un$ positively correlate with their accuracy rates in the two conditions that were included in the exclusion criteria of Experiment 5 (r=0.32, p=0.02).

Children with ASD: Likewise, children with ASD who performed well in one experiment also appeared to perform well in the others. The percentages of excluded data points in Experiment 1.2/2 and 3 also highly correlate (r=0.61, p<0.001). Those percentages in the two experiments also negatively correlate with the percentages of first-person pronoun production in Experiment 4.2 (Experiment 1.2/2: r=-0.53, p<0.01; Experiment 3: r=-0.48, p<0.01) and the accuracy rates of the *AllMet* and *Filler 3* conditions in Experiment 5 (Experiment 1.2/2: r=-0.52, p<0.01; Experiment 3: r=-0.43, p=0.01). The accuracy rates in comprehending of the formal second-person pronoun $k^h un$ positively correlate with the children being included in Group 1 of Experiment 3 (r=0.36, p=0.04). One major difference between the two participant groups is that not only do Experiment 1.2/2 and the pronoun production in Experiment 4.2 correlate with the accuracy rates of the *AllMet* and *Filler 3* conditions, they also correlate with the children with ASD's covered box rates in the *AllViolated* condition (Experiment 1.2/2: r=-0.40, p=0.02; Experiment 4: r=0.39, p=0.03).

4.4 K-means cluster analysis

Section 4.3.3.3 established that the children's performance across various linguistic tasks correlate with each other. This section aims to continue to detect subgroups of children with ASD by the patterns of performance across linguistic experiments alone *without* developmental or cognitive measures. This section clusters observations that are continuous variables across experiments. These observations include the values that subgrouping criteria of different experiments were based on, including (1) the percentages of excluded data points after the removal of inaccurate responses and extreme response times in Experiment 1.2, 2, and 3 and (2) the accuracy rates in the *AllMet* and *Filler 3* conditions in Experiment 5. Moreover, they also include observations where children with ASD differ from TD children, including (1) the production of first-person pronouns, (2) the comprehension of the formal second-person pronoun $k^h un$, and (3) the covered box rates in the *AllViolated* condition of Experiment 5.

A k-means cluster analysis was performed on the data of children with ASD using the `cluster` package (Version 2.1.0; Maechler et al. 2019), the `factoextra` package (Version 1.0.5; Kassambara and Mundt 2017), and the `NbClust` package (Version 3.0; Charrad et al. 2014), in the R environment. K-means clustering is an algorithm used in machine learning for classifying observations in a data set into the pre-specified k number of clusters. The classification is done by maximizing the similarity between each objects of the same cluster and minimizing the similarity of objects between different clusters. The data were first standardized before its k-means were computed with the `kmeans` function with 25 initial configurations.

The k number of clusters has to be pre-determined for the computation of k-means. To determine the optimal number of clusters based solely on the children with ASD's performance on linguistic tasks, the average silhouette and the gap static methods (Tibshirani et al., 2001) were used. Both of the methods consistently suggested that the children with ASD can be optimally clustered into two groups, as seen in the result visualizations in

Figure 4.9 and 4.10 respectively for each method.

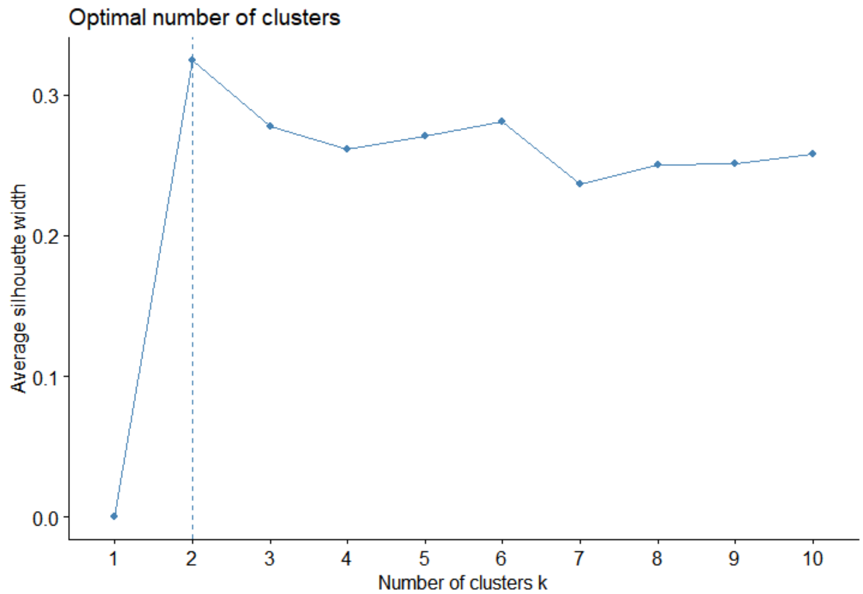


Figure 4.9: The optimal number of clusters by the average silhouette method.

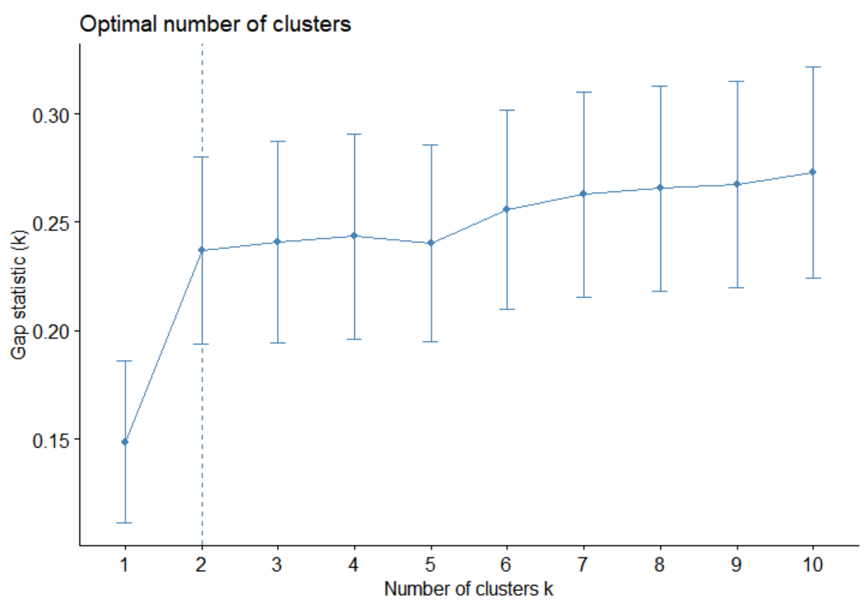


Figure 4.10: The optimal number of clusters by the gap statistic method.

With the two methods suggesting 2 as the optimal number of clusters, k-means were computed, partitioning the data set into 2 clusters. Cluster 1 comprised 13 children with ASD (M age = 10;8, M NVIQ = 101.15), while the other 19 children with ASD (M age

= 8;11, *M* NVIQ = 91.64) were included in Cluster 2. An illustration of the two clusters are presented in Figure 4.11, using the `fviz_cluster` function, which performed principal component analysis (PCA). The first two principal components that captures the majority of the variance were used for plotting the data.

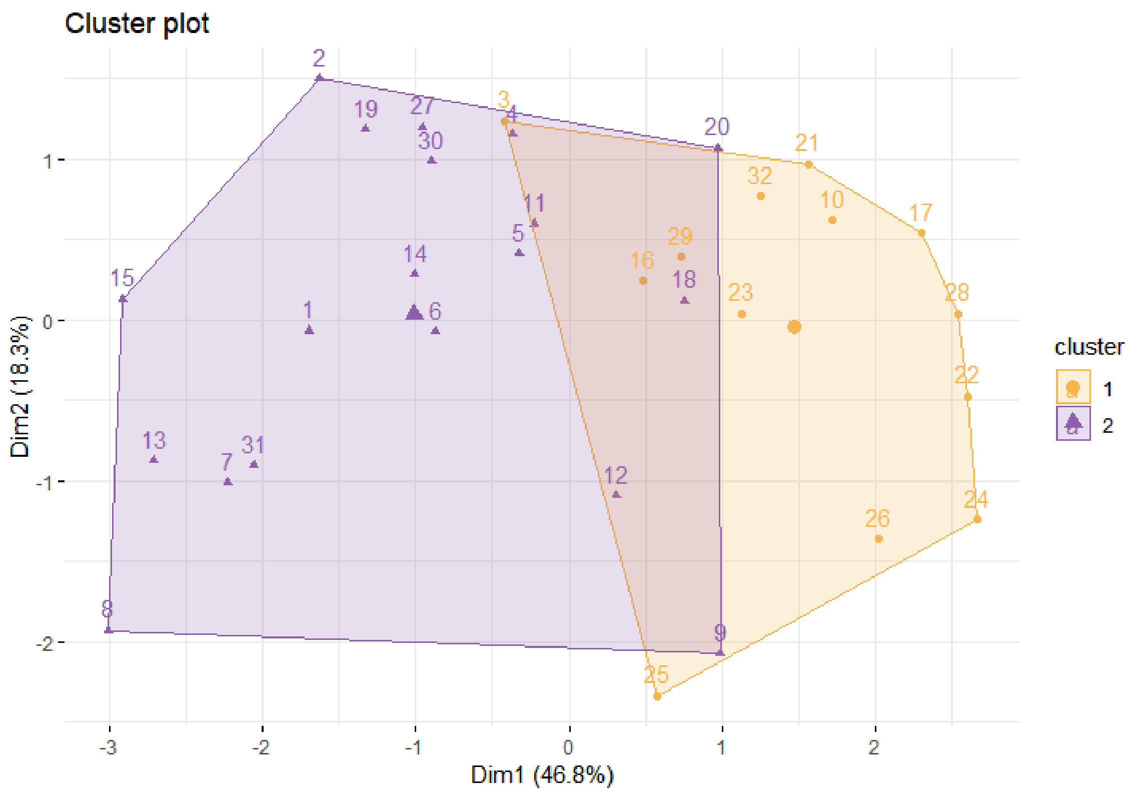


Figure 4.11: The k-means cluster plot of individual children with ASD based on their performance on the linguistic experiments in this dissertation.

Standard pairwise scatter plots were further used to illustrate the two clusters of children with ASD compared to the original variables. Figure 4.12 shows that children with ASD in Cluster 1 generally have fewer excluded data points in Experiment 1.2/2 and 3 than children with ASD in Cluster 2. A visualization of the results of Experiment 4.2 and 5 in Figure 4.13 showed that children with ASD in Cluster 1 chose to produce more first-person pronouns, while having relatively high accuracy in the *AllMet* and *Filler 3* conditions, compared to Cluster 2. Figure 4.14 shows that the children with ASD in Cluster 1 were generally highly accurate in detecting the marked person feature of the second-person pronoun

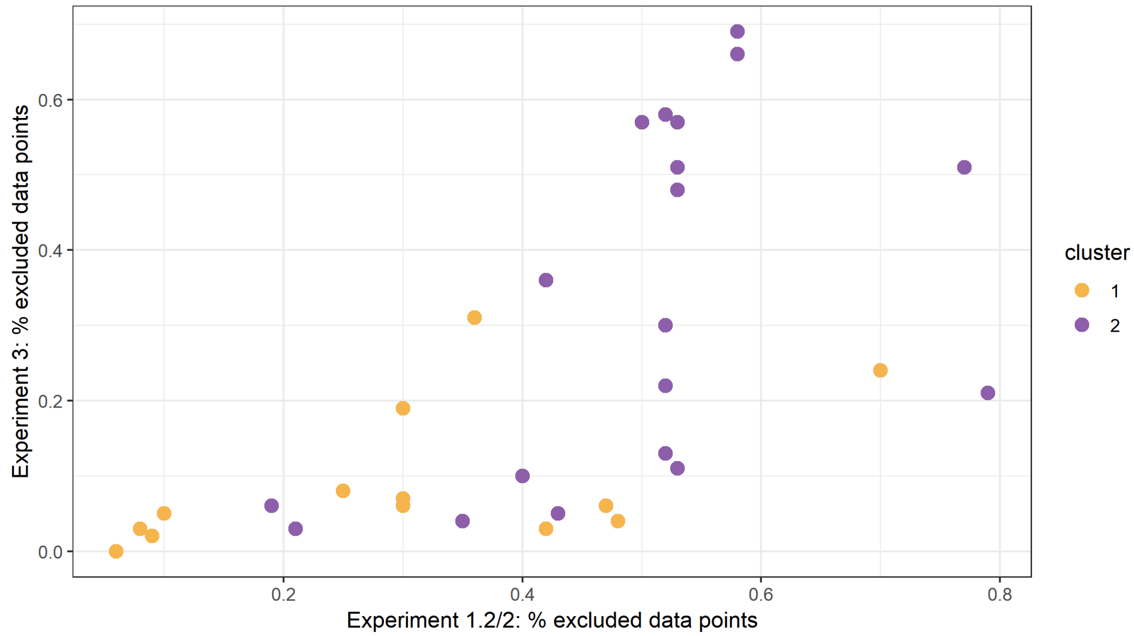


Figure 4.12: The children with ASD's performance on Experiment 1.2/2 (x axis) and 3 (y axis) by their k-means clusters (Cluster 1 in yellow; 2 in purple).

Figure 4.13: The children with ASD's accuracy rates in the *AllMet* and *Filler 3* conditions in Experiment 5 (x axis) and their rates of first-person pronoun production in Experiment 4 (y axis) by their k-means clusters (Cluster 1 in yellow; 2 in purple).

$k^h un$, despite the pronoun's social awkwardness, while also tended to reject the literal meaning in the *AllViolated* condition.

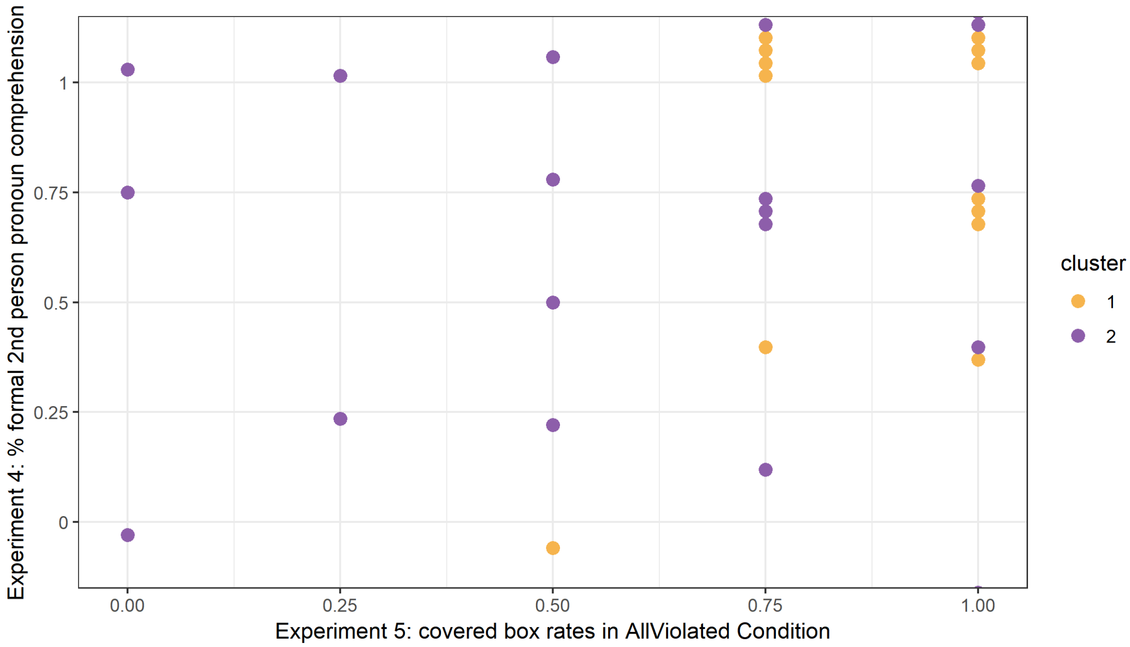


Figure 4.14: The children with ASD's covered box rates in the *AllViolated* condition in Experiment 5 (x axis) and their accuracy rates of formal second-person pronoun comprehension in Experiment 4 (y axis) and by their k-means clusters (Cluster 1 in yellow; 2 in purple).

