# WORD ASSOCIATION AND SEMANTIC PRIMING IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDERS

by

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A dissertation submitted to the Graduate Faculty in Speech-Language-Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2012

This manuscript has been read and accepted for the
Graduate Faculty in Speech-Language-Hearing Sciences in satisfaction of the
dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

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Lexical organization in individuals with Autism Spectrum Disorders (ASD) is not fully understood. This study investigated the nature of word association in individuals with ASD using two experimental paradigms: a word association task (Experiment 1), followed by an individualized semantic priming task (Experiment 2). In Experiment 1, participants were asked to name as many semantically related words as possible when auditorily presented with a target (e.g., participants heard the word *cat* and were asked to name semantically related words, within 60 seconds). In Experiment 2, participants were asked to name a target picture, preceded in time by 50 ms. Four types of auditory primes were used: Associated (e.g., bird-nest), Individual Semantic (e.g., bird-(tree)), Identity (e.g., bird-bird), and Unrelated (e.g., bird-car). The primes in the Individual Semantic condition were semantic associates obtained from responses in Experiment 1. Participants were 15 individuals with ASD (aged 14;0 to 19;2), 16 with typical language development matched for chronological age (CAM) (aged 15;0 to 19;7), and 14 with typical language development matched for raw score (VM) on the *Peabody Picture Vocabulary Test 4$^{th}$ ed* (aged 8;1 to 13;4) (Dunn & Dunn, 2007). In Experiment 1, while individuals with ASD produced many appropriate word associations, they also produced more unrelated word associations than both control groups. In Experiment 2, participants' reaction times revealed that individuals with ASD performed similarly to both control groups in all conditions: they exhibited priming in the Identity condition, but not in the Associated and Individual Semantic conditions. Absence of group x condition interaction in the Associated condition calls method into question. Results from Experiment 1 suggest that individuals with ASD have a similarly organized lexicon (i.e., more associated than unrelated responses to a given target), but the breadth and depth of their lexicons may be immature (i.e., higher proportion of unrelated responses, relative to both control groups). Findings have clinical and educational implications for vocabulary instruction in individuals with ASD. Word associations may first appear to be typical. However, in-depth analyses (i.e., monitoring associated, perseveration, proper noun, phrase, or unrelated responses), provides robust information regarding lexical organization.

## Dedication

This dissertation is dedicated to my wonderful and loving husband, James. You are my partner in life who is always by my side. You make the bad times tolerable and to good times the best times. You have traveled this road with me, and shared in the challenges and celebrations of this work. Every fiber of my being is better because of you. I love you forever.

**Acknowledgements**

It truly takes a village to complete a project of this magnitude. I am very blessed. First and foremost, I would like to thank God for giving me the gifts of intellect, strength and character to choose the road less traveled and to ask the difficult questions. Thank you to my advisor, Dr. Richard G. Schwartz, who pushed me beyond what I thought was within the realm of possibility, building my research skills along the way. Thank you for your encouragement and perseverance with me during this project.

Thank you to my committee members, Drs. Joanne Gerenser and Liat Seiger-Gardner. Joanne, you have exposed me to individuals with autism spectrum disorders from the very beginning. The experiences I have had under your tutelage can never be measured. Liat, your expertise in research and writing have helped to develop this work into a piece which is not only presentable, but something to be proud of. I would like to thank Dr. Michelle Macroy-Higgins, the "voice" of this study. Michelle, you never said no to any request, regardless of how big or small, and were an instrumental part in stimuli development. You have further doubled as my outside reader, whose helpful comments helped to shape the tone of this dissertation. Thank you also to Annabell for making recording in the audio booth lots of fun! Thank you to Gary Chant, whose engineering expertise helped in the development of the data collection methods of this work. Gary, you were always available for either troubleshooting and/or encouragement (usually both).

I would like to thank Dr. Robert A. Domingo, whose generosity is boundless. Bob, you always made yourself available for emotional support. Your generous allowance of office space allowed for this project to physically occur. I would also like to acknowledge Dr. Ronald L. Bloom, whose gentle way and constructive criticism gave me the strength to keep on keeping on.

Thank you to the most amazing staff at the Eden II/Genesis Programs (too numerous to name individually). Your perpetual assistance with recruiting, understanding, encouragement, flexibility and release time gave me the strength to complete this project. I would also like to thank my colleagues at Adelphi University who have proofread, provided feedback, and planted seeds for future projects. You have taken a vested interest in me as a colleague and friend, and I am in awe of your support.

To a very special person who I am now honored to call a true friend, Dr. Mary E. McDonald. We began this journey in 1995, when I met my first child with autism spectrum disorders. Over the (now) decades, we have grown to become not only colleagues, but great friends. Thank you for your support in the times of self-doubt, and celebrating with me in the good times.

I would like to thank the Long Island Speech-Language Hearing Association (LISHA), Organization of Autism Research (OAR) and the CUNY Graduate Center for their generous financial support of this project. To be validate by such organizations has been an honor.

Thank you to my parents, Tony and Nina Montemagni, who always supported me and saved the best bottles of wine for when I passed my exams. Thank you to my mother-in-law, Marian Battaglia, who gave me both support and space when I needed it (sometimes simultaneously). Thank you to my family who always understood when I was late or a no show to a gathering because of my schoolwork. To my best friend in life, Veronica Jordan. I wouldn't know where to begin and end. To have a friend like you is a rare gift in life.

This acknowledgement would be incomplete without thanking the individuals with autism spectrum disorders and their families, with whom I have had the great privilege to work. You are both a mystery and an inspiration to me.

In summary, the completion of this project can be credited to my family who has supported me, my friends who have humored me, my colleagues who have guided me, and my clients who inspire me. I will be forever grateful.

# Table of Contents

# List of Tables

# List of Figures

# List of Appendixes

# Chapter 1

## Introduction

Individuals with autism spectrum disorders (ASD) demonstrate impairments in three major areas: social interaction, linguistic and nonlinguistic communication, and behavioral/sensory interests (American Psychiatric Association, 2000). ASDs include individuals with pervasive developmental disorder-not otherwise specified (PDD-NOS), autistic disorder, Asperger's syndrome, childhood disintegrative disorder, and Rett's disorder. This study will solely examine, and therefore refer to, individuals with autistic disorder, Asperger's syndrome, and PDD-NOS.

Numerous studies have suggested that children with autism process semantic information in an atypical manner (Geurts & Embrechts, 2008; Perkins, Dobbinson, Boucher, Bol, & Bloom, 2006; Boucher, 2003; Wilkinson, 1998). These children exhibit unusual lexical patterns, including the use of idiosyncratic words, neologisms, echolalia (Wilkinson, 1998), and delays in lexical development (Charman, Drew, Baird, & Baird, 2003; Hobson, 1993; Tager-Flusberg, Lord & Paul, 2005). In contrast, other studies have indicated that, in some respects, children with autism do process semantic information similarly to their typically developing peers (Kamio & Toichi, 2000; Minshew, Goldstein, & Seigal, 1995; Tager-Flusberg, 1985; Toichi & Kamio, 2001, Toichi & Kamio, 2002; Vogindroukas, Papageorgiou & Vostanis, 2003). The ability to perform on tasks involving yes/no judgment (Toichi & Kamio, 2001), semantic memory (Kamio & Toichi, 2000), verbal association (Toichi & Kamio, 2002), and detail-oriented word association (Vogindroukas, Papageorgiou & Vostanis, 2003) suggest that the lexicon in individuals with autism is largely intact. The inconsistency in the aforementioned literature may be attributed to the different populations tested within the autism spectrum (e.g., high-functioning adults with autism, high- and low-functioning adolescents with autism, children with autism and mild learning disabilities). Given these inconsistent findings, the question remains as to whether individuals with ASD have a lexicon organized comparable to their typical counterparts.

**Linguistic Profiles**

**Typical language development.** In typical language acquisition, a child can produce approximately 50 words by approximately 18 months of age. These words tend to be predominantly nominal (e.g., *ball*), followed by action words (e.g., *go*), modifiers (e.g., *big*), personal social (e.g., please), and grammatical function (e.g., *what*; Nelson, 1973). New lexical items are acquired, organized, and stored at exponential rates (Locke, 1993). Thematic (i.e., associative) and taxonomic (i.e., categorical) relationships among words emerge and influence the developing lexicon. Early acquired referents are stored thematically (e.g., *DOG – BONE*), while later acquired referents are stored taxonomically (e.g., *DOG – CAT)* (Dunham & Dunham, 1995; Fenson, Vella, & Kennedy, 1989; Markman & Hutchinson, 1984). This transition from associative (thematic) to categorical (taxonomic) has been shown to occur as early as 36 months of age (Dunham & Dunham, 1995; Fenson, Vella, & Kennedy, 1989). Word associations that typically developing children produce are developmentally and experientially dynamic. These associations are subject to change, based on increased exposure to more examples of a specific referent (De Dyne & Storm, 2008). In an intact mature system, word associations are the result of repeated exposure to and acquisition of language. As children develop into adolescence and adulthood, there is a parametric change in the lexicon (Jaeger, 1992; Stemberger, 1989; Warren, 1986; Wijnen, 1992), resulting in an increase in the number of referents per concept and increased efficiency of access.

**Autism spectrum disorders.** Tager-Flusberg (2006) first described two subtypes of individuals with ASD by administering a battery of standardized tests to 35 children with ASD, ages 7 to 14. The first type, autism language impaired (ALI), comprised 75% of verbal children with ASD. The ALI phenotype was described as performing significantly below the mean on all language measures with the exception of articulation. Across language measures, individuals with ASD, who are also ALI, demonstrated moderate impairments in vocabulary and phonological processing, and more severe impairments in higher-order semantics and syntax.

The second phenotype of individuals with ASD was described by Tager-Flusberg as autism language normal (ALN). These individuals comprised the remaining 25% of participants with ASD, with all language scores falling within the normal range. A moderate relationship was reported between language and IQ scores. In addition, delayed onset of language appeared in both (ALI and ALN) subgroups. The author concluded that individuals with ALI may overlap with linguistic profiles of individuals with specific language impairment (Tager-Flusberg, 2006). Language development and linguisitic profiles in other clinical populations have also been described (Leonard, 2002; Marder & Cholman, 2006; Mervis & Becerra, 2007; van der Schuit, Segers, Balkom, & Verhoeven, 2011).

**Other clinical populations.** Children with specific language impairment (SLI) have been reported to be late in acquiring first words (Leonard, 2002). However, the topography of the words they do acquire resembles those of typically developing children (i.e., a majority of general nominal, followed by actions). There has been mixed evidence for fast mapping (Dollaghan, 1987; Rice, Buhr, & Nemeth, 1990). Dollaghan (1987) reported that individuals with SLI were able to comprehend newly acquired nouns using fast mapping, but failed in production of new words. Rice and colleagues (1990) found children with SLI to perform more poorly than their mean length of utterance (MLU)-matched controls in both comprehension and production. Many children with SLI exhibit word-finding difficulties (German 1984; 1987; Leonard, Nippold, Kail & Hale, 1983; McGregor & Leonard, 1989; McGregor & Waxman, 1998; Nippold, 1992), and name pictures more slowly than their peers with typical language development (Lahey & Edwards, 1996; Seiger-Gardner & Brooks, 2008; Seiger-Gardner & Schwartz, 2008). Their naming errors, while significantly greater than their typical developing counterparts (Seiger-Gardner & Schwartz, 2008; Lahey & Edwards, 1999; McGregor, 1997), are predominantly semantic in nature. These findings indicate that individuals with SLI may have intact semantic organization, but with less breadth and depth of semantic representation than that of their peers (Seiger-Gardner, Brooks, & Cadavid, 2007; McGregor & Waxman, 1998).

Language development and lexical organization has been studied in individuals with Williams syndrome, Down syndrome, and intellectual disabilities as well. Individuals with Williams syndrome are frequently delayed in language acquisition (Mervis & Becerra, 2007). However, they have been reported to respond to bids for joint attention during early development. Further, they produce an average of 100 words at approximately 41 months of age, as opposed to their typical counterparts who demonstrate 100 words at approximately 28 months (Fenson, et al., 2006). Semantic organization has been reported to be appropriate in 9- and 10-year olds with Williams syndrome, as observed in their ability to perform on a semantic verbal fluency task (i.e., Tell me as many *animals* as you can think of; Klein & Mervis, 1999).

Nonverbal intelligence was found to predict phonological working memory, vocabulary, and syntax in children with intellectual disabilities (van der Schuit, Segers, Balkom, & Verhoeven, 2011). In children with Down syndrome, speech and language skills show patterns of development similar to typically developing children of a younger age (Marder & Cholman, 2006). They also demonstrate uneven patterns of development across domains of language, with comprehension often better than expression. These delays and splinter skills in development have been attributed to cognitive impairment often seen in Down Syndrome (Marder & Cholman, 2006). Taken together, while several other clinical populations (i.e., Williams syndrome, intellectual disabilities, Down syndrome) demonstrate language delays, their semantic organization may be comparable to peers matched for nonverbal IQ.