4.5 Individual profiles

Individual profiles were created for each child based on their performance on linguistic and non-linguistic tasks in this dissertation. The individual profiles combined aspects of the data from all five experiments, including (1) their age, (2) gender, (3) NVIQ, (4) NVWM, (5) which subgroup they were grouped to in each experiment, (6) Experiment 1.2 and 2: percentages of excluded data points (Exclusion criteria), (7) Experiment 3: percentages of excluded data points (Exclusion criteria), (8) Experiment 4.2: percentages of first-person pronoun production, (9) Experiment 4.2: accuracy rates in comprehending the second-person pronoun $k^h un$ in the formal register, (10) Experiment 5: accuracy rates in the *AllMet* condition and Filler 3 (Exclusion criteria), (11) Experiment 5: accuracy rates in the

AllViolated condition, and (12) Children with ASD's k-means cluster (see Section 4.4 for more details). The individual profiles are provided in Appendix B.

4.6 General discussion

This chapter aims at investigating the last hypothesis of this dissertation which is the Cognitive Factor Hypothesis: that cognitive factors, as opposed to a developmental factor like age, would correlate more with the performance of children with ASD than that of TD children. It additionally attempts to create individual profiles for each of the children who participated in all of the experiments in Fall 2017 in order to detect certain patterns in their performance that may assist in subgrouping children with ASD.

Correlation analyses were performed on (1) age and cognitive measures, including non-verbal intelligence quotient (NVIQ) and non-verbal working memory (NVWM), (2) age and performance across experiments, (3) cognitive measures and performance across experiments, and (4) between-experiment performance. Age and NVIQ, which were included in previous models in the previous chapters, were not found to correlate with each other. However, age correlate with NVWM for the TD group but not in the group of children with ASD. On the other hand, NVWM was found to correlate with NVIQ in the group of children with ASD, but not in the TD group.

With regards to the correlations between age and the children's performance on different tasks, age was found to be an important factor in certain aspects of all of the experiments. However, the extent to which age correlates with and affects the task performance was not significantly different between participant groups. In contrast, NVIQ and NVWM were both found to differ in its effects on the two group of children's performance in Experiment 3. Higher NVIQ and NVWM correlate with better task performance in children with ASD but not in TD children. While NVIQ and NVWM have different pattern of correlations with Experiment 3 performance in children with ASD, compared to TD children, they did not yield different interaction effects on the performance in the other experiments. This may be partly due to the fact that all but one TD child's performance was below the exclusion criteria. The nature of the task in Experiment 3 might be the least challenging among all of the tasks. The fact that it still poses challenges for a subgroup of children with ASD, but not TD children, with lower NVIQ and NVWM suggests group difference between children with ASD and TD children that are present regardless of NVIQ and NVWM. Since Experiment 3 was the only experiment which yielded different interaction between NVIQ/NVWM and participant group effects, no definitive conclusions can be reached for the Cognitive Factor Hypothesis. It however suggests that there could be certain differences between the two groups of children's reliance on these cognitive factors in performing linguistic tasks.

Further correlation analyses revealed that the performance across tasks correlate with each other for both children with ASD and TD children. The major findings in each of the experiments were compiled for each individual child. Experiment 1.2 and 2 involved a lexical decision task, where as Experiment 3 used picture-sound congruity decision task. The two tasks involved lexical knowledge and lexical processing in an accurate and timely manner. Two variables from Experiment 4.2 were selected based on what was found to be the major difference between children with ASD and TD children. Those variables include the percentages of their choice in producing first-person pronoun, as opposed to other terms such as personal names that also belong in the Thai personal reference system and the accuracy rates in the comprehension of the formal second-person pronoun k^hun, which suggests their ability to detect marked grammatical features on pronouns but their insensitivity to social deictic information. For Experiment 5, the accuracy rates in the *AllMet* and the *Filler 3*, which were the bases for the exclusion criteria, and the covered box rates in the *AllViolated* condition were included in the k-means cluster analysis.

A k-means cluster analysis were performed on the observations in the data of children with ASD to explore if they give rise to detectable subgroups in the children with ASD. Both the average silhouette and the gap static methods (Tibshirani et al., 2001) suggested that the number of optimal clusters are 2. Based on the number, k-means were computed for the number of 2 clusters for children with ASD. The results revealed that children with ASD in Cluster 1 have better global linguistic abilities than children with ASD in Cluster

2. This links back to the literature on the heterogeneity in autism and the proposals of subgroups of children with ASD with and without language impairments (ALI and ALN respectively; Boucher 2012; Tager-Flusberg 2004). The results in this dissertation supports subgrouping of children with ASD based on linguistic abilities. It leaves open for future research, however, the question of whether the nature of language impairments in autism is similar to that of language impairments in Specific Language Impairments (SLI).

Another implication from the results in this chapter lies in the nature of the language profiles of the children with ASD in Cluster 1, compared to the children with ASD in Cluster 2. The children with ASD in Cluster 1 appear to have intact lexical processing, produce first-person pronouns, and rely less on the literal meaning when inferred meanings are violated. Interestingly, they also tend to be highly sensitive to the marked person feature in second-person pronouns, despite the pragmatic oddness in formality with regards to social deixis.

Chapter 5

Conclusion

In this dissertation, I explore topics in language and autism in Thai. Properties of Thai such as lexical tones, vowel length distinctions, compounding, highly complex personal reference system, and deictic-center shifting were employed in designing carefully-planned experiments. This dissertation examined three main hypotheses through 5 sets of linguistic experiments and 2 non-linguistic tasks done by Thai children with autism and typically developing controls.

The first hypothesis is that ASD children (perhaps limited to the subgroup with co-morbid language impairments) have difficulties activating abstract lexical representations as effectively as TD children, due to their hyperattention to phonetic details of speech. Second, pragmatics is predicted to be particularly difficult for all the ASD children, while morphological and semantic aspects of language are relatively intact. Third, cognitive factors such as nonverbal intelligence quotient (NVIQ) and nonverbal working memory play a greater role in the ASD than the TD performance on linguistic tasks.

5.1 Contributions

This dissertation provides a linguistically-motivated investigation into different areas of language in children with ASD, compared to TD children and in parts, to adults. It illustrates how fine distinctions among linguistic units may affect language production and comprehension in children. This dissertation mainly adds to the literature on morphological, semantic, and pragmatic abilities of children with autism with the major findings and contributions reviewed by chapter.

Chapter 2, which investigates morpho-phonological and semantic aspects of lexical processing, provides evidence for the Independent Morphological Processing (IMP) hypothesis (Bacovcin et al., 2017), showing robust morphological effects that are independent of phonology and semantics on the processing of Thai compounds in adults. Children with ASD in Group 2 displayed some signs of deviance, showing hyper-attention to the acoustic differences between primes and targets, compared to their TD peers in the same performance groups. Both children with ASD and TD children in the performance group 1, on the other hand, showed similar effects as adults, except that phonological effects were absent in the child data. The major finding lies in the enhanced morphological facilitation effects in children with ASD of Group, compared to their TD peers in the same group. Children with ASD, however, were not more facilitated by the primes that are both morphologically and semantically related to the targets, than TD children, suggesting that their enhanced morphological effects can appear independent of enhanced semantic effects.

To explore the children's sensitivity to phonological details in speech further, children with ASD got significantly lower facilitation than TD children in the conditions where targets that are natural-sounding surface forms, as opposed to the less frequent full forms. The results suggest a deeper, but slower, processing of surface forms, compared to full forms, in Experiment 2. With the assistance of visual information, children with ASD performed equally well as TD children in Experiment 3, supporting that such slower processing found in Experiment 2 may result from their slower lexical semantic processing. The Abstract Representation Difficulty Hypothesis, thus, holds for a subgroup of children with ASD, while other children with ASD display intact phonological representation, enhaced morphological processing compared to TD controls, and intact but slower lexical processing.

Chapter 3 explores the Pragmatic over Grammatical Deficits Hypothesis. Using fine distinctions within personal reference terms that may have been overlooked in previous studies on language and autism, consistent replicated results suggests that while grammatical person ϕ-features are intact in children with ASD's representation of pronouns, they are less sensitive to deictic information in their interpretation of pronouns. In a language where personal names and other options are available for use, lower rates of pronoun use can go undetected. Given such freedom of choice, children with ASD were also more likely to choose not to use the first-person pronoun, which is higher in its deictic level than personal names. Children with ASD also performed more poorly in the comprehension of unmarked pronouns which require *implicated presupposition*, suggesting fine pragmatic deficits in children with ASD also manifest themselves at a smaller level of language. Even with minimal comparisons among pronouns, lexically-encoded core grammatical features and pragmatic ones are distinguished in children's language processing.

Chapter 3 also adds to the literature on lexical presuppositions, scalar implicature, and implicated presuppositions the observation that not only adolescents, but also children with ASD are on par with their TD peers in deriving scalar implicatures. This suggests that they are age-appropriate in deriving scalar implicatures and that not all kinds of pragmatic inferences are equally challenging for children with ASD. Both children and TD children in this study, however, differ from adults in their rates of calculating scalar implicatures, with children in both groups relying more on literal, logical meaning than adults. Children with ASD consistently showed their intact ability in arriving at lexically presupposed meanings in both the task related to personal reference terms and negated quantifiers *not every*, supporting that lexical presuppositions are generally less challenging for children than scalar implicature. As for implicated presuppositions, the personal reference term experiments support that implicated presuppositions are later to be acquired than lexical presuppositions. The additive effect of implicated presupposition violation on top of scalar implicature, however, was not found in this experiment. The most indicative difference between the group of children with ASD and the TD group lies in the children with ASD's heavier reliance on literal, logical meaning when other semantically- and pragmatically-inferred meanings are violated.

Chapter 4 partly contributes to the Cognitive Factor Hypothesis, suggesting the possibility that cognitive factors, as opposed to developmental factors, correlates more with children with ASD's performance on linguistic tasks. The evidence for the hypothesis was only present in Experiment 3, where both NVIQ and NVWM correlate more with the performance of children with ASD than with TD children. Other experiments did not yield significant difference in correlation patterns with developmental nor cognitive factors.

Additionally, children in both groups displayed correlations in their performance across all of the experiments in the dissertation. Chapter 4 compiled selected results, that were shown to yield group differences between children with ASD and TD children, from previous chapters as individual language profiles for each child. Two subgroups of children with ASD were identified through k-means cluster analysis. Children with ASD in Cluster 1 have globally better performance across experiments than children with ASD in Cluster 2, supporting that subgroups of ASD children, including ALI and ALN, may be able to be classified based on their performance on linguistic tasks alone. Children with ASD in Cluster 1 were found to have more intact lexical processing, produce more first-person pronouns, and be more likely to reject literal meaning when inferred meanings are violated. The ability to detect lexical ɸ-features also appeared to be better in the children with ASD in Cluster 1 but that simultaneously suggests that they were still less sensitive to the social-deictic information that is pragmatically encoded in the formal 2nd person pronoun.

5.2 Future directions

As with other experimental studies, the experimental results in this dissertation should be replicated and extended in Thai and other languages. Specifically, the comparability between Experiment 1.1 and 1.2 should be maximized by using the same ISIs and the same proportion of fillers. In general, lexical decision tasks appear to be more challenging for children than picture-sound-congruity decision tasks as the task heavily relate to children's language experience. Pseudowords that conforms to the phonotactics of a given language may not be decided as non-words for younger children. While Experiment 3 involves a relatively less challenging task, it may also benefit from certain improvements in the future, including counterbalancing whether pictures and sounds match with each other or not within the fillers, instead of within critical items. Other adjustments in designs include keeping constant the properties of the tested items, e.g., including exclusively monosyllabic or disyllabic nouns or verbs, keeping targets constant across conditions. In languages with other available measures, such as frequency, neighborhood density, and age of acquisition for words or other standardized clinical measures, those measures should be controlled for and modelled in lexical processing experiments.

Apart from improvements in experimental design, the results from Chapter 2 raises interesting questions. Future studies may explore further the hypersensitivity to acoustic differences in a subgroup of children with ASD and the enhanced morphological effects but delayed lexical semantic processing in another subgroup of children with ASD. Chapter 3 also raises a question on the acquisition of implicated presuppositions as a pure, rather than an additive, effect by both TD children and children with autism. Chapter 4 raises questions on the similarities and differences between the language profiles of a subgroup children with ASD and children with Specific Language Impairment.

Appendix A

Stimuli

A.1 Experiment 1.1 and 1.2

The table below presents all of the stimuli in Experiment 1.1 and 1.2. Experiment 1.1 included Conditions MS, M, and S, while Experiment 1.2 included Conditions MS, M, Ph, and C. In each condition, the IPA transcription is provided on the first line. The meaning of the entire compound is provided on the second line, while the meaning of each component is on the third line. Most of the items were included in both Experiment 1.1 and 1.2. Exceptions were indicated by gray boxes. The items with gray boxes in the S condition were only present in Experiment 1.1, but not Experiment 1.2. The items with gray boxes in the Ph and C conditions were exclusive to Experiment 1.2 and were not included in Experiment 1.1.

No.		Root	MS	M	S	Ph	C
				Compound Nouns			
1	IPA:	naːm	naːm taː	naːm taːn	k^{h}ɔːŋ leːw	sɯːa klaːm	siː liːam
	Meaning (whole):	'water'	'tear' <	'sugar', 'brown' <	'liquid' <	'tank top' <	'square' <
	Meaning (parts):		'water' + 'eye'	'water' + 'palm'	'thing' + 'liquidy'	'shirt' + 'muscle'	'four' + 'angle'
	Rating:		5.48	2.28	5.71	1.69	1.08
2	IPA:	p^{h}raʔ	p^{h}ra-soŋ	p^{h}ra-ʔeːk	nak buːat	rɔːj laʔ	tuː jen
	Meaning (whole):	'monk'	'monk' <	'leading actor' <	'priest' <	'percent' <	'fridge' <
	Meaning (parts):		'monk' + 'monk'	'monk' + 'one'	'expert' + 'ordain'	'hundred' + 'per'	'cabinet' + 'cool'
	Rating:		6.63	2.04	5.81	1.08	1.08
3	IPA:	mɛː	mɛː dek	mɛː lek	maːn daː	klɯːa rɛː	tiːan k^{h}aj
	Meaning (whole):	'mother'	'mother' <	'magnet' <	'mother' (formal)	'mineral' <	'candle' <
	Meaning (parts):		'mother' + 'child'	'mother' + 'iron'	NA	'salt' + 'mineral'	'candle' + 'fat'
	Rating:		6.44	2.14	6.86	1.88	2.31
4	IPA:	mɔː	mɔː fan	mɔː lam	p^{h}ɛːt	rɯːan hɔː	k^{h}an maːk
	Meaning (whole):	'doctor'	'dentist' <	'a type of singer' <	'doctor' (formal)	'matrimonial home' <	'tray of gifts' <
	Meaning (parts):		'doctor' + 'tooth'	'doctor' + 'song'	NA	'house' + 'dorm'	'bowl' + 'betel nut'
	Rating:		6.30	2.14	6.90	1.31	1.60

No.		Root	MS	M	S	Ph	C
5	IPA:	huːa	huːa ka-loːk	huːa k^{h}am	siː sa	sɛːŋ sa-luːa	raːn k^{h}aː
	Meaning (whole):	‘head’	‘skull’ <	‘early evening’ <	‘head’ (formal)	‘glimmer’ <	‘store’ <
	Meaning (parts):		‘head’ + ‘skull’	‘head’ + ‘evening’	NA	‘light’ + ‘dim’	‘store’ + ‘trade’
	Rating:		6.06	2.28	6.85	1.75	1.23
6	IPA:	k^{h}aːw	k^{h}aːw saːn	k^{h}aːw poːt	ʔaː-haːn	sip kaːw	rot meː
	Meaning (whole):	‘rice’	‘rice’ <	‘corn’ <	‘food’	‘nineteen’ <	‘bus’ <
	Meaning (parts):		‘rice’ + ‘type of rice’	‘rice’ + ‘corn’	NA	‘ten’ + ‘nine’	‘car’ + ‘mail’
	Rating:		6.58	2.89	5.39	1.00	1.13
7	IPA:	paːk	paːk pet	paːk-kaː	p^{h}ra-oːt	ŋɤn faːk	roːŋ naŋ
	Meaning (whole):	‘mouth’	‘duck’s beak’ <	‘pen’ <	‘mouth’ (royal) <	‘deposit’ <	‘cinema’ <
	Meaning (parts):		‘mouth’ + ‘duck’	‘mouth’ + ‘crow’	prefix + ‘mouth’	‘money’ + ‘entrust’	‘hall’ + ‘movie’
	Rating:		5.34	2.01	6.75	1.23	1.85
8	IPA:	luːk	luːk laːn	luːk kroŋ	but t^{h}i-daː	naːm muːk	k^{h}rɯːaŋ bin
	Meaning (whole):	‘child’	‘lineage’ <	‘balustrade’ <	‘children’ (formal) <	‘snot’ <	‘airplane’ <
	Meaning (parts):		‘child’ + ‘grandchild’	‘child’ + ‘cage’	‘son’ + ‘daughter’	‘water’ + ‘mucus’	‘machine’ + ‘fly’
	Rating:		5.73	1.66	6.84	2.19	2.63

No.		Root	MS	M	S	Ph	C
9	IPA:	wɛːn	wɛːn taː	wɛːn k^{h}wɛːn	kra-cok len		
	Meaning (whole):	'glasses'	'glasses' <	'region' <	'lens' <		
	Meaning (parts):		'glasses' + 'eye'	'glasses' + 'country'	'mirror' + 'lens'		
	Rating:		6.76	1.86	5.59		
10	IPA:	t^{h}ɔːŋ	t^{h}ɔːŋ saj	t^{h}ɔːŋ t^{h}in	p^{h}uŋ	nak rɔːŋ	krɔːp ruːp
	Meaning (whole):	'abdomen'	'stomach' <	'region, area' <	'belly'	'singer' <	'frame' <
	Meaning (parts):		'stomach' + 'intestine'	'stomach' + 'area'	NA	'expert' + 'sing'	'frame' + 'picture'
	Rating:		5.87	1.72	6.25	1.69	1.08
11	IPA:	ba	baj maːj	baj naː	kiŋ kaːn	kon kaj	jaː mɔŋ
	Meaning (whole):	'leaf'	'leaf' <	'face' <	'branch' <	'mechanism' <	'balm' <
	Meaning (parts):		'leaf' + 'tree'	'leaf' + 'face'	'branch' + 'stick'	'trick' + 'trigger'	'medicine' + 'balm'
	Rating:		6.47	2.22	4.39	1.08	1.38
12	IPA:	kluːaj	kluːaj hɔːm	kluːaj maːj	wiː k^{h}rɯːa	p^{h}uː c^{h}uːaj	cut den
	Meaning (whole):	'banana'	a kind of banana <	'orchid' <	'CLS banana' <	'assistant' <	'prominent feature' <
	Meaning (parts):		'banana' + 'fragrant'	'banana' + 'wood'	'a hand of banana' + 'a bunch of banana'	'person' + 'help'	'point' + 'prominent'
	Rating:		6.53	1.72	5.85	2.63	1.56

No.		Root	MS	M	S	Ph	C
13	IPA:	maː	maː k^{h}ɛŋ	maː mɯːt	ʔaː-c^{h}aː	sin k^{h}aː	mɯːaŋ nɔːk
	Meaning (whole):	‘horse’	‘racehorse’ <	‘dark horse’ <	‘horse’ (literature)	‘goods’ <	‘foreign country’ <
	Meaning (parts):		‘horse’ + ‘race’	‘horse’ + ‘dark’	NA	‘money’ + ‘trade’	‘country’ + ‘outside’
	Rating:		6.29	2.57	6.91	2.75	2.75
14	IPA:	k^{h}aː	k^{h}aː niːp	k^{h}aː klap	kɛŋ	k^{h}ɔː haː	taw riːt
	Meaning (whole):	‘leg’	‘groin’ <	‘return trip’ <	‘shin’	‘allegation’ <	‘iron’ <
	Meaning (parts):		‘leg’ + ‘clamp’	‘leg’ + ‘return’	NA	‘item’ + ‘accuse’	‘stove’ + ‘iron’
	Rating:		5.33	1.99	5.84	1.54	1.23
15	IPA:	mɯː	mɯː cap	mɯː praːp	p^{h}ra-hat	k^{h}aːw lɯː	mɛːŋ mum
	Meaning (whole):	‘hand’	‘handle’ <	‘buster’ <	‘hand’ (royal)	‘rumor’ <	‘spider’ <
	Meaning (parts):		‘hand’ + ‘catch’	‘hand’ + ‘subdue’	prefix + ‘hand’	‘news’ + ‘spread’	‘bug’ + ‘corner’
	Rating:		4.67	2.30	6.89	1.31	2.31
16	IPA:	taː	taː toː	taː c^{h}aŋ	duːaŋ neːt	t^{h}uŋ naː	k^{h}am sap
	Meaning (whole):	‘eye’	‘big eye’ <	‘scale’ <	‘eye’ <	‘rice field’ <	‘vocabulary’ <
	Meaning (parts):		‘eye’ + ‘big’	‘eye’ + ‘weigh’	CLS + ‘eye (formal)’	‘field’ + ‘paddy’	‘word’ + ‘term’
	Rating:		6.25	1.80	6.82	1.50	1.50

No.		Root	MS	M	S	Ph	C
17	IPA:	kuŋ	kuŋ ten	kuŋ jiŋ	kaŋ	p^haː nuŋ	jaːŋ lop
	Meaning (whole):	‘shrimp’	‘Orchestia agilis’ <	‘stye’ <	‘mantis shrimp’	‘loincloth’ <	‘eraser’ <
	Meaning (parts):		‘shrimp’ + ‘dance’	‘shrimp’ + ‘shoot’	NA	‘cloth’ + ‘wear’	‘rubber’ + ‘erase’
	Rating:		6.23	1.54	4.42	1.06	1.00
18	IPA:	k^hem	k^hem klat	k^hem kat	mut	duːan tem	rɔːj jim
	Meaning (whole):	‘needle, pin’	‘safety pin’ <	‘belt’ <	‘pin’	‘full moon’ <	‘smile’ <
	Meaning (parts):		‘needle’ + ‘clasp’	‘needle’ + ‘cross’	NA	‘moon’ + ‘full’	‘trace’ + ‘smile’
	Rating:		5.48	2.38	5.47	1.08	1.08
19	IPA:	bɔʔ	boʔ naŋ	boʔ sɛː	fuːk	muː kɔʔ	kan saːt
	Meaning (whole):	‘cushion’	‘cushion’ <	‘clue’ <	‘mattress’	‘archipelago’ <	‘awning’ <
	Meaning (parts):		‘cushion’ + ‘sit’	‘cushion’ + ‘reveal, clear up’	NA	‘group’ + ‘island’	‘prevent’ + ‘splash’
	Rating:		6.48	1.61	6.00	1.23	2.31
20	IPA:	naː	naː-paːk	naː-taːŋ	p^hra-pak	ton jaː	laːj sen
	Meaning (whole):	‘face’	‘forehead’ <	‘window’ <	‘face’ (royal)	‘grass’ <	‘signature’ <
	Meaning (parts):		‘face’ + ‘dry’	‘face’ + ‘represent’	prefix + ‘face’	‘plant’ + ‘grass’	‘pattern’ + ‘sign’
	Rating:		5.48	1.94	6.84	1.88	1.81

No.		Root	MS	M	S	Ph	C
21	IPA:	faː	faː pit	faː fɛːt	t^{h}iː krɔːp	p^{h}uː p^{h}aː	p^{h}uː kan
	Meaning (whole):	‘lid’	‘lid’ <	‘twin’ <	‘lid’ <	‘rocky mountain’ <	‘paintbrush’ <
	Meaning (parts):		‘lid’ + ‘close’	‘lid’ + ‘be attached’	‘that’ + ‘cover’	‘mountain’ + ‘cliff’	‘tuft’ + ‘trim’
	Rating:		6.28	1.94	6.34	1.75	1.63
22	IPA:	din	din niːaw	din-sɔː	kloːn	plaː nin	k^{h}aj ciːaw
	Meaning (whole):	‘soil’	‘clay’ <	‘pencil’ <	‘mud’	‘tilapia’ <	‘omelette’ <
	Meaning (parts):		‘soil’ + ‘sticky’	‘soil’ + ‘white’	NA	‘fish’ + ‘black gem’	‘egg’ + ‘fry’
	Rating:		6.34	2.24	6.10	2.85	1.08
23	IPA:	k^{h}iː	k^{h}iː maː	k^{h}iː rɯːan	muːn sat		
	Meaning (whole):	‘poop’	‘dog’s poop’ <	‘leprosy’ <	‘animal poop’ <		
	Meaning (parts):		‘poop’ + ‘dog’	‘poop’ + ‘leprosy’	‘poop’ + ‘animal’		
	Rating:		6.34	2.14	6.76		
24	IPA:	naŋ	naŋ sat	naŋ sɯː	c^{h}an p^{h}iw	p^{h}ɛːn p^{h}aŋ	baːn rɯːan
	Meaning (whole):	‘skin’	‘animal skin’ <	‘book’	‘skin layer’ <	‘diagram’ <	‘habitation’ <
	Meaning (parts):		‘skin’ + ‘animal’	‘skin’ + ‘script’	‘shelf’ + ‘skin’	‘plan’ + ‘plan’	‘house’ + ‘house’ <
	Rating:		6.15	2.23	6.03	1.38	1.46

No.		Root	MS	M	S	Ph	C
25	IPA:	nok	nok nɔːj	nok wiːt	sat piːk	k^{h}a-nom krok	lin c^{h}ak
	Meaning (whole):	‘bird’	‘little bird’ <	‘whistle’ <	‘bird’ <	‘a Thai dessert’ <	‘drawer’ <
	Meaning (parts):		‘bird’ + ‘little’	‘bird’ + ‘cry’	‘animal’ + ‘wing’	‘dessert’ + ‘mortar’	‘tongue’ + ‘pull’
	Rating:		6.47	2.25	6.23	1.13	1.19
26	IPA:	mɔːn	mɔːn k^{h}aːŋ	mɔːn t^{h}ɔːŋ	k^{h}rɯːaŋ nɔːn	tuːa nɔːn	kɛːŋ p^{h}et
	Meaning (whole):	‘pillow’	‘bolster’ <	a kind of durian <	‘bedding’ <	‘worm’ <	‘red curry’ <
	Meaning (parts):		‘pillow’ + ‘side’	‘pillow’ + ‘gold’	‘things’ + ‘sleep’	CLS + ‘worm’	‘curry’ + ‘spicy’
	Rating:		6.20	1.63	5.84	1.94	1.00

Compound Verbs

No.		Root	MS	M	S	Ph	C
1	IPA:	law	law k^{h}aːn	law riːan	bɔːk klaːw		
	Meaning (whole):	‘tell’	‘tell (a story)’ <	‘study’ <	‘notify’ <		
	Meaning (parts):		‘tell’ + ‘cry out’	‘tell’ + ‘study’	‘tell’ + ‘say’		
	Rating:		5.90	2.41	5.61		
2	IPA:	nɔːn	nɔːn lap	nɔːn maː	ʔeːn raːp	tɛːŋ klɔːn	jiːap jam
	Meaning (whole):	‘sleep’	‘sleep’ <	‘have a landslide victory’ <	‘lie down’ <	‘compose’ <	‘disparage’ <
	Meaning (parts):		‘sleep’ + ‘asleep’	‘sleep’ + ‘come’	‘recline’ + ‘(lie) flat’	‘compose’ + ‘poem’	‘step’ + ‘tramp’
	Rating:		6.24	2.57	4.73	1.46	2.15

No.		Root	MS	M	S	Ph	C
3	IPA:	klan	klan krɔːŋ	klan klɛːŋ	hɯːat ra-hɤːj	naːw san	taːk dɛːt
	Meaning (whole):	‘sift, distill’	‘screen’ <	‘defame’ <	‘evaporate’ <	‘tremble’ <	‘dry in the sun’ <
	Meaning (parts):		‘distill’ + ‘filter’	‘distill’ + ‘tease’	‘dry up’ + ‘evaporate’	‘cold’ + ‘shiver’	‘bask’ + ‘sunlight’
	Rating:		4.09	1.54	4.32	1.08	1.85
4	IPA:	laj	laj ɔːk	laj liːa	plak saj		
	Meaning (whole):	‘expel’	‘fire, lay off’ <	‘be at similar level’ <	‘expel’ <		
	Meaning (parts):		‘expel’ + ‘exit’	‘expel’ +‘be similar’	‘push’ + ‘push’		
	Rating:		5.57	2.78	5.94		
5	IPA:	saŋ	saŋ haːm	saŋ som	baŋ-k^{h}ap ban-c^{h}aː	k^{h}aːm faŋ	lot liːaw
	Meaning (whole):	‘demand’	‘forbid’ <	‘collect’ <	‘order’ <	‘cross’ <	‘zigzag’ <
	Meaning (parts):		‘demand’ + ‘forbid’	‘demand’ + ‘collect’	‘force’ + ‘demand’	‘cross’ + ‘side’	‘drop’ + ‘turn’
	Rating:		5.22	1.94	5.53	1.38	1.63
6	IPA:	k^{h}ap	k^{h}ap k^{h}ɛːp	k^{h}ap k^{h}an	ʔɯt ʔat	lɯk lap	juŋ jɤːŋ
	Meaning (whole):	‘tight’	‘narrow and tight’ <	‘critical’ <	‘feel cramped’ <	‘mysterious’ <	‘chaotic’ <
	Meaning (parts):		‘tight’ + ‘narrow’	‘tight’ + ‘cry (chicken)’	‘endure’ + ‘press’	‘deep’ + ‘secretive’	‘messy’ + ‘disheveled’
	Rating:		4.96	2.39	5.52	2.08	1.46