**Early Word Learning**

**Fast mapping.** Individuals with ASD typically demonstrate semantic deficits (e.g., reduced representation for basic and abstract concepts; Fay & Schuler, 1980), though the specific nature of these deficits is unclear. By contrast, typically developing children learn the meaning of new words incidentally and experientially (Bloom, 2002). That is, they automatically fast map new labels for referents (Carey, 1978) predominantly through joint attention experiences. In addition, when a typically developing child fast maps a new label onto a referent, it is automatically categorized and associated with other words (Bloom, 2002).

**Joint attention.** Deficits in joint attention discriminates individuals with ASD from children with other developmental disabilities (Jones & Carr, 2004) and is observed prior to one year of age (Baron-Cohen, Allen, & Gillberg, 1992). Two different types of joint attention have been described: *responding* to joint attention (initiated by a communicative partner) and *initiating* joint attention (on the part of the child; Mundy & Gomes, 1998). While children with ASD may learn to respond to joint attention, they continue to be deficient in initiating joint attention (Charman, 1998). If children with ASD are not engaging in joint attention bids, they will inevitably map incorrect representations to referents. Inappropriate joint attention can explain how when a caregiver says, “look at the fire truck” while pointing, and a child is looking at Elmo, a child with ASD will map the referent “fire truck” to the representation of Elmo.

A striking observation about typical language development is the seemingly effortless way in which children acquire and use words as labels for referents. Individuals in other clinical populations (i.e., specific language impairment, Williams syndrome, intellectual disabilities) appear to follow a similar trajectory, but at a slower rate. This is not the case in individuals with ASD who demonstrate a reduction in the expression of basic and abstract concepts. By examining lexical organization in individuals with ASD, one can learn about their semantic representations and word associations. There are several tasks that have been designed to study lexical organization (e.g., gating, picture word interference). Of particular interest is word association as a representation of lexical organization (Bousfield & Sedgewick, 1944) and cross-modal semantic priming as a representation of lexical access and semantic representation (Schriefers, Meyer, & Levelt, 1990).

**Semantic Priming**

Lexical priming is a method to examine lexical access and is typically elicited in tasks such as lexical decision, categorical judgment, or picture naming. When searching for a particular word, associated items become activated. This activation is called *priming* (Collins & Loftus, 1975). Priming is an automatic process in which response to a target stimulus is either sped up (facilitated) or slowed down (inhibited) as a result of a priming stimulus (Neely, 1991; McNamara, 2005).

Most models of lexical access include word representation with a semantic level and a phonological level. There are three dominant theories of lexical access for production: serial (Schreifers, Meyer, & Levelt, 1990; Levelt, et al., 1990), cascading (Peterson & Savoy, 1998), and interactive (Dell, 1986). Although they are all in agreement regarding the general representation levels, the models diverge in the time course of semantic and phonological activation. During lexical access in word production, two subprocesses are delineated: access to a word's semantic-syntactic representation (lemma) and access to a word's phonological form (lexeme) (Jescheniak, Schriefers, & Hantsch, 2001). Schriefers and colleagues (1990) noted that in normal adults, semantic primes may be inhibitory or facilitory, whereas phonological primes are facilitory. More specifically, semantic coordinates (e.g., *CAR* → *TRUCK*) cause inhibition whereas semantic associates (e.g., *CAR* → *WHEEL*) cause facilitation. That is, there is lexical competition among semantic coordinates, which are words that belong to the same semantic category, but not among semantic associates, which are words that do not belong to the same semantic category but tend to co-occur frequently in the language. This "shift" from thematic association to taxonomic association has been observed in children as early as 36 months (Dunham & Dunham, 1995). Using a match to sample task (i.e., matching either *RABBIT* or *TOMATO* with the target *CARROT*), 24-month-old children matched pictures thematically (i.e., *CARROT – RABBIT)*, while 36-month-old children matched pictures taxonomically (i.e., *CARROT- TOMATO*; Dunham & Dunham, 1995).

Adults have demonstrated differential responses to associates versus coordinates as well. Alario and colleagues (2000) investigated the difference between priming for semantic coordinates (e.g., *BIRD – CAT)* and semantic associates (e.g., *BIRD – NEST)* at two different stimulus onset asynchronies (SOAs). Stimulus onset asynchrony is the temporal difference between presentation of a prime and a target. Forty college students were presented with these two conditions at 114-millisecond and 234-millisecond SOAs. At 114 SOA, both associated and coordinate primes caused inhibition. At 234 SOA, priming was observed for associates, and no effects were observed of coordinates (Alario, Segui, & Ferrand, 2000). Sailor and colleagues (2009) found the time course of associated priming to overlap between -150 and 0 SOA in typical adults. Differences in inhibition and facilitation may be attributed to the difference in connections between associates and coordinates. Coordinates may produce interference due to competition among lemmas, while associates may produce facilitation due to activation rather than competition (Sailor, Brooks, Bruening, Seiger-Gardner, & Guterman, 2009).

While differential responses in associates versus coordinates is observed in both adults and children (Dunham & Dunham, 1995; Sailor, et al., 2009; Alario, et al., 2000), children differ in their reaction times and error rates (Jescheniak, et al., 2006; Seiger-Gardner & Schwartz, 2008). Using a cross-modal semantic (i.e., *BELT – TIE*) and phonological (i.e., *BELT – BOAT)* priming task, Seiger-Gardner and Schwartz (2008) found that typically developing school-aged children demonstrated similar trends in responses as adults, but were generally slower and produced more response errors (Seiger-Gardner & Schwartz, 2008). Using a mediated cross-modal picture-word interference task (i.e., *DOLL – CAT*), Jescheniak and colleagues (2006) found that distractor effects from cross-modal priming were much larger for adults than for children. This effect was found in second and fourth grade children, though more strongly in second graders. Collectively, these findings suggest that organization of the lexical network may be less mature in typically developing children, though similar to adult-like priming patterns.

Semantic priming has been a useful online method to investigate lexical access in adults and typically developing children. *Online* tasks (e.g., semantic priming, lexical decision) investigate the process of generating a response (e.g., reaction time). The additional timing information obtained contributes to understanding lexical access and organization. *Offline* procedures (e.g., word association, verbal fluency) provide information about word knowledge (e.g., total number of responses, response types), whereby the focus of the experiment is on the end product rather than the process as it occurs as in online tasks.

How individuals perform in verbal fluency tasks may also support the aforementioned priming data and potentially converge findings from online and offline studies. This study proposes the use of both online (i.e., semantic priming) and offline (i.e., verbal word association) methods to gain more information about lexical organization in word production tasks.

**Verbal Fluency and Word Associations**

A verbal fluency task examines words generated in response to a specific cue (e.g., category name, letter, phoneme) within a specified amount of time (e.g., 60 seconds) (Bousfield & Sedgewich, 1944; Boucher, 1988). For example, a child may be asked to name as many vehicles as possible within one minute. Verbal fluency tasks measure both cognitive flexibility and search strategy. Success in such tasks depends on one's ability to initiate a search for specific referents and to efficiently retrieve this information from the lexicon (Hurks, et al., 2006). Fluency tasks depend on executive functions that regulate goal-directed behavior, are volitional, and take several seconds to complete (Lezak, 1995, Barkley, 1998, Martin, Wiggs, Lalonde, & Mack, 1994; Monsch et al., 1994; Rosser & Hodges, 1994).

Different aspects of verbal fluency in typical adults and children have been explored to shed light on lexical organization (Crowe, 1998, Hurks et al., 2006, Troyer, 2000). Some specific measures of verbal fluency include clustering and switching (Troyer, 2000), repetitions (Hurks, et al., 2006; Troyer, 2000), correct responses (Hurks, et al., 2006), degradation of responses over quartiles (Hurks, et al., 2006; Crowe, 1998), intrusions (Troyer, 2000), frequency of fluency responses (Crowe, 1998), and total number of responses (Hurks, et al, 2006).

Normative data are now available in normal, healthy adults (ages 18 to 91) regarding clustering (i.e., semantic groupings) and switching (i.e., shifting between categories) during verbal fluency tasks, both in semantic (e.g., *ANIMALS*) and phonemic (e.g., letter *F*) domains (Troyer, 2000). In young, healthy adults, Crowe (1998) found a significant decrease in the word frequency and number of responses over time. These results were consistent across semantic (i.e., *FRUIT, ANIMALS*) and phonemic (i.e., *F, A, S*) categories, with more semantic than phonological responses. These findings suggest that the most dominant word associations are produced within the first two quartiles (i.e., 15-second time frames; Crowe, 1998). In healthy, 9- to 10-year-old children, Hurks and colleagues (2006) found that word production decreased over time, with more semantic (e.g., things you can *eat*) versus initial letter fluency (e.g., letter *M*) responses over each trial. In addition, more intrusions (i.e., noncategorical or non-initial letter category responses) on the initial letter fluency than on the semantic task were observed. Finally, children tended to produce more responses during the first 15 seconds (i.e., the first quartile) than subsequent time intervals. Taken together, findings in children and adults in verbal fluency indicate that the highest number and most frequent words are produced first, with fewer and less frequent words being produced once the stores in the lexicon are exhausted. How individuals with and without ASD respond to a verbal word association task is of particular interest to this study.

Verbal fluency tasks provide an established way to evaluate the cognitive and linguistic processes involved in lexical organization, word association, and retrieval. The associative hypothesis, which states that the frequency of co-occurrence of words creates strengthened associations among them, may account for verbal fluency responses focused on semantic coordinates (Palermo, 1971; Oldfield & Wingfield, 1965; Humphreys, Riddoch, & Quinlan, 1988).

In summary, verbal word association is essentially a volitional, offline task that can illuminate lexical organization. Semantic priming is a non-volitional task that can provide information concerning lexical access and the organization of the mental lexicon, as an online method. Together, verbal word association and semantic priming can provide information about the lexical access and organization in clinical populations, such as autism spectrum disorders.

**Autism Spectrum Disorders (ASD)**

The deficits observed in ASD are heterogeneous. A child with ASD may atypically perceive and organize lexical items in the mental lexicon, leading to atypical word associations. These atypical associations may be due to initial learning experiences (Fay & Schuler, 1980), causing children with ASD to fast map inappropriate referents to their underlying concepts (Baron-Cohen, Baldwin, & Crowson, 1997). Kanner (1943) described an example of inappropriate fast mapping in one of his case studies: a child who labeled “saucepan” as “Peter Peter Pumpkin Eater.” This incorrect label was reported to occur because the child’s mother was reciting this nursery rhyme and dropped the saucepan she was using to prepare dinner. The child fast mapped the (inappropriate) label (i.e. “Peter Peter Pumpkin Eater”) to the referent (i.e., “saucepan.”)

Individuals with ASD may also demonstrate stimulus over-selectivity (Lovaas, Koegel, & Schreibman, 1979), in which objects are defined not by the sum of their parts, but rather an idiosyncration (and potentially irrelevant) isolated segment (i.e., “foot” for “rabbit”) (Jolliffe & Baron-Cohen, 2001; Baron-Cohen, Ashwin, Ashwin, Tavasolli, & Chakabarti, 2009). If a child with ASD stores a newly acquired word according to first exposure to it, or a part of the visual presentation rather than the underlying integrated semantic concept, he or she may associate words qualitatively differently than typically developing children. Over time, these associations may become increasingly rigid.

Rawlings and Locarnini (2008) found a tendency for artists to make idiosyncratic word associations (e.g., *TABLE - MAN*) and for scientists to make more opposite word associations (e.g., *DARK - LIGHT*). Interestingly, the diagnosis of autism in adults was found to be more highly correlated with participants having scientific expertise than with participants having artistic expertise. Individuals with autism systematize language and are less likely to be creative, flexible, and/or fluent with language (Minshew, et al., 1995). For example, rather than integrating multiple exemplars of dogs into a synthesized representation of *DOG*, an individual with autism may refer to each different type of dog as an isolated and distinct referent based on idiosyncratic criteria (e.g., first experience with a particular dog, categorization of a dog based on texture of fur). As a result, they may store five different types of dogs as five different lexical items rather than one cohesive lexical item to represent many variations of the concept *DOG.*

Related literature has supported the notion that language is systematized in autism (Minshew, et al., 1995). A psychometric test battery administered to young adults with high-functioning autism revealed a discrepancy between interpretive (i.e., inferencing) versus procedural (i.e., word association) abilities. Individuals with ASD were able to make word associations similar to their typical peers as a function of rule-based learning as opposed to experiential learning. The discrepancy between interpretive and procedural abilities is relevant because it indicates a rule-based versus experiential-based learning process.