No.		Root	MS	M	S	Ph	C
7	IPA:	kin	kin kʰaːw	kin rɛːŋ	rap pra-tʰaːn		
	Meaning (whole):	‘eat’	‘have a meal’ <	‘be a parasite’ <	‘eat’ <		
	Meaning (parts):		‘eat’ + ‘rice’	‘eat’ + ‘labor’	‘receive’ + ‘give’		
	Rating:		6.25	2.70	6.91		
8	IPA:	hen	hen naː	hen caj	mɔːŋ duː		
	Meaning (whole):	‘see’	‘meet someone’ <	‘feel for’ <	‘look’ <		
	Meaning (parts):		‘see’ + ‘face’	‘see’ + ‘heart’	‘look’ + ‘look’		
	Rating:		5.86	3.04	6.03		
9	IPA:	kʰaːj	kʰaːj kʰɔːŋ	kʰaːj naː	cat cam-naːj	rap saːj	lon laːm
	Meaning (whole):	‘sell’	‘sell something’ <	‘be in disgrace’ <	‘sell’ <	‘answer (phone)’ <	‘excessive’ <
	Meaning (parts):		‘sell’ + ‘thing’	‘sell’ + ‘face’	‘organize’ + ‘sell’	‘accept’ + ‘line’	‘overflow’ + ‘overflow’ <
	Rating:		6.53	2.10	6.62	2.50	3.63
10	IPA:	haːj	haːj tuːa	haːj caj	saːp suːn	nat maːj	jɯː jɛːŋ
	Meaning (whole):	‘be lost’	‘disappear’ <	‘breathe’ <	‘disappear’ <	‘schedule’ <	‘snatch’ <
	Meaning (parts):		‘be lost’ + ‘body’	‘be lost’ + ‘heart’	‘be lost’ + ‘lose’	‘appointment’ + ‘aim’ <	‘pull’ + ‘wrest’
	Rating:		5.61	1.59	6.43	1.77	1.69

No.		Root	MS	M	S	Ph	C
11	IPA:	t^{h}ɯː	t^{h}ɯː k^{h}ɔːŋ	t^{h}ɯː tua	hɔːp hiw		
	Meaning (whole):	‘hold’	‘carry something’ <	‘be conceited’ <	‘carry’ <		
	Meaning (parts):		‘hold’ + ‘thing’	‘hold’ + ‘body’	‘carry’ + ‘carry’		
	Rating:		6.18	2.61	5.82		
12	IPA:	dɤːn	dɤːn t^{h}aːw	dɤːn rɯːaŋ	kaːw jaːŋ		
	Meaning (whole):	‘walk’	‘walk’ <	‘proceed’ <	‘step’ <		
	Meaning (parts):		‘walk’ + ‘foot’	‘walk’ + ‘story’	‘step’ + ‘walk’		
	Rating:		6.41	2.92	6.06		
13	IPA:	cap	cap mɯː	cap klum	jip c^{h}uːaj		
	Meaning (whole):	‘catch’	‘shake hands’ <	‘assemble’ <	‘snatch’ <		
	Meaning (parts):		‘catch’ + ‘hand’	‘catch’ + ‘group’	‘pick’ + ‘snatch’		
	Rating:		5.81	3.01	4.67		
14	IPA:	tok	tok heːw	tok caj	ruːaŋ lon	hɔː pok	rɔːp k^{h}ɔːp
	Meaning (whole):	‘fall’	‘fall off a cliff’ <	‘be frightened’ <	‘fall’ <	‘cover a book’ <	‘cautious’ <
	Meaning (parts):		‘fall’ + ‘cliff’	‘fall’ + ‘heart’	‘drop’ + ‘fall’	‘wrap’ + ‘cover’	‘around’ + ‘cover’
	Rating:		5.65	2.43	6.46	1.38	2.38

No.		Root	MS	M	S	Ph	C
15	IPA:	len	len kon	len ŋaːn	plɤːt plɤːn		
	Meaning (whole):	‘play’	‘play tricks’ <	‘tackle’ <	‘enjoy’ <		
	Meaning (parts):		‘play’ + ‘trick’	‘play’ + ‘work’	‘enjoy’ + ‘enjoy’		
	Rating:		4.42	2.25	4.29		
16	IPA:	k^{h}ɯn	k^{h}ɯn k^{h}aw	k^{h}ɯn c^{h}ɯː	p^{h}ɤːm suːŋ	raːp rɯːn	lɔːk liːan
	Meaning (whole):	‘go up’	‘go uphill’	‘be famous’	‘increase’ <	‘smooth’ <	‘imitate’ <
	Meaning (parts):		‘go up’ + ‘hill’	‘go up’ + ‘name’	‘increase’ + ‘high’	‘flat’ + ‘happy’	‘copy’ + ‘mimic’
	Rating:		5.58	2.76	5.37	1.69	2.00
17	IPA:	com	com naːm	com plak	jup loŋ		
	Meaning (whole):	‘sink’	‘sink’ <	‘be stagnant’ <	‘go down’ <		
	Meaning (parts):		‘sink’ + ‘water’	‘sink’ + ‘muddy puddle’	‘go down’ + ‘down’		
	Rating:		6.15	2.99	4.32		
18	IPA:	k^{h}aːt	k^{h}aːt daw	k^{h}aːt k^{h}an	nɯk k^{h}a-neː	ruːam jaːt	ruːaŋ lon
	Meaning (whole):	‘predict’	‘predict’ <	‘force’ <	‘guess’ <	‘family get-together’ <<	‘fall’ <
	Meaning (parts):		‘predict’ + ‘guess’	‘predict’ + ‘squeeze’	‘think’ + ‘guess’	‘combine’ + ‘relative’	‘drop’ + ‘fall’
	Rating:		5.25	2.67	6.10	1.50	1.50

No.		Root	MS	M	S	Ph	C
19	IPA:	tɔː	tɔː nɯːaŋ	tɔː suː	p^{h}ɤːm tɤːm	tɯk tak	reŋ riːp
	Meaning (whole):	‘extend’	‘continue’ <	‘fight’ <	‘add’ <	‘assume’ <	‘hasten’ <
	Meaning (parts):		‘extend’ + ‘continue’	‘extend’ + ‘fight’	‘increase’ + ‘add’	‘presume’ + ‘remark’	‘hasten’ + rush’
	Rating:		5.48	2.05	4.90	1.88	1.15
20	IPA:	tak	tak tuːaŋ	tak tɯan	c^{h}ɔːn	pak lak	reː ron
	Meaning (whole):	‘scoop’	‘grab’ <	‘warn’ <	‘scoop’	‘settle down’ <	‘nomadic’ <
	Meaning (parts):		‘scoop’ + ‘measure’	‘scoop’ + ‘warn’	NA	‘stab down’ + ‘stake’	‘wander’ + ‘winnow’
	Rating:		4.80	1.95	5.59	1.31	1.46
21	IPA:	k^{h}lum	k^{h}lum pɔːŋ	k^{h}lum k^{h}rɯːa	k^{h}rɔːp pit	hak mum	luːaŋ lɤːj
	Meaning (whole):	‘cover’	‘cover the body’ <	‘vague’ <	‘cover’ <	‘plot twist’ <	‘pass’ <
	Meaning (parts):		‘cover’ + ‘fold of a blanket’	‘cover’ + ‘bunch’	‘cover’ + ‘close’	‘break’ + ‘angle’	‘go beyond’ + ‘pass’
	Rating:		5.92	2.99	5.96	1.00	1.94
22	IPA:	t^{h}ɔːn	t^{h}ɔːn k^{h}on	t^{h}ɔːn saj-buːa	det dɯŋ	haw hɔːn	kak k^{h}aŋ
	Meaning (whole):	‘pull out’	‘pluck’ <	‘curtsy’ <	‘pluck’ <	‘howl’ <	‘detain’ <
	Meaning (parts):		‘pull out’ + ‘hair’	‘pull out’ + ‘stem’ + ‘lotus’ <	‘pick’ + ‘pull’	‘bark’ + ‘howl’	‘confine’ + ‘imprison’
	Rating:		5.82	2.20	5.49	1.31	1.50

No.		Root	MS	M	S	Ph	C
23	IPA:	tat	tat tɛːŋ	tat sin		biːp ʔat	plɤːt plɤːn
	Meaning (whole):	‘cut’	‘trim’ <	‘decide’ <		‘compress’ <	‘enjoy’ <
	Meaning (parts):		‘cut’ + ‘decorate’	‘cut’ + ‘cut’		‘squeeze’ + ‘pack’	NA + ‘enjoy’
	Rating:		5.15	2.72		1.63	1.81
24	IPA:	ʔap	ʔap c^hɯːn	ʔap ʔaːj		tit kap	plaŋ plɤː
	Meaning (whole):	‘stuffy’	‘musty’	‘be disgraceful’		‘trap’ <	‘negligent’ <
	Meaning (parts):		‘stuffy’ + ‘damp’	‘stuffy’ + ‘embarrassed’		‘stick’ + ‘trap’	‘err’ + ‘careless’
	Rating:		5.88	1.94		2.23	1.15
25	IPA:	jok	jok mɯː	jok lɤːk		k^hiː ŋok	pluk plaːn
	Meaning (whole):	‘raise’	‘raise one’s hand’	‘cancel’		‘stingy’ <	‘swarm’ <
	Meaning (parts):		‘raise’ + ‘hand’	‘raise’ + ‘stop’		‘poop’ + ‘stingy’	‘disorderly’ + ‘turbulently’ <
	Rating:		5.08	2.75		1.25	1.46
26	IPA:	loŋ	loŋ ban-daj	loŋ tuːa		ŋun ŋoŋ	k^hwak k^hwaj
	Meaning (whole):	‘descend’	‘descend the stairs’	‘be balanced’		‘baffled’ <	‘busily’
	Meaning (parts):		‘descend’ + ‘stairs’	‘descend’ + ‘body’		NA + ‘confused’	NA + ‘busily’
	Rating:		5.08	2.62		1.13	1.46

No.		Root	MS	M	S	Ph	C
27	IPA:	tɔj	tɔj paːk	tɔj hɔj		plot plɔj	waːŋ plaːw
	Meaning (whole):	‘punch’	‘punch one’s mouth’	‘punch’ + ‘shellfish’		‘liberate’ <	‘vacant’ <
	Meaning (parts):		‘punch’ + ‘mouth’	‘talkatively’		‘discharge’ + ‘release’	‘blank’ + ‘empty’
	Rating:		6.13	2.06		2.15	1.08
28	IPA:	jip	jip c^huːaj	jip jɔːŋ		k^hom krip	loːt p^hoːn
	Meaning (whole):	‘grab’	‘snatch’	‘be flighty’		‘sharp’ <	‘thrilling’ <
	Meaning (parts):		‘grab’ + ‘snatch’	‘grab’ + ‘on tiptoe’		‘sharp’ + ‘extremely’	‘fast’ + ‘leap’
	Rating:		4.94	2.54		1.23	1.50
29	IPA:	p^haː	p^haː tat	p^haː p^hɤːj		fan faː	wok won
	Meaning (whole):	‘cleave’	‘perform operation’	‘dignified’		‘overcome’ <	‘go round’ <
	Meaning (parts):		‘cleave’ + ‘cut’	‘cleave’ + ‘reveal’		‘cut’ + ‘go through’	‘turn back’ + ‘circle’
	Rating:		5.88	1.94		2.85	1.31
30	IPA:	tɯːn	tɯːn k^hɤːn	tɯːn tan		sot c^hɯːn	pan puːan
	Meaning (whole):	‘shallow’	‘shallow’	‘delighted’		‘feel fresh’ <	‘frantic’ <
	Meaning (parts):		‘shallow’ + ‘shallow’	‘shallow’ + ‘clog’		‘fresh’ + ‘joyful’	‘spin’ + ‘turbulent’
	Rating:		4.92	1.54		1.63	1.75

A.2 Experiment 2

The stimuli in Experiment 2 are listed with their full tones in the table below:

Simplex Nouns			Simplex Verbs		
No.	**IPA**	**Meaning**	**No.**	**IPA**	**Meaning**
1	*kràʔ-pǎw*	'bag'	23	*kràʔ-doːt*	'jump'
2	*kràʔ-tàːj*	'rabbit'	24	*kràʔ-caːj*	'disperse'
3	*kràʔ-dàːt*	'paper'	25	*kràʔ-prip*	'blink'
4	*kʰàʔ-nǒm*	'dessert'	26	*kʰàʔ-nǎːn*	'parallel'
5	*kʰàʔ-jàʔ*	'trash'	27	*kʰàʔ-jàw*	'shake'
6	*kʰáʔ-nɛːn*	'score'	28	*kʰáʔ-nɔːŋ*	'impetuous'
7	*kʰáʔ-náː*	'Chinese kale'	29	*kʰáʔ-mam*	'fall'
8	*cʰáʔ-niː*	'gibbon'	30	*cʰáʔ-náʔ*	'win'
9	*tàʔ-kìːap*	'chopsticks'	31	*tàʔ-klàʔ*	'greedy'
10	*tàʔ-làːt*	'market'	32	*tàʔ-luj*	'smash'
11	*tàʔ-krâː*	'basket'	33	*tàʔ-koːn*	'shout'
12	*tʰàʔ-nǒn*	'road'	34	*tʰàʔ-wǎːj*	'offer'
13	*tʰáʔ-leː*	'sea'	35	*tʰáʔ-lɔ́ʔ*	'quarrel'
14	*máʔ-naːw*	'lime'	36	*máʔ-laːj*	'demolish'
15	*ráʔ-kʰaŋ*	'bell'	37	*ráʔ-baːj*	'paint'
16	*láʔ-kʰɔːn*	'play'	38	*láʔ-laːj*	'melt'
17	*láʔ-ʔɔːŋ*	'mist'	39	*láʔ-ʔìːat*	'detailed'
18	*láʔ-mút*	'sapodilla'	40	*láʔ-mɤː*	'talk in one's sleep'
19	*pháʔ-nák*	'backrest'	41	*pháʔ-nan*	'gamble'
20	*pháʔ-lóː*	'five-spiced sauce'	42	*pháʔ-juŋ*	'support'
21	*sàʔ-bùː*	'soap'	43	*sàʔ-ʔàːt*	'clean'
22	*sàʔ-paːn*	'bridge'	44	*sàʔ-dùt*	'stumble'

A.3 Experiment 3

No.	IPA	Meaning	No.	IPA	Meaning
1	*tiːaŋ*	'bed'	31	*kâw-ʔîː*	'chair'
2	*pàːk*	'mouth'	32	*kun-cɛː*	'key'
3	*klûːaj*	'banana'	33	*ban-daj*	'stairs'
4	*cʰáːŋ*	'elephant'	34	*kan-kraj*	'scissors'
5	*mǔː*	'pig'	35	*sa-mùt*	'notebook'
6	*caːn*	'plate'	36	*kra-tàːj*	'rabbit'
7	*klɔ̀ŋ*	'box'	37	*kra-pǎw*	'bag'
8	*sôm*	'orange'	38	*pra-tuː*	'door'
9	*máː*	'horse'	39	*má-práːw*	'coconut'
10	*fǒn*	'rain'	40	*má-mûːaŋ*	'mango'
11	*plaː*	'fish'	41	*tʰú-riːan*	'durian'
12	*pèt*	'duck'	42	*maŋ-kʰút*	'mangosteen'
13	*sûːa*	'shirt'	43	*ku-làːp*	'rose'
14	*nók*	'bird'	44	*ca-mùːk*	'nose'
15	*mǎː*	'dog'	45	*ta-krâː*	'basket'
16	*taː*	'eye'	46	*sa-pʰaːn*	'bridge'
17	*kàj*	'egg'	47	*ta-kìːap*	'chopsticks'
18	*kûŋ*	'shrimp'	48	*kra-rɔ̂ːk*	'squirrel'
19	*níw*	'finger'	49	*kaːŋ-keːŋ*	'pants'
20	*hǔː*	'ear'	50	*kra-tʰǎːŋ*	'pot'
21	*kʰɔː*	'neck'	51	*tʰa-leː*	'sea'
22	*mùːak*	'hat'	52	*kra-tʰáʔ*	'pan'
23	*kɛ̂ːm*	'cheek'	53	*má-naːw*	'lime'
24	*kʰíw*	'eyebrow'	54	*kra-dùːk*	'bone'
25	*pʰǒm*	'hair'	55	*cʰom-pʰuː*	'rose apple'
26	*mɯː*	'hand'	56	*kra-dàːt*	'paper'
27	*tàw*	'turtle'	57	*sa-bùː*	'soap'
28	*bâːn*	'house'	58	*kʰa-jàʔ*	'trash'
29	*táːw*	'foot'	59	*tʰa-nǒn*	'road'
30	*rǐːan*	'coin'	60	*ʔa-ŋùn*	'grape'

Appendix B

Individual profiles

ID	Grp	Sex	Age	NVIQ	NV WM	Exp1.2 ExclData	Exp3 ExclData	Exp4.2 AccKhun	Exp4.2 1stPron Prod	Exp5 Criteria Conds	Exp5 AllVio	Exp1.2 Grp	Exp3 Grp	Exp4 Grp	Exp5 Grp	ASD kClstr
1	ASD	M	6.58	115.55	3.5	51.56%	13.33%	75%	0%	50%	0%	G2	G1	G1	G2	2
2	ASD	M	6.58	104.58	3	79.46%	21%	100%	0%	75%	25%	G2	G1	G1	G1	2
3	ASD	F	6.92	65.10	1	70.31%	24.33%	100%	100%	50%	75%	G2	G1	G1	G2	1
4	ASD	M	7.00	118.40	3	52.01%	30.33%	100%	0%	100%	50%	G2	G1	G1	G1	2
5	ASD	M	7.08	104.98	1.5	52.74%	10.67%	75%	0%	75%	75%	G2	G1	G1	G1	2
6	ASD	M	7.17	123.32	4.5	41.74%	36%	75%	50%	50%	50%	G2	G1	G1	G2	2
7	ASD	M	7.42	98.87	4	53.13%	50.67%	25%	0%	50%	50%	G2	G2	G2	G2	2
8	ASD	M	7.67	95.81	4.5	50.22%	56.67%	0%	0%	50%	0%	G2	G2	G1	G2	2
9	ASD	M	7.92	130.81	3.5	21.33%	3.33%	0%	0%	100%	100%	G1	G1	G1	G1	2
10	ASD	M	8.08	95.42	3	30.13%	18.67%	100%	100%	87.50%	100%	G1	G1	G1	G1	1
11	ASD	M	8.17	81.60	3	39.51%	10.33%	100%	0%	100%	0%	G1	G1	G1	G1	2
12	ASD	M	8.50	81.60	3	18.75%	6%	50%	0%	50%	100%	G1	G1	G1	G2	2
13	ASD	M	8.75	56.83	1	57.81%	65.67%	25%	0%	62.50%	25%	G2	G2	G2	G1	2
14	ASD	M	9.08	86.27	1.5	52.01%	22.33%	75%	0%	50%	75%	G2	G1	G2	G2	2
15	ASD	M	9.08	83.10	1	77.01%	50.67%	50%	0%	37.50%	50%	G2	G2	G2	G2	2
16	ASD	M	9.92	88.92	3.5	48.21%	4.33%	75%	50%	62.50%	100%	G2	G1	G1	G2	1
17	ASD	M	10.00	123.32	5	24.55%	8.33%	100%	100%	100%	100%	G1	G1	G1	G1	1
18	ASD	F	10.00	107.44	5.5	35.27%	3.67%	75%	0%	100%	75%	G1	G1	G1	G1	2
19	ASD	M	10.17	76.68	2	53.13%	57.33%	100%	0%	50%	100%	G2	G2	G1	G2	2
20	ASD	M	10.17	96.20	6	42.63%	5.33%	100%	0%	100%	100%	G2	G1	G1	G1	2
21	ASD	M	10.33	91.70	5.5	47.32%	6.33%	100%	100%	87.50%	100%	G2	G1	G1	G1	1
22	ASD	M	10.83	109.19	4.5	9.60%	5%	75%	100%	100%	100%	G1	G1	G1	G1	1
23	ASD	M	10.83	94.22	5	42.19%	3.33%	75%	100%	62.50%	100%	G2	G1	G1	G2	1
24	ASD	M	10.92	155.79	5	6.03%	0.33%	50%	100%	100%	100%	G1	G1	G1	G1	1

ID	Grp	Sex	Age	NVIQ	NV WM	Exp1.2 ExclData	Exp3 ExclData	Exp4.2 AccKhun	Exp4.2 1stPron Prod	Exp5 Criteria Conds	Exp5 AllVio	Exp1.2 Grp	Exp3 Grp	Exp4 Grp	Exp5 Grp	ASD kClstr
25	ASD	M	11.67	63.87	3	30.13%	5.67%	0%	100%	75%	50%	G1	G1	G1	G1	1
26	ASD	F	11.83	106.60	5	8.26%	3%	50%	100%	87.50%	75%	G1	G1	G1	G1	1
27	ASD	M	12.33	53.65	1	53.13%	47.67%	100%	0%	75%	75%	G2	G2	G1	G1	2
28	ASD	M	12.33	119.22	6.5	9.38%	2.33%	100%	100%	100%	75%	G1	G1	G1	G1	1
29	ASD	M	12.42	96.97	4.5	30.13%	7%	100%	50%	62.50%	75%	G1	G1	G1	G2	1
30	ASD	M	12.67	71.79	4	57.81%	69%	75%	0%	100%	100%	G2	G2	G1	G1	2
31	ASD	M	12.83	53.65	1.5	52.46%	58%	25%	0%	50%	75%	G2	G2	G1	G2	2
32	ASD	M	13.00	104.58	5	35.71%	31.33%	100%	100%	100%	75%	G1	G1	G1	G1	1
33	TD	M	4.58	99.62	1.5	61.38%	9.67%	100%	0%	50%	100%	G2	G1	G1	G2	NA
34	TD	M	5.58	104.58	1.5	50%	40%	0%	0%	62.50%	100%	G2	G2	G1	G2	NA
35	TD	F	5.83	134.90	3	51.12%	7%	100%	100%	87.50%	100%	G2	G1	G1	G1	NA
36	TD	M	5.92	155.79	4.5	37.72%	30%	75%	0%	50%	100%	G1	G1	G1	G2	NA
37	TD	M	5.92	119.22	4.5	35.27%	14.67%	25%	0%	50%	75%	G1	G1	G1	G2	NA
38	TD	M	6.00	102.65	2.5	16.29%	7.67%	50%	0%	50%	75%	G1	G1	G1	G2	NA
39	TD	M	6.00	102.65	2.5	42.41%	9.33%	100%	100%	100%	25%	G2	G1	G1	G1	NA
40	TD	M	6.00	102.65	2.5	29.69%	11%	75%	0%	62.50%	50%	G1	G1	G1	G1	NA
41	TD	M	6.00	134.90	4.5	63.84%	22.67%	75%	100%	50%	75%	G2	G1	G1	G2	NA
42	TD	M	6.08	118.40	4	49.55%	25%	75%	100%	75%	100%	G2	G1	G1	G1	NA
43	TD	F	6.17	155.79	4	28.57%	3.67%	75%	100%	100%	100%	G1	G1	G1	G1	NA
44	TD	M	6.25	113.17	4	58.71%	18.67%	75%	100%	50%	100%	G2	G1	G1	G2	NA
45	TD	M	6.25	107.02	2	36.38%	5.33%	100%	66.67%	37.50%	50%	G1	G1	G1	G2	NA
46	TD	M	6.33	113.17	2	34.82%	5.33%	75%	100%	12.50%	100%	G1	G1	G1	G2	NA
47	TD	F	6.33	113.73	4.5	41.29%	7.33%	100%	100%	100%	100%	G2	G1	G1	G1	NA
48	TD	M	6.42	89.88	1	52.46%	5.33%	75%	100%	50%	100%	G2	G1	G1	G2	NA

ID	Grp	Sex	Age	NVIQ	NV WM	Exp1.2 ExclData	Exp3 ExclData	Exp4.2 AccKhun	Exp4.2 1stPron Prod	Exp5 Criteria Conds	Exp5 AllVio	Exp1.2 Grp	Exp3 Grp	Exp4 Grp	Exp5 Grp	ASD kClstr
49	TD	F	6.42	126.26	5	25.67%	12%	25%	0%	62.50%	100%	G1	G1	G1	G2	NA
50	TD	M	6.42	109.19	3	62.95%	8%	25%	0%	75%	100%	G2	G1	G1	G1	NA
51	TD	M	6.42	128.21	3.5	16.52%	10.33%	50%	100%	50%	100%	G1	G1	G1	G2	NA
52	TD	F	6.42	111.58	3.5	18.97%	9%	100%	100%	87.50%	100%	G1	G1	G1	G1	NA
53	TD	M	6.58	111.58	2.5	36.61%	14.67%	0%	100%	87.50%	25%	G1	G1	G1	G1	NA
54	TD	M	6.58	120.11	3.5	55.13%	31%	100%	0%	50%	100%	G2	G1	G1	G2	NA
55	TD	M	6.67	107.02	4	52.90%	23%	75%	0%	50%	50%	G2	G1	G1	G2	NA
56	TD	M	6.75	114.92	4	63.84%	12.67%	50%	0%	100%	75%	G2	G1	G1	G1	NA
57	TD	M	6.83	114.92	4.5	28.13%	8.33%	100%	100%	75%	100%	G1	G1	G1	G1	NA
58	TD	F	7.00	130.81	2	23.66%	5.67%	50%	100%	50%	75%	G1	G1	G1	G2	NA
59	TD	M	7.00	134.90	3	26.79%	16%	0%	0%	50%	100%	G1	G1	G1	G2	NA
60	TD	M	7.08	118.40	3.5	48.88%	35.67%	50%	100%	50%	100%	G2	G1	G1	G2	NA
61	TD	M	7.17	119.22	5	16.52%	13.33%	100%	100%	75%	50%	G1	G1	G1	G1	NA
62	TD	M	7.33	155.79	4.5	31.47%	9%	50%	100%	100%	100%	G1	G1	G1	G1	NA
63	TD	M	7.67	97.35	4.5	18.30%	5.67%	100%	100%	62.50%	75%	G1	G1	G1	G2	NA
64	TD	M	7.92	128.21	4.5	15.18%	6.33%	75%	100%	100%	100%	G1	G1	G1	G1	NA
65	TD	M	7.92	98.49	3.5	26.12%	5.33%	25%	0%	50%	100%	G1	G1	G1	G2	NA
66	TD	M	8.17	155.79	4.5	16.07%	2.67%	50%	100%	100%	100%	G1	G1	G1	G1	NA
67	TD	M	8.33	126.26	5	25.67%	3%	25%	100%	50%	50%	G1	G1	G1	G2	NA
68	TD	M	8.58	123.32	4.5	26.79%	9.33%	50%	100%	100%	0%	G1	G1	G1	G1	NA
69	TD	M	8.67	87.38	3.5	23.66%	16.67%	25%	100%	100%	75%	G1	G1	G1	G1	NA
70	TD	M	8.67	111.08	4.5	25.67%	7.67%	75%	100%	100%	100%	G1	G1	G1	G1	NA
71	TD	M	8.75	155.79	4	17.87%	4%	100%	100%	100%	100%	G1	G1	G1	G1	NA
72	TD	F	8.83	115.55	5	14.51%	3.33%	100%	100%	75%	100%	G1	G1	G1	G1	NA

ID	Grp	Sex	Age	NVIQ	NV WM	Exp1.2 ExclData	Exp3 ExclData	Exp4.2 AccKhun	Exp4.2 1stPron Prod	Exp5 Criteria Conds	Exp5 AllVio	Exp1.2 Grp	Exp3 Grp	Exp4 Grp	Exp5 Grp	ASD kClstr
73	TD	M	9.08	155.79	5.5	11.16%	1.67%	0%	100%	87.50%	100%	G1	G1	G1	G1	NA
74	TD	F	9.17	106.60	5	45.31%	9%	100%	0%	62.50%	100%	G2	G1	G1	G2	NA
75	TD	M	9.17	96.97	5	45.98%	5%	0%	100%	50%	100%	G2	G1	G1	G2	NA
76	TD	M	9.42	96.97	5.5	19.87%	5.33%	0%	100%	37.50%	100%	G1	G1	G1	G2	NA
77	TD	M	9.58	98.49	4	55.80%	5.33%	100%	100%	62.50%	100%	G2	G1	G1	G2	NA
78	TD	M	9.92	87.38	5	21.43%	9.67%	100%	100%	100%	75%	G1	G1	G1	G1	NA
79	TD	F	10.00	97.74	5	50.22%	6.33%	50%	100%	100%	100%	G2	G1	G1	G1	NA
80	TD	M	10.00	155.79	5.5	25.67%	1%	100%	100%	100%	100%	G1	G1	G1	G1	NA
81	TD	F	10.08	97.74	4	9.82%	8.67%	100%	100%	75%	75%	G1	G1	G1	G1	NA
82	TD	M	10.25	102.65	5	9.38%	3.33%	0%	100%	37.50%	100%	G1	G1	G1	G2	NA
83	TD	M	10.42	114.31	5	12.05%	1.67%	100%	100%	100%	100%	G1	G1	G1	G1	NA
84	TD	M	10.42	134.90	6	15.40%	4%	100%	100%	87.50%	100%	G1	G1	G1	G1	NA
85	TD	M	10.58	122.14	7	9.15%	2.33%	50%	100%	12.50%	100%	G1	G1	G1	G2	NA
86	TD	M	10.92	123.32	5	14.29%	0.67%	100%	100%	100%	100%	G1	G1	G1	G1	NA
87	TD	M	11.00	104.58	6.5	13.62%	2%	100%	100%	75%	100%	G1	G1	G1	G1	NA
88	TD	M	11.08	111.08	4.5	19.20%	6.33%	100%	100%	100%	100%	G1	G1	G1	G1	NA
89	TD	M	11.17	134.90	4.5	21.88%	16.33%	100%	100%	87.50%	100%	G1	G1	G1	G1	NA
90	TD	M	11.42	102.65	6	12.28%	1%	25%	100%	87.50%	100%	G1	G1	G1	G1	NA
91	TD	M	11.75	101.88	6.5	23.21%	5%	0%	100%	12.50%	75%	G1	G1	G1	G2	NA

References

Allen, D. A. (1989). Developmental language disorders in preschool children: clinical subtypes and syndromes. *School Psychology Review*, 18:442–451.