While children with ASD have been shown to categorize information using rule-based strategies (Minshew, et al., 1995; Rawlings & Locarnini, 2008), they are unable to form prototypes based on average exemplars of a given category (e.g., *ANIMAL*; Klinger & Dawson, 1995). They do not demonstrate category grouping strategies (Hermelin & O'Connor, 1970; Minshew, Goldstein, Muenz, & Payton, 1992), suggesting that they do not undergo mental processes similar to individuals with typical language development (Klinger & Dawson, 1995). As a result, individuals with ASD may demonstrate deficits in their ability to infer meaning from experiences (Noach, 1974). The issue is not whether individuals with ASD *can* develop categories, but rather *how* they do so. In the absence of a rule, individuals with ASD are challenged in formulating categories similarly to their typical counterparts; they do not possess synthesized averages of representations of semantic referents of the world around them. Such deficits can lead to incorrect inferences and subsequent interpretations about the environment, ultimately affecting social skills and vocabulary development. How individuals with ASD perform on word association and verbal semantic fluency tasks may provide robust information regarding lexical organization.

**Word association and autism spectrum disorders.** In a study including a small sample of participants with autism (i.e., seven) and one control group matched for chronological age and language ability, Boucher (1988) investigated how adolescents with ASD performed on verbal fluency tasks when given a superordinate cue (e.g., *Tell me as many colors as you can think of*), versus when not given a cue (e.g., *Tell me as many words as you can think of*). Individuals with ASD performed similarly to the control group in their production of exemplars within a category. They were markedly different, however, in their ability to provide random words. Individuals with ASD provided numbers, months of the year, and phrases as opposed to their control counterparts matched for chronological age and nonverbal IQ, who provided responses including a variety of nouns. These results may be due to qualitative rather than quantitative differences in the experimental group.

Individuals with ASD struggle with fluency-related tasks that are uncued versus those that are cued. Turner (1999) conducted a series of fluency tasks divided into two category types: (1) verbal fluency (i.e., letter and category), and (2) ideational (i.e., explaining uses of objects and pattern meanings). Turner (1999) further divided participants into four different groups: High Functioning with Autism (HFA), High Functioning Controls (HFC), Globally Learning Disabled with Autism (LDA) (note that this term is the equivalent to Intellectual Disability in North America), and Learning Disabled Controls (LDC). Word fluency tasks cued by initial letter (i.e., *L*) and cued by category (i.e., *COUNTRIES*) were significantly impaired in children with ASD in comparison to controls matched by age or functioning levels, in that there were a smaller proportion of responses clustered into semantically related groupings (Turner, 1999). Regardless of functioning level, Turner (1999) concluded individuals with ASD demonstrated a failure to generate strategies to improve performance. This study expanded findings from Boucher (1988), in that individuals with ASD were found to have a reduced proportion of clusters regardless of number of cued responses. In addition, there were two groups of participants with ASD separated by functioning level (HFA and LDA). Functioning level was important because this population is highly heterogeneous. Subcategorizing individuals with ASD was a first step toward trying to homogenize this diverse clinical population.

Children with autism (aged 4;4 – 9;2) have been shown to produce the same number of categorical exemplars as their typical counterparts and counterparts with SLI (Dunn, Gomes, & Sebastian, 1996). They differed from both groups, however, in the quality of their responses. Their responses were significantly different from those of both groups (e.g., *OCELOT* (autism) versus *ELEPHANT* (typical) in response to the category cue *ANIMAL*). Such findings indicate either that the lexical organization or access in children with autism is different from that of typically developing peers and other clinical populations. These results supported previous findings (Turner, 1999; Boucher, 1988) of quantitatively similar, but qualitatively different, performances by individuals with ASD compared to typical peers.

In a free recall task, adolescents and young adults with ASD did not perform as well as the control group for recall of concrete nouns (Toichi & Kamio, 2003). The control adults produced more concrete nouns (e.g., clock, lion) than the ASD group. Participants with ASD produced a comparable number of abstract nouns (e.g., trust, special) as the concrete nouns. Lack of differentiated responses between concrete versus abstract nouns in the ASD group suggest that the associative values between these referents may not be stored as they are in typical adults. The organization of semantic memory in adolescents and young adults with ASD may therefore be qualitatively different (Toichi & Kamio, 2003).

Taken together, the aforementioned findings indicate fundamental differences in word association in children and young adults with ASD when compared to their typical counterparts. What remains unknown, however, is *how* the semantic organization of the lexicon differs from that of typically developing individuals. The word association task conducted in this study will describe differences between individuals with ASD and their chronological- and vocabulary-matched peers by categorizing productions as either: associated, perseveration, proper noun, phrase, or other responses. Further, the number of clusters and switches will be discussed.

**Semantic priming and autism spectrum disorders.** Picture-word (Kamio & Toichi, 2000) and fragmented-word (Toichi & Kamio, 2001) priming paradigms have been used to assess responses of young adults with ASD. These young adults primed fragmented words

(Toichi & Kamio, 2001) and demonstrated priming in both picture-word and word-word conditions (Kamio & Toichi, 2000). Both of these studies, however, used long durations of presentations of the prime (i.e., 2 seconds), followed by a 2-second interstimulus interval (ISI), and presentation of a target for 15 seconds. The extended duration of prime-target presentation call the automatic processing of semantic priming into question. In addition, the phonological influence of the reading process raises further concerns. Because there is a higher rate of hyperlexia in ASD than in the typical population (Newman, et al., 2007), any study involving written stimuli needs to control for this potentially confounding factor.

To date, only two reported studies have used priming tasks to examine lexical organization in individuals with autism (Henderson, Clarke, & Snowling, 2011; Gerenser & Schwartz, 2004). In the first study, Henderson and colleagues (2011) used a cross-modal semantic priming paradigm to investigate responses to homonyms in high-functioning children and adolescents with ASD (aged 7;4-15;6). Reaction time and error rates were compared to a control group matched for chronological age and receptive vocabulary. Participants heard a homonym (e.g., *BANK)* as an auditory prime followed by a target picture (e.g., *MONEY*) at short and long SOAs (i.e., 250 milliseconds and 1000 milliseconds, respectively). While children with ASD produced more errors than the control group, they did not reach significant levels for post-hoc analyses. At 250 SOA, the ASD group named target pictures similar to their controls, meaning that they primed pictures that were preceded by homonyms. At 1000 SOA, however, the ASD group did not demonstrate priming effects while the control group did. The authors concluded that when priming is more automatic (i.e., at short SOA), individuals with ASD can perform comparably to their age- and receptive-vocabulary-matched peers. When priming is more strategic or volitional (i.e., at long SOA), there appeared to be a breakdown in executive function.  Though results were significantly different in both groups, the long SOA (i.e., 1000 milliseconds) used in this study calls the automatic process of priming into question.

In the second study, a picture-naming task with picture primes was used to investigate whether children (aged 6;2 to12;3) with and without High Functioning Autism (HFA) exhibited effects of categorical, associate, identity, and rhyme primes (Gerenser & Schwartz, 2004). Identity priming was found for both groups of participants. Typically developing children demonstrated stronger associative priming (i.e., shorter reaction time) than children with HFA. These results suggested a difference in lexical processing and possibly organizational abilities between children with autism and their vocabulary-matched peers. Note that this study used associative primes that were obtained using adult association norms (Nelson, McEvoy, & Schreiber, 1998). Given that language acquisition in ASD has been reported to be idiosyncratic and atypical (Charman, et al., 2003; Hobson, 1993; Tager-Flusberg, et al., 2005; Wilkinson, 1998), these individuals are even less likely than typically developing peers to have associations that correspond to these adult-based norms.

The purpose of the present study was to investigate the nature of word association in high-functioning adolescents and young adults with autism spectrum disorders (aged 14;0 – 19;2), as well as to determine if these individuals exhibit semantic priming effects. This study combined a verbal word association task (Experiment 1) with a semantic priming task (Experiment 2).  Word association responses were based on a specific coordinate word (e.g., *HOUSE* or *SKIRT*) rather than providing an individual with a superordinate category (e.g., *ANIMAL* or *FOOD*) as seen in traditional verbal fluency tasks. These methodological refinements may enable a better understanding of the lexical organization in adolescents/young adults with ASD.  Furthermore, the use of the individual responses as primes in the follow up semantic priming task (Experiment 2) allowed for examination of atypical priming effects, which has not been detected using the traditional priming paradigms.

This study was composed of two experiments. In Experiment 1, participants were auditorily presented with a word and asked to provide as many semantically related word associations as possible in 60 seconds. Experiment 2 examined priming using auditory primes (associated, individualized semantic, identity, or unrelated) followed by a picture to be named. The individualized semantic primes were selected from the first response each child gave to the target words in Experiment 1.

**Research Questions and Hypotheses**

The first (and general) question is whether individuals with autism spectrum disorders exhibit different lexical organization than that of their typically developing peers. The individuals with ASD are postulated to differ from typically developing peers in lexical semantic organization, as demonstrated by their word associations (i.e., less typical and more unrelated responses) and in the effects of standard associated and individualized primes on their picture naming (i.e., no differences in reaction time in associated priming task). Second, do individuals with ASD provide different word associations than their typically developing peers? The individuals with ASD are postulated to exhibit differences in word association, as evidenced by the first associations they produce. Typically developing individuals are expected to produce responses that are highly associated. Individuals with ASD are expected to produce words that, according to the word association norms, are not highly associated. Finally, do individuals with ASD respond differently to self-generated versus typically associated primes, as compared to their typical counterparts? The ASD group (as well as the chronological- and vocabulary-matched groups) is postulated to demonstrate increased priming in the individual semantic condition in Experiment 2, because primes will be generated from their own word associations elicited in Experiment 1. Individuals with ASD, however, are not expected to demonstrate priming in the associated condition where words are selected from the word association norms.

# Chapter 2

## Method

This investigation consisted of two experiments. Experiment 1 examined word association. Experiment 2 examined semantic priming, including an individualized semantic priming condition. The individualized semantic primes used in Experiment 2 were obtained from initial responses in each trial from Experiment 1.

### Experiment 1: Word Association

**Participants.** Three groups participated in this study. All participants had minimum IQ scores within 1 SD of the mean (ASD group mean 110, standard deviation 4; chronological-age-matched group mean 115, standard deviation 6; vocabulary-matched-group mean 112, standard deviation 5). The first group consisted of 15 individuals with ASD with a mean age of 16;7 (14;0 – 19;2). Four of the 15 participants with ASD were diagnosed as having “autism spectrum” according to the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 2003). The remaining 11 were diagnosed as having “autism.” The second group consisted of 16 adolescents/young adults with typical language development with a mean age of 16;9 (15;0 – 19;7) matched for chronological age (CAM group). The third group consisted of 14 individuals matched by raw scores on vocabulary (VM group) on the Peabody Picture Vocabulary Test, 4$^{th}$ edition (PPVT-4) (Dunn & Dunn, 2007) to the ASD group. Note that language scores were not controlled for in the ASD group, yielding lower standard scores. If standard scores were used as a measure to match vocabulary, the VA group may have been linguistically delayed. Therefore, raw scores on the PPVT-4 were used as a matching measure.

Participants were recruited via fliers at public schools, word of mouth, and on parent websites. All individuals with ASD met the following criteria for inclusion: enrollment in a district-based inclusion program, 14 to 20 years of age, nonverbal abilities with a minimum standard score of 85 on the Test of Nonverbal Intelligence, 3rd edition (TONI-3) (Brown, Sherbenou, & Johnson, 1990) and had an English-dominant language-speaking background. Criteria for exclusion were: the inability to perform the word association task, an inability to label target nouns in practice, an inability to repeat words in practice, nonverbal IQ score below 1.5 standard deviations from the mean, or diagnosis of autism not verified by administration of the ADOS (Lord, Rutter, DiLavore, & Risi, 2003). One participant with ASD was excluded from this study due to an IQ score not meeting criteria for inclusion. Two participants with ASD were excluded due to refusal to participate after the initial evaluation. See Table 1 for summary of the main characteristics of participants.

Table 1. Summary of main characteristics of participants (e.g., Test of Nonverbal Intelligence, 3rd edition (TONI-3), Expressive Vocabulary Test, 2nd edition (EVT-2), Peabody Picture Vocabulary Test, 4th edition (PPVT-4) and the Autism Diagnostic Observation Schedule (ADOS). For autism spectrum disorder (ASD), chronological age matched (CAM), and vocabulary matched (VM) All values are standard scores, with the exception of the chronological age (CA), PPVT-4 Raw Score (RS), and Diagnosis on ADOS. Under ADOS, A = autism and AS = autism spectrum.

| | | | *Evaluation Measure* | | | | | |
|---|---|---|---|---|---|---|---|---|
| *ASD* | | | | | | | | |
| *Part* | *Sex* | *CA* | *TONI-3* | *EVT-2* | *PPVT-4* | *PPVT-4(RS)* | *CELF-4* | *ADOS* |
| 1 | M | 15;11 | 107 | 73 | 61 | 126 | 66 | A |
| 2 | F | 18;4 | 109 | 105 | 90 | 185 | 109 | AS |
| 3 | M | 17;4 | 109 | 111 | 96 | 188 | 104 | AS |
| 4 | F | 16;1 | 108 | 94 | 98 | 189 | 81 | A |
| 5 | M | 18;9 | 109 | 78 | 70 | 149 | 54 | A |
| 6 | M | 19;2 | 120 | 124 | 106 | 206 | 112 | A |
| 7 | M | 18;2 | 115 | 79 | 65 | 148 | 42 | A |
| 8 | M | 16;4 | 110 | 100 | 104 | 197 | 81 | AS |
| 9 | M | 16;10 | 110 | 124 | 109 | 203 | 115 | AS |
| 10 | F | 17;5 | 109 | 89 | 84 | 173 | 48 | A |
| 11 | F | 15;3 | 107 | 88 | 89 | 170 | 75 | A |
| 12 | M | 15;6 | 107 | 110 | 108 | 198 | 106 | A |
| 13 | M | 14;11 | 106 | 79 | 80 | 153 | 70 | A |
| 14 | M | 18;6 | 109 | 89 | 93 | 190 | 100 | A |

*Table 1 continued.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | M | 14;0 | 113 | 82 | 84 | 153 | 46 | A |
| *CAM* | | | | | | | | |
| 1 | M | 17;1 | 115 | 122 | 116 | 209 | 108 | |
| 2 | F | 16;7 | 115 | 110 | 124 | 213 | 120 | |
| 3 | F | 19;3 | 125 | 134 | 123 | 217 | 111 | |
| 4 | F | 17;9 | 115 | 140 | 119 | 212 | 118 | |
| 5 | M | 16;9 | 109 | 104 | 106 | 199 | 112 | |
| 6 | F | 15;1 | 115 | 106 | 97 | 182 | 111 | |
| 7 | F | 19;7 | 113 | 97 | 94 | 194 | 109 | |
| 8 | M | 17;8 | 115 | 145 | 126 | 216 | 118 | |
| 9 | M | 17;4 | 125 | 137 | 120 | 212 | 109 | |
| 10 | F | 16;8 | 115 | 136 | 121 | 211 | 121 | |
| 11 | M | 16;7 | 125 | 107 | 126 | 214 | 102 | |
| 12 | F | 14;9 | 108 | 100 | 100 | 186 | 100 | |
| 13 | M | 15;0 | 111 | 115 | 110 | 199 | 117 | |
| 14 | F | 18;7 | 115 | 108 | 106 | 204 | 117 | |
| 15 | F | 15;5 | 109 | 106 | 104 | 193 | 121 | |
| 16 | F | 15;0 | 107 | 112 | 114 | 201 | 121 | |
| *VM* | | | | | | | | |
| 1 | M | 10;7 | 108 | 120 | 124 | 184 | 102 | |
| 2 | F | 12;0 | 112 | 106 | 102 | 173 | 121 | |
| 3 | M | 9;1 | 108 | 102 | 92 | 131 | 98 | |
| 4 | F | 13;4 | 109 | 97 | 111 | 191 | 123 | |
| 5 | M | 9;11 | 118 | 94 | 111 | 164 | 93 | |
| 6 | F | 12;2 | 107 | 115 | 116 | 189 | 104 | |
| 7 | M | 8;1 | 108 | 113 | 113 | 145 | 106 | |
| 8 | F | 12;5 | 120 | 118 | 112 | 185 | 100 | |
| 9 | F | 8;4 | 108 | 110 | 114 | 146 | 104 | |
| 10 | F | 10;1 | 113 | 97 | 95 | 145 | 106 | |
| 11 | F | 13;1 | 109 | 94 | 96 | 167 | 99 | |
| 12 | F | 12;0 | 112 | 100 | 109 | 181 | 100 | |
| 13 | F | 13;4 | 125 | 122 | 128 | 206 | 121 | |
| 14 | F | 12;1 | 106 | 106 | 113 | 187 | 108 | |
| ***ASD*** | | | | | | | | |
| *M* | | 16;7 | 110 | 95 | 89 | 175 | 80 | |
| *SD* | | 1;7 | 4 | 17 | 15 | 24 | 26 | |
| ***CAM*** | | | | | | | | |
| *M* | | 16;9 | 115 | 117 | 113 | 204 | 113 | |
| *SD* | | 1;5 | 6 | 16 | 10 | 11 | 7 | |
| ***VM*** | | | | | | | | |
| *M* | | 11;1 | 112 | 108 | 110 | 176 | 108 | |
| *SD* | | 1;9 | 5 | 10 | 10 | 24 | 10 | |

Participants with ASD received their diagnoses from formal multidisciplinary evaluations, as reported by their parents. The diagnosis of autism was then confirmed with administration of the ADOS (Lord, Rutter, DiLavore, & Risi, 2003). All individuals were also given the Core Language portion of the Clinical Evaluation of Language Fundamentals, fourth edition (CELF-4) (Semel, Wiig, & Secord, 2003), The Peabody Picture Vocabulary Test, fourth edition (PPVT-4) (Dunn & Dunn, 2007), and the Expressive Vocabulary Test, second edition (EVT-2) (Williams, 2007). Finally, a hearing screening was administered to rule out potential hearing loss. All participants were able to articulate clearly and generally used complete sentences. They were able to follow directions as well as communicate the need for a break or termination of testing, if necessary. All participants with autism were considered to be high functioning although there are no specific criteria for this characterization.

All control participants attended regular education classes and received no special support services. No familial history of autism was present in either control group. Participants in the control group were recruited via word of mouth and neighborhood groups (e.g., local martial arts studio).

**Stimuli.** A set of 40 single syllable nouns (see Appendix A) with frequency ratings of 10 or higher (Kucera, & Francis, 1967) was taken from a list developed by Snodgrass and Vanderwart (1980). The words were recorded by an adult female speaker of Northeastern American English from Western New York at a sampling rate of 22,050 at 16 bits. Recorded stimuli were normalized to -20 dBVU and DC offset was set to zero using Sound Forge version 4.5 (1998). Four pseudorandomized lists were created (i.e., no word was preceded or followed by a word that was semantically or phonologically related to the target) and were balanced across participants (see Appendix B).

**Description of apparatus.** All stimuli were presented via PC desktop computer. Black-and-white line drawings of the auditory stimuli were presented on the computer monitor to ensure correct labeling. Auditory stimuli were presented at 70 dB SPL via TDH-50P Telephonic headphones (See Appendix C). The experiment was delivered using E-Prime 1.2 (2006), which controlled presentation of stimuli and collected response times (RT). Responses were recorded using an ATR20 audio-technica microphone attached to a voice key. The voice key began collecting data from the onset of the auditory stimulus and was triggered by the participant's response. Participant responses were recorded by a Marantz Professional CD recorder (CDR30/UIB) and microphone. A light detector was attached to the monitor and generated a pure tone in the right channel, while the participant's speech was recorded in the left channel (see Appendix D). The pure tone was generated for the duration of presentation of the GO sign, which was presented for the entire duration of the trial (i.e., 60 seconds). All responses were later measured and analyzed using Sound Forge version 4.5 (1998). This was used to recover responses that would have been lost due to nonspeech sounds produced prior to the participant's actual response.

**Procedure.** Each participant was tested individually in a quiet space over three sessions. The first session, which lasted for approximately one and a half hours, was dedicated to examining speech, language, hearing skills, and (for experimental participants) to confirm the diagnosis of autism. This session took place either in the participant's home or in an office. Two subsequent sessions were devoted to conducting Experiments 1 and 2 and took place in an office. The average number of days between experimental sessions was 12 ($SD = 6$). At the beginning of the first experimental session, to insure that participants were familiar with the target words, a *picture naming* and *word repetition* task were administered.

During the *picture naming* task, the experimenter presented the participant with line drawings corresponding to the auditory stimuli. The participant was asked to label each line drawing. Pictures were presented one at a time with no time constraints. When a participant labeled a picture incorrectly, the experimenter modeled the target and asked the participant to repeat it.

For the *word repetition* task, each participant was asked to repeat each of the auditorily presented words. Once familiarized with target labels, the practice session began. The practice block contained 15 words. Following the practice block, the word association task was administered.

Each participant was instructed to say as many related words as he/she could think of, as quickly as possible, within a 60-second time frame for each auditorily presented word (See Appendix E for visual display of trial and directions). A GO sign appeared on the computer screen for the duration of the 60 seconds, and a STOP sign appeared at the end. If 20 seconds elapsed with no response, the examiner reminded the participant to continue to actively search for referents, by using a phrase such as *keep thinking*. There was a 3000 millisecond pause between trials. For the duration of the experiment, the experimenter was seated behind the participant and provided positive reinforcement when necessary.

Reaction time for the first response was collected via E-Prime (Psychology Software Tools, Inc., 2006) and all responses were audio recorded. Responses were transcribed following the session. Audio recording allowed review and monitoring of false triggers (e.g., clicks, false starts) and review of each child's associations. Analyses were conducted for reaction time to the first word, number of words elicited in 60 seconds, comparison of word association responses to the free association norms database from the University of South Florida (Nelson, McEvoy, &

Schrieber, 1998), categorization of responses (i.e., *associated, perseveration, proper noun, phrase,* and *other*), and Clusters and Switches.

**Experiment 2: Individualized Semantic Priming**

**Participants.** The participants were the same as in Experiment 1.

**Stimuli.** The same 40 target words presented in Experiment 1 were presented as target pictures in a cross-modal priming paradigm. Primes in each condition were based on their relationship to the picture: Associated (AS), Individual Semantic (IS), Identity (ID), or Unrelated (UN). Associated primes were identified according to the University of South Florida (USF) Free Association Norms database (Nelson, et al., 1998). Individual Semantic primes were identified as the first response of each participant in the word association task in Experiment 1. Identity primes were a repetition of the target. Unrelated primes were neither listed on the USF database, not phonologically related, nor an associate provided by the participant in Experiment 1.

Stimuli were pseudorandomized in four blocks for a total of 160 target presentations. An additional 64 foils were included, resulting in a ratio of 40% of stimuli that were foils (Coane & Balota, 2010). Auditory primes were recorded by the same speaker who recorded the stimuli for Experiment 1. There were four prime-target conditions in this experiment: (1) Identity prime (e.g., *ball* paired with target picture BALL); (2) Individualized Semantic prime (e.g., <u>*word obtained in Experiment 1*</u> paired with target picture BALL; (3) Unrelated prime (e.g. *hat* paired with target picture BALL); (4) Associated prime (e.g., *game* paired with target picture BALL). See Appendix F for a list of prime – target pairs, and Appendix G for a visual depiction of trial and directions.

**Description of apparatus.** The same apparatus was used in Experiment 2 as in Experiment 1, with the following modifications. The voice key began collecting data from the onset of presentation of the auditory prime. The pure tone was generated for the duration of presentation of the stimulus picture on the screen in Experiment 2. As soon as the participant verbally produced a response, the picture disappeared and the light detector ceased production of the pure tone.

**Procedure.** The auditory prime was presented prior to the target picture to be named. There was a 50 milliseconds Interstimulus Interval (ISI) between the offset of the word to the onset of the picture (Hutchinson, Balota, Cortese, & Watson, 2008). This study used a short ISI (50 milliseconds) because it had been supported in a large-scale study as a reliable measure of semantic priming (Hutchinson, et al., 2008). Hutchinson and colleagues (2008) conducted a lexical decision and priming task that found priming effects for neutral, unrelated, and related prime-target pairs at 50 milliseconds. Because this study did not use multiple SOAs as Picture-Word Interference (PWI), a short ISI was chosen in an effort to minimize volitional processing as a potential methodological confound. Data collected were analyzed for accuracy of responses and reaction time (RT) in order to determine semantic effects.

# Chapter 3

# Results

## Analyses for Experiment 1

Six analyses were conducted with the data obtained in Experiment 1. First, mean reaction time (RT) for the first response for each target was analyzed, followed by analysis of mean number of responses. Since the first word association response would be used in Experiment 2, a systematic investigation of strength of association to the target was warranted. Therefore, analyses of responses in relation to association norms, total number of typical associates, and categorization of response types (i.e., Associated, Perseveration, Proper Noun, Phrase, and Other) were conducted. Finally, analysis of the number of Clusters and Switches produced by each participant was conducted. Note that an item analysis was conducted based on the results from Experiment 2. The item analysis revealed the need to remove three items because of technical errors (e.g., *BARN, BELT,* and *WHEEL).* To maintain continuity across both experiments, these same items were removed from analyses in Experiment 1. Therefore, all six analyses were conducted on 37 targets. See Appendix H and Experiment 2 for further details on item analysis.