Allen, D. A. and Rapin, I. (1980). Language disorders in preschool children: predictors of outcome – A preliminary report. *Brain and Development*, 2:73–80.

Amenta, S. and Crepaldi, D. (2012). Morphological processing as we know it: an analytical review of morphological effects in visual word identification. *Frontiers in psychology*, 3.

American Academy of Pediatrics, Committee on Children with Disabilities (2001). The pediatrician's role in the diagnosis and management of autistic spectrum disorder in children. 107(5):1221–1226.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders (4th ed., Text Revision)*. American Psychiatric Association, Washington, DC.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders (5th ed.)*. American Psychiatric Association, Arlington, VA.

Anderson, S. R. (1992). *A-morphous morphology*, volume 62. Cambridge University Press.

Aronoff, M. and Fudeman, K. (2010). *Morphology and Morphological Analysis*. Blackwell Publishing, Oxford.

Baayen, R. H. (2014). Experimental and psycholinguistic approaches to studying derivation.

In Lieber, R. and Štekauer, P., editors, *The Oxford handbook of derivational morphology*, pages 95–117. Oxford University Press, Oxford.

Baayen, R. H., Dijkstra, T., and Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language*, 37(1):94–117.

Baayen, R. H. and Milin, P. (2010). Analyzing reaction times. *International Journal of Psychological Research*, 3:12–28.

Baayen, R. H., Milin, P., urević, D. F., Hendrix, P., and Marelli, M. (2011). An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. *Psychological review*, 118(3):438.

Bacovcin, H. A., Davies, A. G., Wilder, R. J., and Embick, D. (2017). Auditory morphological processing: Evidence from phonological priming. *Cognition*, 164:102 – 106.

Bailey, A., Phillips, W., and Rutter, M. (1996). Autism: Towards an integration of clinical, genetic, neuropsychological, and neurobiological perspectives. *Journal of Child Psychology and Psychiatry*, 37:89–126.

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., Kurzius-Spencer, M., Zahorodny, W., Rosenberg, C. R., White, T., Durkin, M. S., Imm, P., Nikolaou, L., Yeargin-Allsopp, M., Lee, L.-C., Harrington, R., Lopez, M., Fitzgerald, R. T., Hewitt, A., Pettygrove, S., Constantino, J. N., Vehorn, A., Shenouda, J., Hall-Lande, J., Braun, K. V. N., and Dowling, N. F. (2018). Prevalence of autism spectrum disorder among children aged 8 years - Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2014. *Morbidity and mortality weekly report. Surveillance summaries*, 67(6):1–23.

Bandhumedha, N. (2011). *Waiyakorn Thai, [Thai grammar]*. Academic Publications Project, Faculty of Arts, Chulalongkorn University, Bangkok, sixth edition.

Baron-Cohen, S. (1988). An assessment of violence in a young man with aspergers syndrome. *Journal of Child Psychology and Psychiatry*, 29:351–360.

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

Barone, R., Spampinato, C., Pino, C., Palermo, F., Scuderi, A., Zavattieri, A., and Rizzo, R. (2019). Online comprehension across different semantic categories in preschool children with autism spectrum disorder. *PloS one*, 14(2).

Bartak, L. and Rutter, M. (1974). The use of personal pronouns by autistic children. *Journal of Autism and Childhood Schizophrenia*, 4:127–145.

Bartak, L., Rutter, M., and Cox, A. (1975). Comparative study of infantile autism and specific developmental receptive language disorder 1: Children. *British Journal of Psychiatry*, 126:127–145.

Bartolucci, G., Pierce, S., and Streiner, D. (1980). Cross-sectional studies of grammatical morphemes in autistic and mentally retarded children. *Journal of Autism and Developmental Disorders*, 10:39–50.

Barton, K. (2019). *MuMIn: Multi-Model Inference*. R package version 1.43.6.

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1):1–48.

Bates, D., Mullen, K. M., Nash, J. C., and Varadhan, R. (2014). *minqa: Derivative-free optimization algorithms by quadratic approximation*. R package version 1.2.4.

Bauer, L. (2005). The borderline between derivation and compounding. In Dressler, W. U., Kastovsky, D., Pfeiffer, O. E., and Rainer, F., editors, *Morphology and its demarcations*, pages 97–108. John Benjamins, Amsterdam, The Netherlands.

Bauer, L., Lieber, R., and Plag, I. (2013). *The Oxford reference guide to English morphology.* Oxford University Press, Oxford.

Bernard-Opitz, V. (1982). Pragmatic analysis of the communicative behavior of an autistic child. *Journal of Speech and Hearing Disorders*, 47:99–109.

Beyersmann, E., Ziegler, J. C., Castles, A., Coltheart, M., Kezilas, Y., and Grainger, J. (2016). Morpho-orthographic segmentation without semantics. *Psychonomic bulletin & review*, 23(2):533–539.

Bishop, D. V. M. (2014). Ten questions about terminology for children with unexplained language problems. *International Journal of Language & Communication Disorders*, 49(4):381–415.

Bodner, G. E. and Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin and Review*, 10(3):645–652.

Bolton, P., Macdonald, H., Pickles, A., Rios, P., Goode, S., Crowson, M., Bailey, A., and Rutter, M. (1994). A case-control family history study of autism. *Journal of Child Psychology and Psychiatry*, 35:877–900.

Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., Burack, J. A., and Mottron, L. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not asperger syndrome. *Neuropsychologia*, 48:2465–2475.

Botting, N. and ContiRamsden, G. (2003). Autism, primary pragmatic difficulties, and specific language impairment: can we distinguish them using psycholinguistic markers? *Developmental Medicine & Child Neurology*, 45(8):515–524.

Boucher, J. (2012). Research review: Structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology and Psychiatry*, 53:219–233.

Boucher, J., Mayes, A., and Bigham, S. (2008). Memory, language and intellectual ability in low-functioning autism. In Boucher, J. and Bowler, D. M., editors, *Memory in autism: Theory and research*, pages 487–535. Cambridge University Press, Cambridge.

Burani, Cristina, D. S. and Caramazza, A. (1984). Morphological structure and lexical access. *Visible Language*, 18:342–352.

Burnham, D. and Francis, E. (1997). Role of linguistic experience in the perception of thai tones. In Abramson, A., editor, *Southeast Asian Linguistics Studies In Honor of Vichin Panupong*, pages 29–48. Chulalongkorn University Press, Bangkok.

Butterworth, B. (1983). Lexical representation. *B. Butterworth (ed.), Language Production*, 2.

Cantiani, C., Choudhury, N. A., Yu, Y. H., Shafer, V. L., Schwartz, R. G., and Benasich, A. A. (2016). From sensory perception to lexical-semantic processing: An ERP study in non-verbal children with autism. *PLoS ONE*, 11(8).

Caramazza, A., Laudanna, A., and Romani, C. (1988). Lexical access and inflectional morphology. *Cognition*, 28(3):297–332.

Carstairs-McCarthy, A. (1992). *Current Morphology*. Routledge, New York.

Chanchaochai, N. (2013). “Well, there are no pronoun reversals here”: Case studies of person-referring terms used by Thai-speaking children with Autism Spectrum Disorders. Paper presented at Thai Student Academic Conference - Thai Student Interdisciplinary Symposium 2013 (TSAC-TSIS 2013), March 29-31.

Chanchaochai, N. (2017). On acquiring a complex personal reference system: Experimental results from thai children with autism. Poster presented at Sinn und Bedeutung 22, September 7-10.

Charney, R. (1980). Speech roles and the development of personal pronouns. *Journal of Child Language*, 7:509–528.

Charrad, M., Ghazzali, N., Boiteau, V., and Niknafs, A. (2014). NbClust: An R package for determining the relevant number of clusters in a data set. *Journal of Statistical Software*, 61(6):1–36.

Chen, M.-H. (2018). *Tone Sandhi Phenomena In Taiwan Southern Min.* Doctoral dissertation, Department of Linguistics, University of Pennsylvania.

Chevallier, C., Wilson, D., Happ, F., and Noveck, I. (2010). Scalar inferences in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 40:1104–1117.

Chiat, S. (1982). If i were you and you were me: the analysis of pronouns in a pronoun-reversing child. *Journal of Child Language*, 9:359–379.

Chierchia, G., Crain, S., Guasti, M. T., Gualmini, A., , and Meroni, L. (2001). The acquisition of disjunction: evidence for a grammatical view of scalar implicatures. In Anna H.-J. Do, L. D. and Johansen, A., editors, *Proceedings of the 25th Boston University Conference on Language Development*, pages 157–168, Somerville, MA. Cascadilla Press.

Chierchia, G. and McConnell-Ginet, S., editors (1990). *Meaning and grammar. An introduction to semantics.* MIT Press, Cambridge.

Christensen, D. L., Baio, J., Braun, K. V. N., Bilder, D., Charles, J., Constantino, J. N., Daniels, J., Durkin, M. S., Fitzgerald, R. T., Kurzius-Spencer, M., Lee, L.-C., Pettygrove, S., Robinson, C., Schulz, E., Wells, C., Wingate, M. S., Zahorodny, W., and Yeargin-Allsopp, M. (2016). Prevalence and characteristics of autism spectrum disorder among children aged 8 years Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2012. *Morbidity and mortality weekly report. Surveillance summaries*, 65(3):1–23.

Churchill, D. W. (1972). The relation of infantile autism and early childhood schizophrenia to developmental language disorders of childhood. *Journal of autism and childhood schizophrenia*, 2:182–197.

Coderre, E. L. (2017). Linguistic and non-linguistic semantic processing in individuals with autism spectrum disorders: an ERP study. *Journal of Autism and Developmental Disorders*, 47(3):795–812.

Cook, E. H. (1998). Genetics of autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 4(2):113–120.

Cooke, J. R. (1968). *Pronominal Reference in Thai, Burmese, and Vietnamese.* University of California Press, Berkeley and Los Angeles.

Corbett, G. (1991). *Gender.* Cambridge University Press, Cambridge.

Curtin, S., Goad, H., and Pater, J. V. (1998). Phonological transfer and levels of representation: the perceptual acquisition of thai voice and aspiration by English and French speakers. *Second Language Research*, 14(4):389–405.

Cysouw, M. (2003). *The paradigmatic structure of person marking.* Oxford University Press, Oxford.

Cysouw, M. (2013). Inclusive/exclusive distinction in independent pronouns. In Dryer, M. S. and Haspelmath, M., editors, *The World Atlas of Language Structures Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.

Department of Mental Health, Ministry of Public Health (2012). Child and Adolescent Mental Health Rajanagarindra Institute, Department of Mental Health, Ministry of Public Health, Bangkok.

Dewey, M. and Everard, P. (1974). The near normal autistic adolescent. *Journal of Autism and Childhood Schizophrenia*, 4:348–356.

Diependaele, K., Sandra, D., and Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes*, 20(1-2):75–114.

Diependaele, K., Sandra, D., and Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition*, 37(6):895–908.

DiStefano, C., Senturk, D., and Jeste, S. S. (2019). Erp evidence of semantic processing in children with asd. *Developmental Cognitive Neuroscience*, 36:100640.

Dobbinson, S. (2000). *Repetitiveness and productivity in the language of adults with autism.* Doctoral dissertation, University of Sheffield, UK.

Dressler, W. U. (2006). Compound types. In Libben, G. and Jarema, G., editors, *The representation and processing of compound words*, pages 23–44. Oxford University Press, Oxfod.

Dryer, M. S. (2013). Prefixing vs. suffixing in inflectional morphology. In Dryer, M. S. and Haspelmath, M., editors, *The World Atlas of Language Structures Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.

Dunn, M. and Bates, J. C. (2005). Developmental change in neutral processing of words by children with autism. *Journal of Autism and Developmental Disorders*, 35(3).

Ebbels, S. (2014). Introducing the SLI debate. *International Journal of Language & Communication Disorders*, 49(4):377–380.

Eigsti, I. M. and Bennetto, L. (2009). Grammaticality judgments in autism: deviance or delay. *Journal of Child Language*, 36(5):999–1021.

Eigsti, I. M., de Marchena, A. B., Schuh, J. M., and Kelly, E. (2011). Language acquisition in autism spectrum disorders: A developmental review. *Research in Autism Spectrum Disorders*, 5:681–691.

Eigsti, I. M. and Fein, D. A. (2013). More is less: Pitch discrimination and language delays in children with optimal outcomes from autism. *Autism Research*, 6:605–613.

Eisner, F. and McQueen, J. M. (2006). Perceptual learning in speech: Stability over time. *The Journal of the Acoustical Society of America*, 119(4):1950–1953.

El-Bialy, R., Gagné, C. L., and Spalding, T. L. (2013). Processing of English compounds is sensitive to the constituents semantic transparency. *The Mental Lexicon*, 8(1):75–95.

Embick, D. (2015). *The Morpheme: A Theoretical Introduction*. De Gruyter Mouton, Boston/Berlin.

Fay, W. H. (1979). Personal pronouns and the autistic child. *Journal of Autism and Developmental Disorders*, 9:247–60.

Feldman, L. B. and Basnight-Brown, D. M. (2008). List context fosters semantic processing: Parallels between semantic and morphological facilitation when primes are forward masked. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34(3):680–687.

Feldman, L. B., Soltano, E. G., Pastizzo, M. J., and Francis, S. E. (2004). What do graded effects of semantic transparency reveal about morphological processing? *Brain and Language*, 90(1):17–30.

Fillmore, C. J. (1971). Towards a theory of deixis. In *The PCCLLU Papers*. Department of Linguistics, University of Hawaii.

Fillmore, C. J. (1975). *Santa Cruz lectures on deixis, 1971*. Indiana University Linguistics Club, Bloomington, IN.

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

Folstein, S. E., Santangelo, S. L., Gilman, S. E., Piven, J., Landa, R., Lainhart, J., Hein, J., and Wzorek, M. (1999). Predictors of cognitive test patterns in autism families. *Journal of Child Psychology and Psychiatry*, 40:1117–1128.

Fombonne, E., Bolton, P., Prior, J., Jordan, H., and Rutter, M. (1997). A family study of autism: Cognitive patterns and levels in parents and siblings. *Journal of Child Psychology and Psychiatry*, 38:667–683.

Foppolo, F., Guasti, M. T., and Chierchia, G. (2012). Scalar implicatures in child language: Give children a chance. *Language Learning and Development*, 8:365–394.

Forster, K. and Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10:680 – 698.

Forster, K. I., Davis, C., Schoknecht, C., and Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? volume 39, pages 211–251. Taylor & Francis.

Frost, R. (2012). Towards a universal model of reading. *Behavioral and Brain Sciences*, 35(5):263–279.

Frost, R., Grainger, J., and Rastle, K. (2005). Current issues in morphological processing: An introduction. *Language and cognitive processes*, 20:1–5.

Fyffe, C. and Prior, M. (1990). Evidence for language recoding in autistic, retarded and normal children: A re-examination. *British Journal of Developmental Psychology*, 8:9–23.