**Mean reaction time (RT) for first response for each target.** A 3 x 1 one-way ANOVA was conducted, with Group (ASD, CAM, VM) as the dependent variable, and Mean of First Response as the independent variable. Mean RTs across the three groups were not significantly different $F(2, 42) = 2.2194$, $p = .12127$. Table 2 depicts group means and standard deviations. There was considerable variability and some very delayed responses were observed.

Table 2: Group Means (M) and Standard Deviations (SD) of Reaction Time (RT) of first word association response.

| | *Participant* | | |
|---|---|---|---|
| *RT* | *ASD* | *CAM* | *VM* |
| Group M | 3755 | 2930 | 3170 |
| Group SD | 4430 | 3996 | 2708 |

In all three groups, the standard deviations were extremely large. Therefore, a follow-up analysis of Group Means per target was conducted. A 3 x 37 repeated measures ANOVA was conducted, with Group (ASD, CAM, VM) as the between subject factor, Stimuli (37 targets) as the independent variable, and reaction times as the dependent variable. Mean RTs across the three groups were not significantly different $F(2, 43) = 1.3757$, $p = .26356$. Mean RTs across stimuli were significantly different $F(36, 1548) = 2.0848$, $p = .00019$. Post hoc Tukey HSD tests revealed that mean RT for the target *KEY* (5064 ms) was significantly greater than for *PEN* (2127 ms) ($p = .037511$). The mean RT for the target *STAR* (5467 ms) was significantly greater than for *BALL* (2412 ms) ($p = .02083$), *BED* (2313 ms) ($p = .012294$), *BOOK* (2405 ms) ($p = .020042$), and *PEN* (2127 ms) ($p = .004329$). See Appendix I for a complete listing of means and standard deviations of RT per target. With the exception of these interactions, all other differences in RT of targets were not significant, and there remained a great amount of variability in RT across targets and groups. Finally, a significant Stimuli x Group interaction was not observed $F(72, 1548) = .71901$, $p = 96314$, meaning that there were no differences in reaction to the targets across groups.

**Mean number of responses.** A 3 x 1 one-way ANOVA was conducted with Group (ASD, CAM, VM) as the dependent variable and Number of Responses as the independent variable. Results showed a significant main effect of Group $F(2,42) = 6.7494$, $p = .00287$. Post hoc Tukey HSD tests revealed that the mean number of responses for the VM group was significantly less than the mean number of responses for the CAM group ($p$ = .002152). However, the number of responses produced by individuals in the ASD group were not significantly different than those produced by the CAM group nor the VM group ($p$ = .379146). See Table 3.

Table 3. Means (M) and Standard Deviations (SD) of number of word association responses by Group.

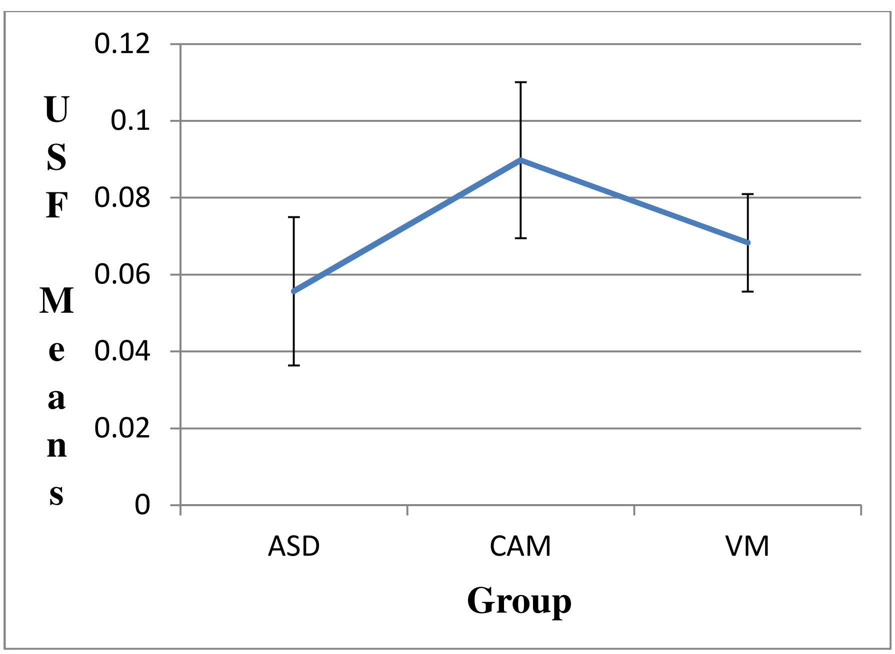
| | *Participant* | | |
|---|---|---|---|
| *Number of Responses* | *ASD* | *CAM* | *VM* |
| Group M | 252 | 290 | 133 |
| Group SD | 31 | 35 | 25 |

A more detailed analysis was subsequently conducted, evaluating the average number of words produced per target in each group of participants. See Appendix J for a complete listing of means and standard deviations of responses per target. A 3 x 37 repeated measures ANOVA was conducted with Group (ASD, CAM, VM) as the between subject factor, Target as the independent variable, and number of responses as the dependent variable. There was a significant main effect of group $F(2,43) = 7.2196$, $p = .00198$. Post hoc Tukey HSD analyses revealed that the VM group produced significantly fewer responses to targets than the ASD ($p$ = .027506) and CAM ($p$ = .001795) groups. A significant main effect of target was observed, $F(36, 1548) = 8.8612$, $p = .0000$. There was no significant Target x Group interaction $F(72, 1548) = 1.2883$, $p = .05533$, indicating that no singular target affected group outcomes.

**Analysis of responses in relation to association norms.** The analysis of responses in relation to association norms was an investigation of the first associative response for each target, per participant. If the first response corresponded to an associate listed on the University of South Florida (USF) Free Association Norms Database (Nelson, et al., 1998), the value assigned by the USF database for that particular associate was used in statistical analyses. If the first response did *not* correspond with an associate available on the USF database, a value of 0 was assigned to that particular associate.

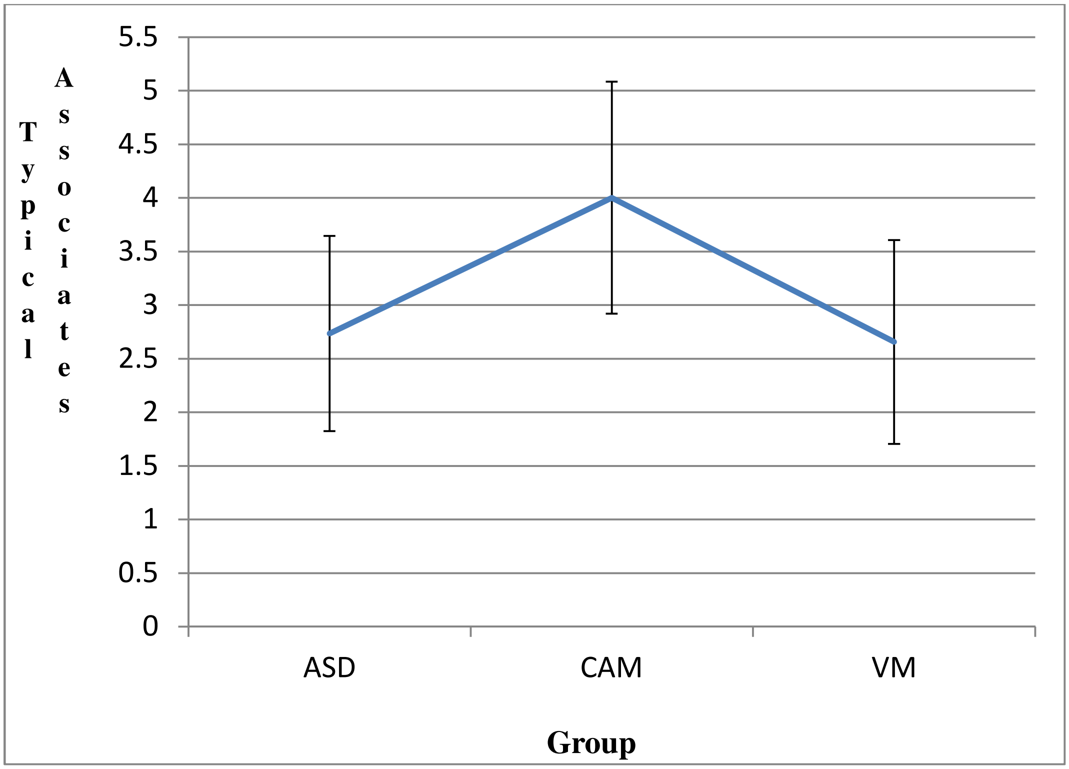
A 3 x 1 one-way ANOVA was conducted, with Group (ASD, CAM, VM) as the dependent variable and USF Mean as the independent variable. There was a significant effect of Group $F(2,1583) = 9.5711$, $p$ = 00007. Post hoc Tukey HSD tests revealed that the ASD group differed significantly from the CAM group ($p$ = .000062), but not the VM group ($p$ = .243517). The ASD group exhibited more related words that were not judged to be associates of the targets by the USF database compared to the CAM group. The VM group differed significantly from the CAM group but not from the ASD group ($p$ = .019344). See Figure 1.

Figure 1. Mean of University of South Florida (USF) Free Association Norms database (Nelson, et al., 1998) value of first response by Group with Standard Errors.



**Total number of typical associates.** The Total Number of Typical Associates across Groups was an analysis *only* of words produced by participants that correspond to the USF database (Nelson, et al., 1998) across trials. Responses that repeated the target or a previous response were not included in analyses. A 3 x 1 one-way ANOVA was conducted, with Group (ASD, CAM, VM) as the dependent variable and Number of Associates per target word (based on associates corresponding to the USF Free Association Norms database; Nelson, et al., 1998) as the independent variable. There was a significant effect of Group $F(2,1662) = 100.70$, $p = .0000$. Post hoc Tukey HSD tests revealed that the ASD group differed significantly from the CAM group ($p = .000022$), but not the VM group ($p = .753356$). The ASD group exhibited significantly fewer responses, which corresponded to the USF database, than the CAM group. The ASD group did not differ, however, from the VM group. Such findings indicate that the ASD group produced fewer associates than the CAM group but not the VM group during this task (see Figure 2).

Figure 2. Mean of Number of Typical Associates per word across Group with Standard Errors.




**Categorization of responses.** Each association response was transcribed. Responses were then placed into one of the following five categories: Association, Perseveration, Proper Noun, Phrase, Other (see Table 4). See Appendix K for a sample of participant responses across groups.

Table 4. Description and example of Associated and Unrelated categories for responses.

*Target MOON*

| *Category* | *Definition* | *Example* |
|---|---|---|
| Associated (A) | Related to target by category, feature, form, or function | Star, Bumpy, Rock, Tide, Light, Apple, Ball, Planets |
| Unrelated (U) | Either a Perseveration, Proper Noun, Phrase, or Other response, as follows: | |
| | *Perseveration*<br>Repetition of target, *or* repetition of previous response (+/- prefix or Suffix) | Moon, Moons |
| | *Proper Noun*<br>Noun that denotes a particular person, place, or thing | Miss Piggy |
| | *Phrase*<br>An expression or string of words | Twinkle, twinkle little star |
| | *Other*<br>No apparent relation to target, or response is unintelligible | Five, XXX |

Note: Perseveration, Proper Noun, Phrase, and Other responses are delineated under Unrelated.

A 3 x 5 repeated measures ANOVA was conducted, with Group (ASD, CAM, VM) as the between subject factor, Category (Perseveration, Association, Proper Noun, Phrase, Other) as the independent variable, and Number of Errors as the dependent variable. A significant main effect of Group $F(2, 42) = 6.5414$, $p = .00336$, and Category $F(4, 168) = 157.61$, $p = .0000$ was observed. A significant Group x Category interaction was also observed $F(8, 168) = 9.2948$, $p = .0000$. All significant interactions were followed up with post hoc Tukey HSD analyses.

Post hoc Tukey HSD analyses of Group revealed that, for the ASD group, there was no significant difference between the mean of total responses compared to the CAM group ($p =$

.654820). Significant differences were observed in the total number of responses between the ASD and VM group (*p* = .033729), as well as the CAM and VM groups (*p* = .003186). The CAM group had the greatest mean, the VM group had the smallest mean, and the ASD group fell between these two control groups.

Post hoc Tukey HSD analyses of Category revealed that there were significantly more responses categorized as Associations (A) than all other categories of responses (*p* = .000017). In addition, there were significantly fewer Proper Nouns (PN) than Other (O) responses (*p* = .027504), and significantly fewer Phrases (PH) than Other (O) responses (*p* = .030444). These results indicated that, across groups, responses categorized as Associations were the majority.

Post hoc Tukey HSD analyses further revealed several Group x Category interactions. There was an interaction of Association responses in the ASD and CAM groups (*p* = .000026), in that there were significantly more Association responses in the CAM group than in the ASD group. There was no significant interaction between Associations produced in the ASD group versus the Associations produced in the VM group (*p* = .999893). The mean number of perseverations was significantly higher in the ASD group than in both control groups (*p* = .000026). The mean number of phrases produced was not significantly different across all three groups (*p* = 1.0000). Finally, the number of responses categorized as Other was significantly different across all three groups (*p* = .000026); the ASD group had the highest number of perseverations, followed by the CAM group then the VM group. See Table 5.

Table 5. Means (M) and Standard Deviations (SD) for each category: Association (A), Perseveration (P), Proper Noun (PN), Phrase (PH), and Other (O) responses by Group.

| | *A* | *P* | *PN* | *PH* | *O* | |
|---|---|---|---|---|---|---|
| *Group* | *M (SD)* | *M (SD)* | *M (SD)* | *M (SD)* | *M (SD)* | *TOTAL* |
| ASD | 356 (119) | 65 (103) | 17 (28) | 17 (21) | 133 (199) | 588 |
| CAM | 597 (220) | 11 (14) | 4 (8) | 2 (5) | 48 (92) | 662 |
| VM | 323 (127) | 7(10) | 4 (5) | 8 (14) | 19 (27) | 361 |

Since there were significantly more Association than all other responses, the data were subsequently collapsed into either Associated (A) or Unrelated (U) categories. The means and standard deviations for each of these two response categories was also calculated. See Table 6.

Table 6. Means (M) and Standard Deviations (SD) of number of responses per Group for collapsed categories: (A) = Association, (U) = Unrelated.

| | *A* | *U* | *Total* |
|---|---|---|---|
| *Group* | *M (SD)* | *M (SD)* | |
| ASD | 356 (119) | 232 (255) | 588 |
| CAM | 597 (220) | 65 (104) | 662 |
| VM | 323 (127) | 38 (49) | 361 |

A 3 x 2 repeated measures ANOVA was conducted, with Group (ASD, CAM, VM) as the between subject factor, Category (Associated, Unrelated) as the independent variable and number of responses as the dependent variable. There was a significant main effect of Group $F(2,42) = 6.5414$, $p = .00336$. Post hoc Tukey HSD tests revealed that the ASD group was not significantly different than the CAM group ($p = .654820$). However, the ASD group produced significantly fewer mean number of total responses than the VM group ($p = .033729$). The CAM and VM groups were significantly different from one another ($p$ = .003186), in that the CAM group produced more responses than the VM group. This finding was consistent with analyses for responses prior to collapsing these data.

There was a significant main effect of Category $F(1,42) = 85.763$, $p = .0000$. Post hoc Tukey HSD tests revealed that there were significantly more Associated responses produced than Unrelated responses ($p = .00019$). Finally, a significant Group x Category Interaction $F(2,42) = 12.735$, $p = .00005$ was observed. Post hoc Tukey HSD tests revealed that there was no significant difference between the mean number of associated versus unrelated responses in the ASD group ($p = .301024$). There were significant differences between Associated versus Unrelated responses in the CAM group ($p = .000141$) and the VM group ($p = .000502$). Both groups produced a significantly greater number of responses categorized as Associated than those categorized as Unrelated. While the individuals with ASD produced a comparable amount of total responses as both control groups, their responses were not differentiated with respect to degree of association to the target.

A final examination of the proportions of Associated versus Unrelated responses was conducted across groups. A 3 x 2 repeated measures ANOVA was conducted with Group (ASD, CAM, VM) as the between subject factor, Proportion (Associated, Unrelated) as the independent variable, and percentage as the dependent variable. No significant main effect of Group $F(2,42) = .0000$, $p = 1.000$ was observed, meaning that all groups produced a similar total proportion of responses. A significant effect of Category $F(1,42) = 209.14$, $p = .0000$ was observed, meaning that there was a significantly higher proportion of responses categorized as Associated than Unrelated. Finally, a significant Group x Proportion interaction was observed $F(2,42) = 12.236$, $p = .00006$. Post hoc Tukey HSD testing revealed that the ASD group produced a significantly greater proportion of responses categorized as Unrelated than the CAM and VM groups ($p$ = .000141). See Table 7.

Table 7. Proportion of responses per Group for category: (A) = Association, (U) = Unrelated). Scores indicated in percentages.

| *Group* | *A* | *U* |
|---|---|---|
| ASD | 61 | 39 |
| CAM | 90 | 10 |
| VM | 89 | 11 |

Note: proportions were calculated by dividing the total number of responses by the total number of either Associated or Unrelated responses. See Table 6.

**Inter-rater reliability.** A speech language pathologist functioned as an independent rater and categorized word association responses. This rater was blind to the objective of the study and scored 20% of the (randomly selected) data. Inter-rater reliability was calculated using the Cronbach Alpha correlation coefficients. There was a large positive correlation between the independent rater and principal investigator ($p < .001$, n = 384, $r = .891$).

**Clusters and switches.** Semantic Clusters were defined as groups of two or more words which are categorically associated (e.g., target *BALL* …. soccer, baseball, basketball, football, golf) (Troyer, 2000, Troyer et al., 1997, Koren et al., 2005). If a superordinate appeared within a cluster, it was included within that specific cluster (e.g., "animal, dog, cat, bird" was considered one cluster). Switches were defined as shifts from one word or cluster to a different word or cluster (Troyer, 2000, Troyer et al., 1997, Koren et al., 2005). Repetitions were included in the analysis of both Clusters and Switches. See Appendix L for an example of Clusters and Switches across groups.

A 3 x 2 repeated measures ANOVA was conducted with Group (ASD, CAM, VM) as the between subject factor, Responses (Clusters and Switches) as the independent variable and number of responses as the dependent variable. A significant main effect of Group $F(2, 1699) = 192.084$, $p = .000$, Response $F(1, 1699) = 3385$, $p = .0000$, and Group x Response interaction were observed $F(2, 1699) = 99.006$, $p = .000$. All significant interactions were followed up with post hoc Tukey HSD analyses.

Post hoc Tukey HSD analyses of Group revealed that the ASD group produced significantly more responses as both Clusters ($p = .001$) and Switches ($p = .000$) than the VM group and significantly fewer responses than the CAM group ($p = .000$, $p = .000$ respectively). Post hoc Tukey HSD analyses of Response revealed that there were significantly fewer Clusters than Switches (p = .000) across groups. Post hoc Tukey *HSD* analyses further revealed several Group x Category interactions. There was an interaction of responses characterized as either Clusters or Switches across all three groups. Clusters in ASD group differed significantly than those in the VM ($p = .000$) and CAM groups ($p = .001$), meaning that there were significantly fewer clusters produced in the ASD group than the CAM group, and significantly more Clusters produced by the ASD group than the VM group. Post hoc Tukey HSD analyses for Switches followed the same pattern. Switches in the ASD group were significantly different than those in the VM ($p$ =.000) and CAM group ($p$ =.000). Further, there were significant differences between the number of Clusters and Switches produced in both control groups. The CAM group produced significantly more clusters ($p = .001$) and switches ($p = .000$) than the VM group. See Table 8.

Table 8. Means (M) and Standard Deviations (SD) for Clusters (C) and Switches (S) across Group.

| | *Participant* | | |
|---|---|---|---|
| *Clusters(C)* | | | |
| | *ASD* | *CAM* | *VM* |
| Group M | 2.57 | 3.39 | 1.76 |
| Group SD | 1.62 | 1.97 | 1.38 |
| *Switches(S)* | | | |
| | *ASD* | *CAM* | *VM* |
| Group M | 8.29 | 10.78 | 5.74 |
| Group SD | 5.05 | 5.1 | 3.31 |

**Experiment 1 summary of results.** ASD, CAM, and VM groups were not significantly different in their reaction time to the first word association response ($p$ = .12127). There was a large amount of variability and delay in response time across groups, with the ASD group demonstrating the largest mean delay (3755 ms) compared to the CAM group (2930 ms) and the VM group (3170 ms). The ASD group did not differ significantly from the CAM or VM group in the mean number of total responses produced per target ($p$ = .379146).

The first response produced per target was compared to association ratings normed on the USF database (Nelson, et al., 1998). The ASD group produced associative responses which were significantly different from those produced by the CAM group ($p$ = .000062). The ASD group did not, however, differ from the VM group ($p$ = .243517). This analysis was followed up by an investigation of the total number of typical associates found on the USF database. The ASD group exhibited significant differences in the number of associations, normed on this database from the CAM group ($p$ = .000022). As with the analysis of responses in relation to association norms, the ASD group did not demonstrate significant differences from the VM group ($p$ =.753356).

Word association responses were then categorized into one of the following: Association, Perseveration, Proper Noun, Phrase, or Other. Individuals with ASD produced significantly less associated responses than the CAM (*p* = .000026) group but not the VM (*p* = .999893) group. The ASD group also produced significantly more responses categorized as either Perseverations (*p* = .000026) and Other (*p* = .000026). Responses were then collapsed into two superordinate categories labeled as either Associated or Unrelated. Repeated measures ANOVA yielded a Group x Category interaction. The ASD group demonstrated no significant difference between responses categorized as either Associated or Unrelated (*p* = .301024). In terms of proportions of responses, the ASD group produced a significantly higher proportion of responses categorized as unrelated (39%) than the CAM (10%) and VM (11%) groups (*p* = .000141).

A final analysis was conducted on Clusters and Switches of word association responses. Individuals with ASD produced significantly fewer Clusters (*p* = .001) and Switches (*p* = .000) than the CAM group, and significantly more Clusters (*p* = .000) and Switches (*p* = .000) than the VM group. The fact that the individuals with ASD produced more Clusters and Switches than the VM group indicates that they may be more skilled than their vocabulary-matched controls in categorization of words. However, production of fewer Clusters and Switches than their chronologically age-matched controls indicates that there is a fundamental difference in organization of the lexicon. The higher proportion of Unrelated versus Associated responses in the ASD group also supports this claim.

**Analyses for Experiment 2**

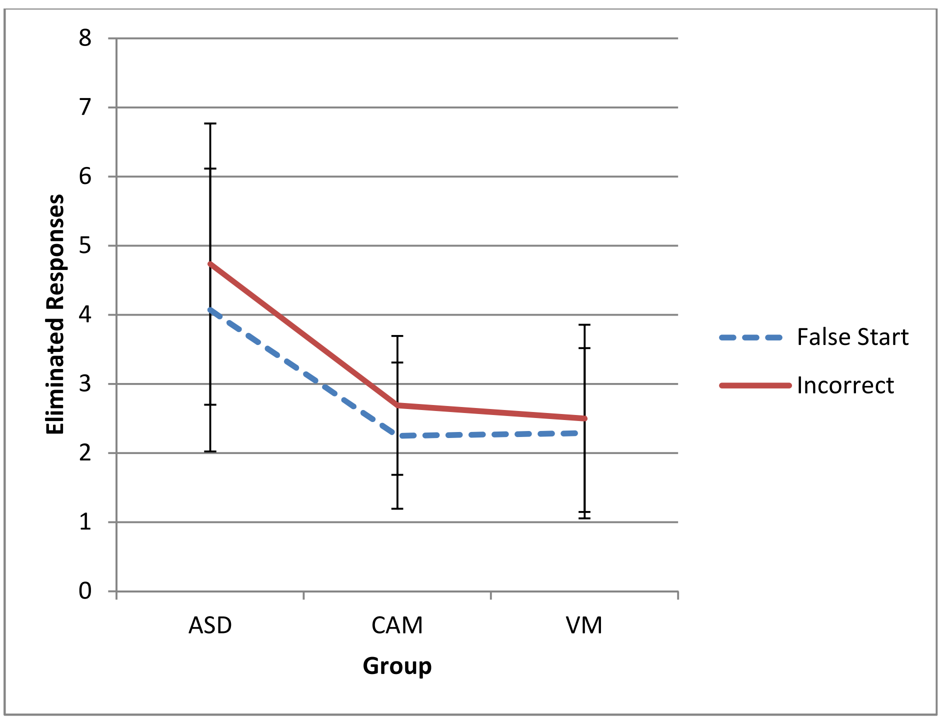
**Item analysis.** An item analysis was conducted based on the log speed of reaction time in Experiment 2, using a partial multilevel model analysis to ensure that prime-target pairs in the associated versus unrelated conditions demonstrated priming effects in both control groups. The purpose of this analysis was to determine if any outliers diminished this priming effect. Two sub-sets of word groups were examined to explore potential interference of targets; stimuli that were either homonyms (e.g., *BEAR, PEN, EYE, RING, BALL, STAR*) and stimuli that were categorical prime-target pairs (e.g., *ARM, CHAIR, CUP, DOG, HAND, NOSE, SHIRT, SKIRT*). In all three groups, with the exception of *BELT, BARN,* and *WHEEL*, none of these tests yielded a difference in response to targets in the associated versus unrelated conditions, meaning that priming was observed in the associated condition, when investigated as a partial multilevel model (see Appendix M). As a result, the targets *BARN, BELT,* and *WHEEL* were removed from analyses. For purposes of continuity across both experiments, these same three targets were eliminated from analyses in Experiment 1, as previously mentioned. The outcome of this item analysis resulted in 37 stimuli included in analyses (see Appendix H).