Gandour, J., Petty, S. H., Dardarananda, R., Dechongkit, S., and Mukngoen, S. (1986). The acquisition of the voicing contrast in thai: a study of voice onset time in word-initial stop consonants. *Journal of Child Language*, 13(3):561–572.

Georgiades, S., Szatmari, P., Boyle, M., Hanna, S., Duku, E., Zwaigenbaum, L., Bryson, S., Fombonne, E., Volden, J., Mirenda, P., Smith, I., Roberts, W., Vaillancourt, T., Waddell, C., Bennett, T., Thompson, A., and in ASD Study Team, P. (2013). Investigating phenotypic heterogeneity in children with autism spectrum disorder: a factor mixture modeling approach. *Journal of Child Psychology and Psychiatry*, 54(2):206–215.

Ghaziuddin, M. and Gerstein, L. (1996). Pedantic speaking style differentiates asperger syndrome from high-functioning autism. *Journal of Autism and Developmental Disorders*, 26:585–595.

Gibbs, V., Aldridge, F., Chandler, F., Witzlsperger, E., and Smith, K. (2012). Brief report: An exploratory study comparing diagnostic outcomes for autism spectrum disorders under DSM-IV-TR with the proposed DSM-5 revision. *Journal of Autism and Developmental Disorders*, 42(8):1750–1756.

Girouard, P., Ricard, M., and Gouin Decarie, T. (1997). The acquisition of personal pronouns in French-speaking and English-speaking children. *Journal of Child Language*, 24:311–326.

Gonnerman, L. M., Seidenberg, M. S., and Andersen, E. S. (2007). Graded semantic and phonological similarity effects in priming: Evidence for a distributed connectionist approach to morphology. *Journal of Experimental Psychology: General*, 136(2):323–345.

Goodwin Davies, A. J. (2018). *Morphological Representations In Lexical Processing*. Doctoral dissertation, Department of Linguistics, University of Pennsylvania.

Greenberg, J. H. (1988). The first person dual as an ambiguous category. *Studies in Language*, 12:1–18.

Grice, H. P. (1975). Logic and conversation. In Cole, P. and Morgan, J. L., editors, *Syntax and semantics: Speech acts*, volume 3, pages 41–58. Academic Press, New York.

Gualmini, A., Crain, S., Meroni, L., Chierchia, G., and Guasti, M. T. (2001). At the semantics/pragmatics interface in child language. In Hastings, R., Jacksonand, B., and Zvolenszkyn, Z., editors, *Proceedings of the 11th Semantics and Linguistic Theory (SALT11) Conference*, pages 231–247, Ithaca, NY. CLC-Publications, Cornell University.

Haebig, E., Kaushanskaya, M., and Ellis Weismer, S. (2015). Lexical processing in school-age children with autism spectrum disorder and children with specific language impairment: The role of semantics. *Journal of Autism and Developmental Disorders*, 45:4109–4123.

Harley, H. (2011). Compounding in distributed morphology. In Lieber, R. and Štekauer, P., editors, *The Oxford handbook of compounding*, pages 129–144. Oxford University Press, Oxford.

Harper-Hill, K., Copland, D., and Arnott, W. (2014a). Efficiency of lexical access in children with autism spectrum disorders: Does modality matter? *Journal of Autism and Developmental Disorders*, 44:1819–1832.

Harper-Hill, K., Copland, D., and Arnott, W. (2014b). Pathways to meaning: Written and spoken word priming in children with ASD versus typically developing peers. *Research in Autism and Developmental Disorders*, 8:1351–1363.

Haspelmath, M. and Sims, A. (2013). *Understanding morphology*. Routledge, London.

Hawkins, J. A. (1981). *Definiteness and Indefiniteness: A Study in Reference and Grammaticality Prediction*. Croom Helm, London.

Heim, I. (1991). Artikel und Definitheit. In Stechow, V. A. and Wunderlich, D., editors, *Semantik: Ein internationales Handbuch der zeitgenoessischen Forschung*, pages 487–535. De Gruyter, Berlin.

Heim, I. (1994). Puzzling reflexive pronouns in de se reports. Paper presented at Bielefeld Conference on Indexicals.

Helmbrecht, J. (2013). Politeness distinctions in pronouns. In Dryer, M. S. and Haspelmath, M., editors, *The World Atlas of Language Structures Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.

Hochstein, L., Bale, A., and Barner, D. (2017). Scalar implicature in absence of epistemic reasoning? The case of autism spectrum disorder. *Language Learning and Development*.

Horn, L. R. (1972). *On the Semantic Properties of Logical Operators in English*. Doctoral dissertation, Department of Linguistics, University of California, Los Angeles.

Horn, L. R. (1989). *A Natural History of Negation*. University of Chicago Press, Chicago.

Howlin, P. and Asgharian, A. (1999). The diagnosis of autism and asperger syndrome: Findings from a survey of 770 families. *Developmental Medicine and Child Neurology*, 41(12):834–839.

Howlin, P. and Moore, A. (1997). Diagnosis in autism: A survey of over 1200 patients in the UK. *Autism*, 1(2):135–162.

Huang, Y. T., Spelke, E., and Snedeker., J. (2013). What exactly do numbers mean? *Language Learning and Development*, 9:105–129.

Ingram, J. C. L. (2007). *Neurolinguistics: An Introduction to Spoken Language Processing and its Disorders*. Cambridge University Press, Cambridge.

Iwasaki, S. and Ingkapirom, P. (2009). *A reference grammar of Thai*. Cambridge University Press, Cambridge.

Jackendoff, R. (2002). *Foundations of language: Brain, meaning, grammar, evolution*. Oxford University Press, Oxford.

Jones, C. R., Happé, F., Baird, G., Simonoff, E., Marsden, A. J., Tregay, J., Phillips, R. J., Goswami, U., Thomson, J. M., and Charman, T. (2009). Auditory discrimination and auditory sensory behaviours in autism spectrum disorders. *Neuropsychologia*, 47:2850–2858.

Kaan, E., Barkley, C.M., Bao, M., and Wayland, R. (2008). Thai lexical tone perception in native speakers of thai, english and mandarin chinese: an event-related potentials training study. *BMC Neuroscience*, 9:53.

Kamio, Y., Robins, D., Kelley, E., Swainson, B., and Fein, D. (2007). Atypical lexical/semantic processing in high-functioning Autism Spectrum Disorders without early language delay. *Journal of Autism and Developmental Disorders*, 37:1116–1122.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2:217–250.

Karttunen, L. (1973). Presuppositions of compound sentences. *Linguistic Inquiry*, 4:169–193.

Kassambara, A. and Mundt, F. (2017). *factoextra: Extract and Visualize the Results of Multivariate Data Analyses*. R package version 1.0.5.

Kielinen, M., Rantala, H., Timonen, E., Linna, S.-L., and Moilanen, I. (2004). Associated medical disorders and disabilities in children with autistic disorder: A population-based study. *Autism*, 8(1):49–60.

Kim, S. H., Paul, R., Tager-Flusberg, H., and Lord, C. (2014). Language and communication in autism. In Volkmar, F. R., Paul, R., Rogers, S. J., and Pelphrey, K. A., editors, *Handbook of Autism and Pervasive Developmental Disorders*, volume 2, pages 230–262. Wiley, New Jersey, 4 edition.

Kjelgaard, M. M. and Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes*, 16:287–308.

Kohsom, C. and Gobet, F. (1997). Adding spaces to thai and english: Effects on reading. In *Proceedings of the 19th Annual Meeting of the Cognitive Science Society*, pages 388–393. Erlbaum, Hillsdale, NJ.

Kouider, S. and Dupoux, E. (2009). Episodic accessibility and morphological processing: Evidence from long-term auditory priming. *Acta Psychologica*, 130(1):38–47.

Kraljic, T. and Samuel, A. G. (2005). Perceptual learning for speech: Is there a return to normal? *Cognitive psychology*, 51(2):141–178.

Kratzer, A. (2009). Making a pronoun: Fake indexicals as windows into the properties of pronouns. *Linguistic Inquiry*, 40:187–237.

Kuznetsova, A., Bruun Brockhoff, P., and Haubo Bojesen Christensen, R. (2016). *lmerTest: Tests in Linear Mixed Effects Models*. R package version 2.0-32.

Landry, S. H. and Loveland, K. A. (1989). The effect of social context on the functional communication skills of autistic children. *Journal of Autism and Developmental Disorders*, 19:283–299.

Langendoen, D. T. and Savin, H. (1971). The projection problem for presuppositions. In Fillmore, C. and Langendoen, D. T., editors, *Studies in Linguistic Semantics*. Holt, Reinhardt and Winston, NewYork.

Legendre, G., Barrière, I., Goyet, L., and Nazzi, T. (2011). Quantifier acquisition: presuppositions of 'every'. In Pirvulescu, M. et al., editors, *Selected Proceedings of the 4th Conference on Generative Approaches to Language Acquisition North America (GALANA 2010)*, pages 150–162, Somerville, MA. Cascadilla Proceedings Project.

Lenroot, R. and Yeung, P. K. (2013). Heterogeneity within autism spectrum disorders: What have we learned from neuroimaging studies? *Frontiers in Human Neuroscience*, 7:733.

Levinson, S. C. (1983). *Pragmatics*. Cambridge University Press, Cambridge.

Levinson, S. C., editor (2000). *Presumptive Meanings: The Theory of Generalized Conversational Implicature*. MIT Press, Cambridge.

Lewis, S. and Phillips, C. (2015). Aligning grammatical theories and language processing models. *Journal of Psycholinguistic Research*, 44:27–46.

Libben, G. (2006). Why study compound processing? An overview of the issues. *The representation and processing of compound words*, pages 1–22.

Libben, G., Buchanan, L., and Colangelo, A. (2004). Morphology, semantics, and the mental lexicon: The failure of deactivation hypothesis. *Logos and Language*, 4(1):45–53.

Libben, G. and de Almeida, R. G. (2002). Is there a morphological parser? *Bendjaballah, Sabrina; Dressler, Wolfgang U.; Pfeiffer, Oskar E*, pages 213–225.

Liberman, A. M., Harris, K. S., Hoffman, H. S., and Griffith, B. C. (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of experimental psychology*, 54(5):358.

Lieber, R. (2017). Derivational morphology. In Aronoff, M., editor, *Oxford Research Encyclopedia of Linguistics*. Oxford University Press, Oxford.

Lieber, R. and Štekauer, P., editors (2011). *The Oxford handbook of compounding*. Oxford University Press, Oxford.

Livingston, L. A. and Happé, F. (2017). Conceptualising compensation in neurodevelopmental disorders: Reflections from autism spectrum disorder. *Neuroscience Biobehavioral Reviews*, 80:729 – 742.

Longtin, C.-M., Segui, J., and Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and cognitive processes*, 18(3):313–334.

Lord, C. and Paul, R. (1997). Language and communication in autism. In Cohen, D. and Volkmar, F., editors, *Handbook of autism and pervasive developmental disorders*. Wiley & Sons, New York.

Lord, C., Risi, S., and Pickles, A. (2004). Trajectory of language development in autistic spectrum disorders. In Rice, M. L. and Warren, S. F., editors, *Developmental Language Disorders: From Phenotypes to Etiologies*. Lawrence Erlbaum Associates, Mahwah, NJ.

Loveland, K. A. (1984). Learning about points of view: Spatial perspective and the acquisition of i/you. *Journal of Child Language*, 11:535–556.

Loveland, K. A., McEvoy, R. E., Tunali, B., and Kelley, M. L. (1990). Narrative story telling in autism and downs syndrome. *British Journal of Developmental Psychology*, 8:9–23.

Lyons, J. (1977). *Semantics*, volume 2. Cambridge University Press, Cambridge.

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., and Hornik, K. (2019). *cluster:*

Cluster Analysis Basics and Extensions. R package version 2.1.0 — For new features, see the 'Changelog' file (in the package source).

Marantz, A. (2013). No escape from morphemes in morphological processing. *Language and Cognitive Processes*, 28(7):905–916.

Marslen-Wilson, W., Tyler, L. K., Waksler, R., and Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological review*, 101(1):3.

Marslen-Wilson, W. D. (2007). Morphological processes in language comprehension. *The Oxford Handbook of Psycholinguistics, Edited by M. Gareth Gaskell*, 11:175–194.

Marslen-Wilson, W. D., Bozic, M., and Randall, B. (2008). Early decomposition in visual word recognition: Dissociating morphology, form, and meaning. *Language and Cognitive Processes*, 23(3):394–421.

Marslen-Wilson, W. D. and Tyler, L. K. (1998). Rules, representations, and the English past tense. *Trends in cognitive sciences*, 2(11):428–435.

McCleery, J. P., Ceponiene, R., Burner, K. M., Townsend, J., Kinnear, M., and Schreibman, L. (2010). Neural correlates of verbal and nonverbal semantic integration in children with autism spectrum disorders. *Journal of Child Psychology and Psychiatry*, 51(3):277–286.

McHale, S., Simeonsson, R. J., Marcus, L. M., and Olley, J. G. (1980). The social and symbolic quality of autistic childrens communication. *Journal of Autism and Developmental Disorders*, 10:299–310.

Méndez, M., Sans, O., Abril, B., and Valdizan, J. R. (2009). Event-related potentials (N 400) in autistic children. *Clinical Neurophysiology*, 120(4):630–638.

Milin, Petar, E. S. and Feldman, L. B. (2018). Models of lexical access and morphological processing. In Fernández, E. M. and Cairns, H. S., editors, *The handbook of psycholinguistics*, pages 240–268. Wiley Blackwell, Hoboken, NJ.

Minshew, N. J., Goldstein, G., and Siegel, D. J. (1997). Neuropsychologic functioning in autism: Profile of a complex information processing disorder. *Journal of the International Neuropsychological Society*, 3:303–316.

Mizuno, A., Liu, Y., Williams, D. L., Keller, T. A., Minshew, N. J., and Just, M. A. (2011). The neural basis of deictic shifting in linguistic perspective-taking in high-functioning autism. *Brain*, 134:2422–2435.

Monsell, S. and Hirsh, K. W. (1998). Competitor priming in spoken word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24:1495–1520.

Mullennix, J. W., Pisoni, D. B., and Martin, C. S. (1989). Some effects of talker variability on spoken word recognition. *The Journal of the Acoustical Society of America*, 85(1):365–378.

Mundy, P. and Markus, J. (1997). On the nature of communication and language impairment in autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 3(4):343–349.

Napps, S. E. and Fowler, C. A. (1987). Formal relationships among words and the organization of the mental lexicon. *Journal of Psycholinguistic Research*, 16:257–272.

Nelson, D. L., McEvoy, C. L., and Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. `http://www.usf.edu/FreeAssociation/`.

Nielsen, K. (2011). Specificity and abstractness of vot imitation. *Journal of Phonetics*, 39(2):132–142.

Norris, D., McQueen, J. M., and Cutler, A. (2002). Bias effects in facilitatory phonological priming. *Memory & Cognition*, 30:399–411.

Norris, D., McQueen, J. M., and Cutler, A. (2005). Perceptual learning in speech. *Cognitive psychology*, 47(2):204–238.

Noss, R. B. (1964). *Thai Reference Grammar.* Foreign Service Institute, Department of State, United States Government, Washington.

Noveck, I. A. (2001). When children are more logical than adults: experimental investigations of scalar implicature. *Cognition*, 78:165–188.