Upon completion of the item analysis, subsequent analyses included accuracy, reaction time, and participant characteristics (i.e., chronological age, standard scores). Accuracy of responses was calculated for each participant in this experiment using repeated measures ANOVA. Reaction time and participant characteristic data were analyzed using Mixed Effects Models.

**Accuracy**. Responses were categorized according to the following criteria. *Correct* – the target was correctly labeled. *Remeasured* – the target was correctly labeled, but reaction time data was not recorded (e.g., low volume of participant). *Incorrect* – the target was incorrectly labeled (e.g., target was *HAND*, and participant labeled *foot*). *False Start* – target was partially labeled, and then participant switched response mid-word (e.g., *b – hand*). *Technical Error* – there was an inadvertent skipping of a trial, with no response obtained, which was unable to be remeasured. Analyses were separated into correct (i.e., initially correct or remeasured) versus incorrect responses. Correct and Remeasured responses were included in statistical analyses for investigation of reaction time. False Starts, Technical Errors, and Incorrect Responses were eliminated from analyses, accounting for elimination of 9% of all responses.

A 3 x 2 repeated measures ANOVA was conducted, with Group (ASD, CAM, VM) as the between subject factor, Response Type (*Incorrect, False Start*). There was a significant main effect of Group $F(2,42) = 4.2658$, $p = .02058$. Post hoc Tukey HSD analyses revealed that the ASD group had a significantly higher total number of eliminated responses than the CAM ($p$ = .024056) and VM groups ($p$ = .030117). See Figure 3. No significant difference was revealed in analysis of Response $F(1, 42) = .66996$, $p = .41769$. In addition, no significant Response x Group interaction was observed $F(2,42) = .08129$, $p = .92207$.

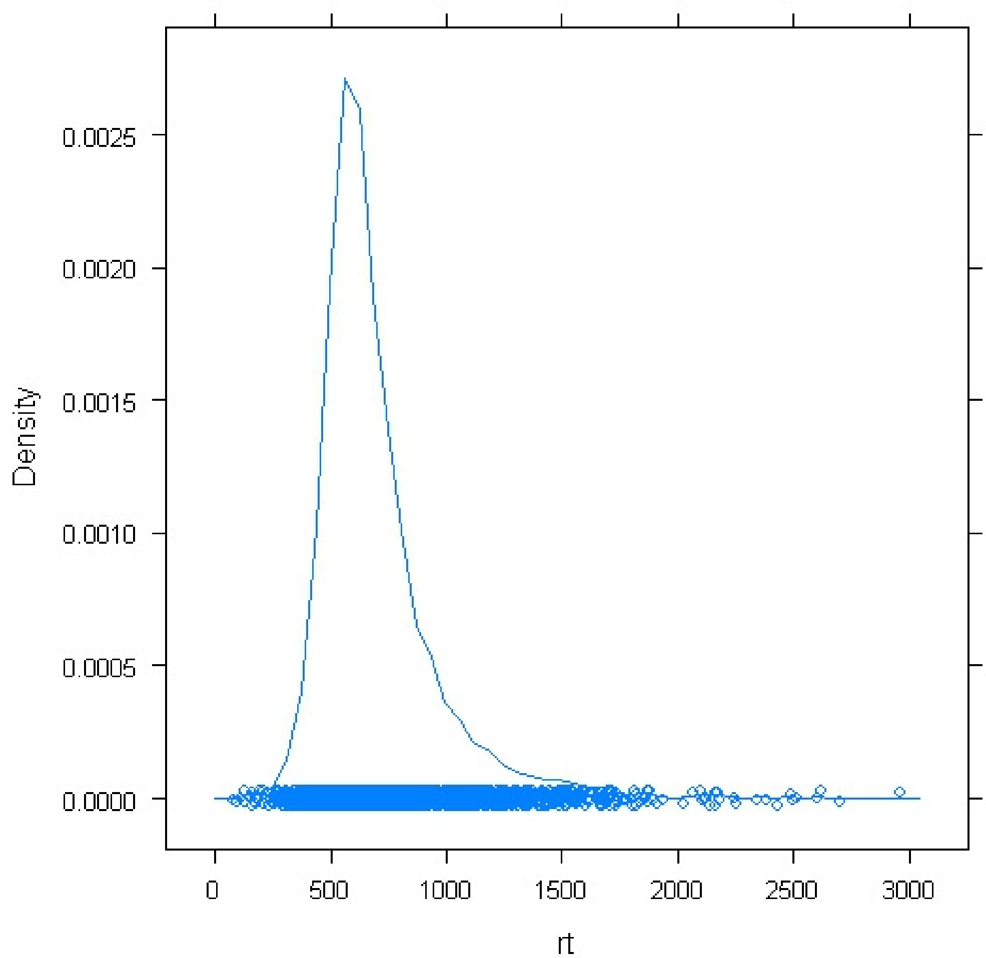
Figure 3: Mean of eliminated responses across Group with Standard Errors.



***Error analysis on incorrect responses.*** A 3 x 4 repeated measures ANOVA was conducted with Group (ASD, CAM, VM) as the between subject factor, Condition (Identity, Associated, Unrelated, Individual Semantic) as the independent variable, and number of incorrect responses as the dependent variable. No significant main effect of Group $F(2,42) = 3.04332$, $p = .05832$ was observed. A significant main effect of Condition was observed $F(3,126) = 7.3082$, $p = .00015$. Post hoc Tukey HSD analyses revealed that there were significantly more incorrect responses in the Identity condition than in the Associated condition ($p = .0003728$), Unrelated condition ($p = .008130$), and Individual Semantic condition ($p = .000063$). No significant Group x Condition interaction was observed $F(6,126) = 1.4505$, $p = .20069$. Since there was no significant difference in errors across groups, qualitative analyses of errors (i.e., semantic errors, phonological errors, perseverations) were not conducted.

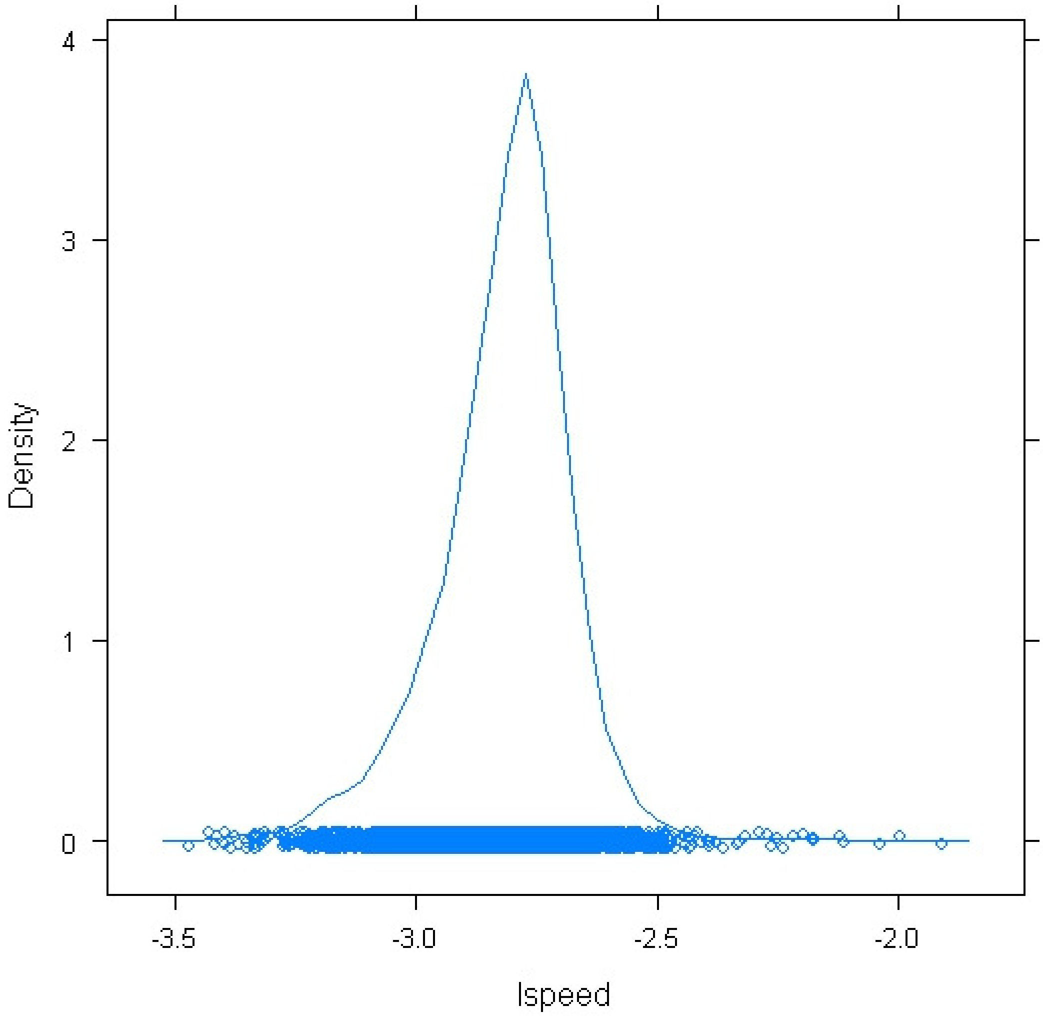
**Mixed effects analyses of reaction time (RT)**. Correct responses were analyzed using a mixed effects model with subjects, items (words), and trials as random factors. The primary dependent measure was Reaction Time (RT). A comparison of trimmed data (i.e., 2.5 Standard Deviations) and transformed data (log of speed) indicated that the log transformed data (without trimming data) were more normally distributed and more sensitive to detecting differences between groups and conditions than RT on the original scale (milliseconds), which was highly skewed across trials and subjects (see Figure 4). Therefore, all trials for 37 targets were included in subsequent analyses.

Figure 4. Distribution for response time for the final subset of participants and words, skewed (skew=2.29) with Mean 692.24 (SD=255.42).




The RT data were subsequently transformed using the logarithm of the inverse of RT (log speed), which greatly improved normality (Figure 5).

Figure 5. Transformed RT variable (log of speed) with more normal distribution (skew=-0.43).




Following Baayen, Davidson, and Bates (2008), the basic structure of the model can be summarized as follows:

Equation (1)

$\mathbf{y}_{ijk} = \mathbf{X}_{ijk}\mathbf{B} + \mathbf{S}_i\mathbf{s}_i + \mathbf{W}_j\mathbf{wj} + \mathbf{T}_k\mathbf{t}_k + \varepsilon_{ij}$

where $y_{ij}$ represents the function of response time of subject i to word j on trial k. XB represents the design matrix and coefficients for the fixed effects factors and covariates. This includes contrasts for type of subjects (ASD/CAM/VM), type of prime (IS/AS/ID/UN), and their interaction. The $S_is_j$, $W_jw_j$, and $T_kt_k$ terms represent the adjustments to the intercept for individual subjects, words, and trials.

Using the lmer function in R (Bates, 2005), the model represented in equation (1) was fit to the data with:

```
hyp1 <- lmer(lspeed ~ subtypf + primef + subtypf:primef + (1|subjf) + (1|trialf) + (1|twordf))
```

where lspeed is the log of speed; subtypf is a three-level categorical variable representing the type of subjects (ASD/CAM/VM) with the first group, ASD as the reference group; primef is a four-level categorical variable representing type of prime (IS/AS/ID/UN). UN is the reference condition to test the hypothesis that the comparison groups (CAM & VM) would differ from the ASD group in their response times to the IS compared to the AS primes. Table 9 depicts Means and Standard Deviations of Reaction Time for Associated (AS), Identity (ID), Individual Semantic (IS), and Unrelated (UN) conditions after having been converted back from log speed. Note that summarizing repeated measures data descriptively may not be sensitive enough to significance, which is why multilevel analyses were subsequently conducted. See Table 10.