Noyer, R. (1992). *Features, positions, and affixes in autonomous morphological structure.* Doctoral dissertation, Department of Linguistics and Philosophy, Massachusetts Institute of Technology.

Olsen, S. (2014). Delineating derivation and compounding. In Lieber, R. and Štekauer, P., editors, *The Oxford handbook of derivational morphology*, pages 26–49. Oxford University Press, Oxford.

Oshima, D. Y. (2006). GO and COME revisited: What serves as a reference point? In *Annual Meeting of the Berkeley Linguistics Society 32.* The Berkeley Linguistics Society and The Linguistic Society of America.

Papafragou, A. and Musolino, J. (2003). Scalar implicatures: experiments at the semantics-pragmatics interface. *Cognition*, 86:253–282.

Pater, J. (2003). The perceptual acquisition of thai phonology by English speakers: task and stimulus effects. *Second Language Research*, 19(3):209–223.

Paul, R. and Feldman, C. (1984). Communication deficits in autism. Paper presented at the Institute for Communication Deficits in Autistic Youth, Columbia University, New York, NY.

Paul, R., Landa, R., and Simmons, E. (2014). Assessing and treating communication. In McPartland, J., Klin, A., and Volkmar, F., editors, *Asperger syndrome: Assessing and treating highfunctioning autism spectrum disorder*, pages 103–142. Guilford Press, New York, 2 edition.

Paul, R., Orlovski, S., Marchinko, H., and Volkmar, F. (2009). Conversational behaviors in youth with high-functioning autism and asperger syndrome. *Journal of Autism and Developmental Disorders*, 39:115–125.

Perkins, M. R., Dobbinson, S., Boucher, J., Bol, S., and Bloom, P. (2006). Lexical knowledge and lexical use in autism. *Journal of Autism and Developmental Disorders*, 36:795–805.

Peyasantiwong, P. (1986). Stress in Thai. In Bickner, R. J., editor, *A Conference on Thai Studies In Honor of William J. Gedney* , pages 211–230. Center for South and Southeast Asian studies, the University of Michigan.

Pijnacker, J., Hagoort, P., Buitelaar, J., Teunisse, J. P., and Geurts, B. (2009). Pragmatic inferences in high-functioning adults with autism and asperger syndrome. *Journal of Autism and Developmental Disorders*, 39:607–618.

Pinker, S. and Ullman, M. T. (2002). The past-tense debate. *cognitive processing*, 5:7.

Pittayaporn, P. (2016). Chindamani and reconstruction of Thai tones in the 17th century. *Diachronica*, 33(2):187–219.

Piven, J. and Palmer, P. (1997). Cognitive deficits in parents from multiple-incidence autism families. *Journal of Child Psychology and Psychiatry*, 38:1011–1021.

R Core Team (2016). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Radeau, M., Morais, J., and Dewier, A. (1989). Phonological priming in spoken word recognition: Task effects. *Memory & Cognition*, 17:525–535.

Ralli, A. (2010). Compounding versus derivation. In Scalise, S. and Vogel, I., editors, *Cross-disciplinary issues in compounding*, pages 57–76. John Benjamins, Amsterdam, The Netherlands.

Rapin, I. and Dunn, M. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and Development*, 25:166–172.

Rastle, K. and Davis, M. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes*, 23(7-8):942–971.

Rastle, K., Davis, M. H., Marslen-Wilson, D., W., and Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, 15:507–537.

Rastle, K., Davis, M. H., and New, B. (2004). The broth in my brothers brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, 11:1090 – 1098.

Raven, J. (2000). The Ravens progressive matrices: Change and stability over culture and time. *Cognitive Psychology*, 41:1–48.

Raven, J., Raven, J. C., and Court, J. H. (2000). *Raven manual: Section 3, standard progressive matrices, including the parallel and plus versions, 2000 edition*. Oxford Psychologists Press, Oxford.

Reilly, S., Bishop, D. V. M., and Tomblin, B. (2014a). Terminological debate over language impairment in children: forward movement and sticking points. *International Journal of Language & Communication Disorders*, 49(4):452–462.

Reilly, S., Tomblin, B., Law, J., McKean, C., Mensah, F. K., Morgan, A., Goldfeld, S., Nicholson, J. M., and Wake, M. (2014b). Specific language impairment: a convenient label for whom? *International Journal of Language & Communication Disorders*, 49(4):416–451.

Remington, A. and Fairnie, J. (2017). A sound advantage: Increased auditory capacity in autism. *Cognition*, 166:459–465.

Riches, N. G., Loucas, T., Baird, G., Charman, T., and Simonoff, E. (2012). Interpretation of compound nouns by adolescents with specific language impairment and autism spectrum disorders: An investigation of phenotypic overlap. *International Journal of Speech-Language Pathology*, 14(4):307–317.

Roberts, C. (2004). Pronouns as Definites. In Reimer, M. and Bezuidenhout, A., editors, *Descriptions and Beyond*. Oxford University Press, Oxford.

Roberts, J. A., Rice, M. L., and Tager-Flusberg, H. (2004). Tense marking in children with autism. *Applied Psycholinguistics*, 25:429–448.

Rutter, M. (1970). Autistic children: infancy to adulthood. *Seminars in psychiatry*, 2(4):435.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *The quarterly journal of Experimental Psychology*, 42(3):529–567.

Sauerland, U. (2003). A new semantics for number. In *Proceedings of SALT13*, pages 258–275.

Sauerland, U. (2008a). Implicated presuppositions. In Steube, A., editor, *Sentence and Context*. Mouton de Gruyter.

Sauerland, U. (2008b). On the semantic markedness of phi-features. In Harbour, D., Adger, D., and Bejar, S., editors, *Phi Theory: Phi Features across Interfaces and Modules*, pages 57–82. Oxford University Press.

Schaefer, V. and Darcy, I. (2014). Lexical function of pitch in the first language shapes cross-linguistic perception of thai tones. *Laboratory Phonology*, 5:489–522.

Schreuder, R. and Baayen, R. H. (1997). How complex simplex words can be. *Journal of Memory and Language*, 37:118–139.

Seidenberg, M. S. and Gonnerman, L. M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in cognitive sciences*, 4(9):353–361.

Slowiaczek, L. M., McQueen, J., Soltano, E. G., and Lynch, M. (2000). Phonological representations in prelexical speech processing: Evidence from form-based priming. *Journal of Memory and Language*, 43:530–560.

Smolka, E., Komlosi, S., and Rösler, F. (2009). When semantics means less than morphology: The processing of German prefixed verbs. *Language and Cognitive Processes*, 24(3):337–375.

Smolka, E., Preller, K. H., and Eulitz, C. (2014). Verstehen (understand) primes stehen (stand): Morphological structure overrides semantic compositionality in the lexical representation of German complex verbs. *Journal of Memory and Language*, 72:16–36.

Speirs, S., Yelland, G., Rinehart, N., and Tonge, B. (2011). Lexical processing in individuals with high-functioning autism and asperger's disorder. *Autism*, 15:307–325.

Spinelli, E., Segui, J., and Radeau, M. (2001). Phonological priming in spoken word recognition with bisyllabic targets. *Language and Cognitive Processes*, 16:367–392.

Stalnaker, R. (1973). Presuppositions. *Journal of Philosophical Logic*, 2:447–457.

Stalnaker, R. (1974). Pragmatic presupposition. In Milton, M. K. and Unger, P. K., editors, *Semantics and philosophy*. NewYork University Press, NewYork.

Stockall, L. C. (2004). *Magnetoencephalographic investigations of morphological identity and irregularity*. Doctoral dissertation, Massachusetts Institute of Technology.

Sudo, Y. (2012). *On the Semantics of Phi Features on Pronouns*. Doctoral dissertation, Department of Linguistics, Massachusetts Institute of Technology.

Szatmari, P., MacLean, J. E., Jones, M. B., Bryson, S. E., Zwaigenbaum, L., Bartolucci, G., Mahoney, W. J., and Tuff, L. (2000). The familial aggregation of the lesser variant in biological and nonbiological relatives of pdd probands: a family history study. *Journal of Child Psychology and Psychiatry*, 41:579–586.

Taft, M. (2001). Cognitive psychology of lexical access. In Smelser, N. J. and Baltes, P. J., editors, *International encyclopedia of the social behavioral sciences*, pages 8743–8748. Pergamon, Oxford.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *Quarterly Journal of Experimental Psychology Section A*, 57(4):745–765.

Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders*, 11:45–56.

Tager-Flusberg, H. (1994). Dissociation in form and function in the acquisition of language by autistic children. In Tager-Flusberg, H., editor, *Constraints on language acquisition: Studies of atypical children*. Erlbaum, Hillsdale, NJ.

Tager-Flusberg, H. (1999). A psychological approach to understanding the social and language impairments in autism. *International Review of Psychiatry*, 11:325–334.

Tager-Flusberg, H. (2004). Strategies for conducting research on language in autism. *Journal of Autism and Developmental Disorders*, 34:75–80.

Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research*, 6:219–224.

Tager-Flusberg, H., Calkins, S., Nolin, T., Baumberger, T., Anderson, M., and Chadwick-Dias, A. (1990). A longitudinal study of language acquisition in autistic and Down syndrome children. *Journal of Autism and Developmental Disorders*, 20:1–21.

Tager-Flusberg, H. and Joseph, R. M. (2003). Identifying neurocognitive phenotypes in autism. *Philosophical Transactions of the Royal Society*, 358:303–314.

Talmy, L. (1975). Semantics and syntax of motion. In Kimball, J. P., editor, *Syntax and Semantics*, volume 4. Academic Press, New York.

Terman, L. M. (1916). *The measurement of intelligence: An explanation of and a complete guide for the use of the Stanford revision and extension of the Binet-Simon intelligence scale*. Houghton Mifflin.

Tibshirani, R., Walther, G., and Hastie, T. (2001). Estimating the number of clusters in a data set via the gap static. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 63(2):411–423.

Trips, C. (2013). *Lexical semantics and diachronic morphology: The development of -hood, -dom and -ship in the history of English.* Niemeyer, Tbingen, Germany.

Ullman, M. T. and Pullman, M. Y. (2015). A compensatory role for declarative memory in neurodevelopmental disorders. *Neuroscience Biobehavioral Reviews*, 51:205 – 222.

Vanek, A. L. (1977). *Aspects of Subject-Verb Agreement.* Linguistic Research, Edmonton, Canada.

Venker, C. E., Edwards, J., Saffran, J. R., and Weismer, S. E. (2019). Thinking ahead: Incremental language processing is associated with receptive language abilities in preschoolers with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49:1011–1023.

Venter, A., Lord, C., and Schopler, E. (1992). A follow-up study of high-functioning autistic children. *Journal of Child Psychology and Psychiatry*, 33(3):489–597.

Volden, J. and Lord, C. (1991). Neologisms and idiosyncratic language in autistic speakers. *Journal of Autism and Developmental Disorders*, 21:109–130.

Volkmar, F. R. and Reichow, B. (2013). Autism in DSM-5: progress and challenges. *Molecular Autism*, 4(13).

Volkmar, F. R., Sparrow, S. S., Goudrequ, D., Cicchetti, D. V., Paul, R., and Cohen, D. J. (1987). Social deficits in autism: An operational approach using the vineland adaptive behavior scales. *Journal of the Academy of Child and Adolescent Psychiatry*, 26:155–161.

Walenski, M., Mostofsky, S. H., Gidley-Larson, J. C., and Ullman, M. T. (2008). Brief report: Enhanced picture naming in autism. *Journal of Autism and Developmental Disorders*, 38:1395–99.

Walenski, M., Tager-Flusberg, H., and Ullman, M. T. (2006). Language in autism. In Moldin, S. O. and Rubenstein, J. L. R., editors, *Understanding Autism: From Basic Neuroscience to Treatment*. CRC Press, Boca Raton, FL.

Waterhouse, L. and Fein, D. (1982). Language skills in developmentally disabled children. *Brain and Language*, 15:307–333.

Wayland, R. and Guion, S. (2014). Perceptual discrimination of thai tones by nave and experienced learners of thai. *Applied Psycholinguistics*, 24(5):113–129.

Weismer, S. E., Davidson, M. M., Gangopadhyay, I., Sindberg, H., Roebuck, H., and Kaushanskaya, M. (2017). The role of nonverbal working memory in morphosyntactic processing by children with specific language impairment and autism spectrum disorders. *Journal of Neurodevelopmental Disorders*, 28(9):1866–1955.

Wetherby, A., Prizant, B. M., and Schuler, A. (2013). Understanding the nature of the communication and language impairments. In Wetherby, A. and Prizant, B. M., editors, *Autism spectrum disorders: A transactional developmental perspective*, volume 9, pages 109–141. Paul H. Brookes, Baltimore ,MD.

Whitehouse, A. J., Barry, J. G., and Bishop, D. V. M. (2008). Further defining the language impairment of autism: Is there a specific language impairment subtype? *Journal of Communication Disorders*, 41:319–336.

Whitehouse, A. J., Maybery, M. T., and Durkin, K. (2007). Evidence against poor semantic encoding in individuals with autism. *Autism*, 11(3):241–254.

Wiig, E., Secord, W., and Semel, E. (1992). *Clinical Evaluation of Language Fundamentals – Preschool*. Psychological Corporation, San Antonio, TX.

Wilder, R. J. (2018). *Investigating Hybrid Models of Speech Perception*. Doctoral dissertation, Department of Linguistics, University of Pennsylvania.

Wilkins, D. P. and Hill, D. (1995). When GO means COME: Questioning the basicness of basic motion verbs. *Cognitive Linguistics*, 6:209–259.

Wilkinson, K. (1998). Profiles of language and communication skills in autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 4:73–79.

Williams, D., Botting, N., and Boucher, J. (2008). Language in autism and specific language impairment: Where are the links? *Psychological Bulletin*, 134:944–963.

Winskel, H. (2011). Orthographic and phonological parafoveal processing of consonants, vowels, and tones when reading thai. *Applied Psycholinguistics*, 32(4):739–759.

Winskel, H. and Perea, M. (2014). Does tonal information affect the early stages of visual-word processing in thai? *Quarterly Journal of Experimental Psychology*, 67(2):209–219.

Winskel, H., Perea, M., and Ratitamkul, T. (2012). On the flexibility of letter position coding during lexical processing: Evidence from eye movements when reading thai. *Quarterly Journal of Experimental Psychology*, 65(8):1522–1536.

Winskel, H., Radach, R., and Luksaneeyanawin, S. (2009). Eye movements when reading spaced and unspaced thai and english: A comparison of thai-english bilinguals and english monolinguals. *Quarterly Journal of Experimental Psychology*, 61:339–351.

Yatsushiro, K. (2008). Quantifier acquisition: presuppositions of 'every'. In *Proceedings of Sinn und Bedeutung 12*, pages 663–677, Oslo. University of Oslo.

Zehr, J. and Schwarz, F. (2018). Penncontroller for internet based experiments (IBEX).

Zhou, P., Zhan, L., and Ma, H. (2019). Predictive language processing in preschool children with autism spectrum disorder: An eye-tracking study. *Journal of Psycholinguistic Research*, 48:431–452.

Zimmerman, I. L., Steiner, V. G., and Pond, R. E. (2011). *Preschool Language Scales, Fifth Edition (PLS-5)*. Pearson.