Table 9. Means (M) and Standard Deviations (SD) of Reaction Time for Identity (ID), Associated (AS), Individual Semantic (IS), and Unrelated (UN) conditions.

| | *Conditions* | | | |
|---|---|---|---|---|
| | *AS* | *ID* | *IS* | *UN* |
| *Group* | *M (SD)* | *M (SD)* | *M (SD)* | *M (SD)* |
| ASD | 689 (136) | 547 (104) | 689 (120) | 715 (154) |
| CAM | 647 (70) | 543 (80) | 637 (56) | 676 (71) |
| VM | 816 (184) | 706 (163) | 836 (200) | 861 (220) |
| TOTAL | 714 (151) | 595 (138) | 717 (157) | 746 (173) |

Table 10 displays results from the model testing differences between the three groups of participants by condition. The reference group is ASD and the reference prime is UN. Random effects were also included in this model for subject, word, and residual, all of which were minimal.

Table 10: Model results testing differences between ASD, CAM, and VM groups by Condition (IS, AS, ID, UN), using reaction time data. Reference group is ASD and IS condition. *p<.05, ** p<.01. Note that p-values were obtained using the pvals function in the languageR package, and are based on a sample of 10,000 simulations from the fitted model (Baayen & Bates, 2005). Estimates (Est), Standard Errors (SE) and significance levels (P-Val) are itemized.

| | *Est* | *SE* | *P-Val* |
|---|---|---|---|
| Constant | -2.833 | .019 | .000 |
| Group | | | |
| CAM | .014 | .026 | .604 |
| VM | -.077 | .027 | .004* |
| Condition | | | |
| IS | .012 | .006 | .057 |
| AS | .015 | .006 | .022* |
| ID | -.118 | .006 | .000** |
| Group x Condition | | | |
| CAM x IS | .012 | .008 | .188 |
| VM x IS | .002 | .009 | .856 |
| CAM x AS | .006 | .009 | .491 |
| VM x AS | .006 | .009 | .541 |
| CAM x ID | -.019 | .009 | .023* |
| VM x ID | -.034 | .009 | .001* |

*Table 10 continued.*

Random Effects

| *Groups* | *Name* | *Variance* | *SD* |
| --- | --- | --- | --- |
| Subjf | (intercept) | .005 | .07 |
| Twordf | (intercept) | .001 | .028 |
| Residual | (intercept) | .01 | .103 |

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

The analysis of ASD, CAM, and VM groups revealed a main effect of group (b = -.077, SE = .027, $p$ = .004). The VM group demonstrated slower priming in all conditions, relative to the ASD and CAM groups. The analysis of three priming conditions revealed a main effect for the Identity condition (b = -.118, SE = .006, $p$ = .000), as well as for the Associated condition (b = .015, SE = .006, $p$ = .022). While priming in the Individual Semantic condition did not reach significance ($p$ = .057), a trend was observed in this condition, in that it was faster than unrelated, similar to the Associated condition. All three groups demonstrated faster RT for picture labels preceded by the same auditory word as a prime, as well as when targets were preceded by a word which was associated. The analysis of Group x Condition interaction indicated that both the CAM and VM groups performed similarly to the ASD group in the comparison of the ID to the UN condition ($p$ = .023) as well as in the comparison of the AS to the UN condition ($p$ = .001). There were no differences, however, in the comparison of the Unrelated condition to the Individual Semantic condition ($p$ = .057). Thus, the hypothesis that the ASD group would demonstrate priming in the Individual Semantic condition and that the controls would not, was not supported.

**Mixed effects analyses of participant characteristics.** A final set of analyses examined the relations of chronological age and standardized scores (i.e., CELF-4, TONI-3, EVT-2, PPVT-4) to performance on the experimental task (i.e., reaction time). All of the standardized scores were highly correlated. See Table 11.

Table 11. Correlations of participant characteristics (e.g., *Test of Nonverbal Intelligence*, 3rd edition (TONI-3), *Expressive Vocabulary Test,* 2nd edition (EVT-2), and the *Peabody Picture Vocabulary Test*, 4th edition (PPVT-4). Scores shown as standard scores (SS)

| | *Age* | *TONI-3(SS)* | *CELF-4(SS)* | *EVT-2 (SS)* | *PPVT-4(SS)* |
|---|---|---|---|---|---|
| Age | 1 | 0.25 | -0.06 | 0.01 | -0.17 |
| TONI-3(SS) | 0.25 | 1 | 0.24 | 0.3 | 0.33 |
| CELF-4 (SS) | -0.06 | 0.24 | 1 | 0.6 | 0.79 |
| EVT-2 (SS) | 0.01 | .3 | .6 | 1 | .75 |
| PPVT-4(SS) | -0.17 | 0.33 | 0.79 | 0.75 | 1 |

A multilevel analysis was conducted including all of these scores (i.e., CELF-4, EVT-2, PPVT-4, TONI-3). Initially, none of the measures of linguistically ability appeared significantly related. However, based on the amount of shared variance by these four measures, the TONI-3, EVT-2, and the PPVT-4 were eliminated to obtain a model that was the best fit to the current data, including only those measures significant after backward elimination. Note that the other measures *were* correlated (i.e., it is not the case that they did not contribute information about the scores, but rather that they were highly correlated with the CELF-4). The TONI-3, EVT-2, and PPVT-4 provided the same information as the CELF-4 score. Most importantly, none of the analyses of participant characteristics changed the overall findings.

To further investigate this correlation, a multilevel analysis of the full model with subject characteristics was conducted to examine the relations of age and standardized test scores to performance on the experimental task. See Table 12.

Table 12. Analysis of full model of subject characteristics. Estimates (Est), Standard Errors (SE) and significance levels (P-Val) are itemized.

| | *Est* | *SE* | *P Val* |
|---|---|---|---|
| Constant | -2.8 | .02 | .000 |
| Group | | | |
| CAM | .048 | .03 | .0118 |
| VM | .09 | .047 | .059 |
| Condition | | | |
| IS | .012 | .006 | .057 |
| AS | .015 | .006 | .022* |
| ID | .118 | .006 | .000** |
| Participant Characteristics | | | |
| Age | .026 | .006 | .000** |
| TONI-3 | .001 | .69 | .491 |
| EVT-2 | -.001 | .001 | .324 |
| PPVT-4 | .001 | .69 | .4924 |
| CELF-4 | -0.001 | .001 | .122 |
| Group x Condition | | | |
| CAM x IS | .012 | .009 | .187 |
| VM x IS | .002 | .009 | .853 |
| CAM x AS | .006 | .009 | .487 |
| VM x AS | .006 | .009 | .538 |
| CAM x ID | -.019 | .008 | .023* |
| VA x ID | -.034 | .009 | .001** |

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

As Chronological Age score increased, so did the log speed, indicating a faster reaction time. As the CELF-4 scores increased, the log speed decreased, indicating an increase in reaction time. Controlling for these factors (i.e., removing these variables and re-running the model), however, did not alter the findings (i.e., priming effects associated with the identity and associated priming, but no priming effects with individual semantic priming). See Table 13.

Table 13. Re-analysis of significant subject characteristics. Estimates (Est), Standard Errors (SE) and significance levels (P-Val) are itemized.

| | *Est* | *SE* | *P Val* |
|---|---|---|---|
| Constant | -2.907 | .022 | .000 |
| Group | | | |
| CAM | .059 | .027 | .032* |
| VM | .109 | .042 | .01* |
| Condition | | | |
| IS | .012 | .006 | .057 |
| AS | .015 | .006 | .022* |
| ID | .118 | .006 | .000** |
| Participant Characteristics | | | |
| Age | .027 | .005 | .000** |
| CELF-4 | -0.001 | .001 | .011* |
| Group x Condition | | | |
| CAM x IS | .012 | .009 | .187 |
| VM x IS | .002 | .009 | .853 |
| CAM x AS | .006 | .009 | .487 |
| VM x AS | .006 | .009 | .548 |
| CAM x ID | -.02 | .009 | .023* |
| VA x ID | -.034 | .009 | .001** |

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

**Experiment 2 summary of results.** Accuracy of participant responses was investigated using repeated measures ANOVA. While the ASD group demonstrated a trend toward more responses that were either Incorrect or False Starts, there was no significant response by group interaction. Further, only 9% of the data were removed across all participants and conditions, indicating that responses were highly accurate.

Reaction Time was analyzed using mixed effects analyses. When taken as a complete model, with RT being converted back from log transform data, including all groups and conditions, priming was observed in the Identity ($p$ = .000) and Associated ($p$ = .022) conditions. No Group x Condition interaction in Associated versus Unrelated conditions was observed. All participants demonstrated somewhat faster RT to Associated versus Unrelated primes. However, this difference was not powerful enough to indicate an interaction, which warrants further investigation. The difference between RT in Identity versus Unrelated primes, however, was significantly greater. Generally speaking, the chronological age-matched group performed similarly to the ASD group ($p$ = .604). The vocabulary-matched group was slower than the autism spectrum disorder and chronologically age-matched groups ($p$ = .004), but followed similar trends. The hypothesis that individuals with ASD would demonstrate priming in the IS condition was not supported.

Correlational analyses were conducted to ensure that variance in the participant groups did not impacted the RT findings (participant characteristic data). Chronological Age ($p$ = .000), and standard scores on the CELF-4 ($p$ = .011) were most significantly correlated with priming effects. However, controlling for these factors using backward elimination did not alter findings of RT in this study.

# Chapter 4

## Discussion

The purpose of this study was to investigate the nature of lexical organization by way of a word association task (Experiment 1), complemented with an investigation of semantic representation in a semantic priming task (Experiment 2). The combination of conscious off-line processing (i.e., task exploring the total number and type of responses) in Experiment 1 with online processing (i.e., task exploring the process of generating a response) in Experiment 2 could yield information regarding the nature of word associations in individuals with autism spectrum disorders. The limited amount of online research in this area (Gerenser & Schwartz, 2004 Henderson, et al., 2011), paired with conflicted findings in off-line tasks (Kamio & Toichi, 2000; Kamio, Robins, Kelley, Swainson & Fein, 2007; Minshew, Goldstein & Siegal, 1995; Tager-Flusberg, 1985; Toichi & Kamio, 2001, Toichi & Kamio, 2002; Vogindroukas, Papageorgiou & Vostanis, 2003) was the motivation for this work.

### Experiment 1

In Experiment 1, individuals with autism spectrum disorders performed similarly to their typical counterparts matched for vocabulary and chronological age, with respect to reaction time and number of responses. Although the individuals with autism spectrum disorders, as a group, reacted more slowly than both control groups, the results were not statistically significant. There was a trend, however, toward an increased average reaction time in the experimental group (i.e., 3755 ms in the ASD group vs. 2830 ms in the CAM group and 3170 ms in the VM group).

In addition to similar mean reaction times, individuals with autism spectrum disorders exhibited a comparable mean total number of responses to their typical counterparts. These findings indicate that quantitatively, individuals with autism spectrum disorders may produce the same number of responses as their typical peers, which supports previous work (Boucher, 1988; Dunn, Gomes, & Sebastian, 1996; Turner, 1999). Findings may be interpreted as all three groups initiating first responses to the word association task in a similar fashion. In this study, the individuals with autism spectrum disorders were certainly able to verbally produce responses when directed to do so. The *content* of the responses they produced, however, was often unrelated to the target (e.g., numbers, colors). The autism spectrum disorders group produced significantly more word association responses categorized as Unrelated compared to both chronologically and linguistically matched groups. Individuals with autism spectrum disorders may not have been attending to the salient features of the target, resulting in extraneous responses.

When investigating the typicality of the first associate produced by participants, individuals with autism spectrum disorders produced significantly fewer associates that have been normed as typical associations on the University of South Florida Free Association Norms database (Nelson, et al., 1998) than the chronologically age-matched controls. However, the fact that they produced first associates similar to their vocabulary-matched counterparts indicates that their lexicons are immature, rather than idiosyncratic. These findings indicate that the associative networks in individuals with autism spectrum disorders are certainly organized, but not in a way comparable to their chronologically age-matched peers. When given a specific label, associated referents may be delayed in this population. Further, these individuals may demonstrate part-whole stimulus over-selectivity (i.e., responding *foot* for target *RABBIT*, as in *rabbit's foot*), resulting in inefficient retrieval and production of inappropriate associations.

Compared to responses normed on the University of South Florida Free Association Norms database (Nelson, et al., 1998), individuals with autism spectrum disorders demonstrated significantly fewer *total* number of responses listed as associates on this database than their chronological age-matched peers. Individuals with autism spectrum disorders produced associates that were either peripheral to the target (e.g., *BIRD - FLAMINGO*) or unrelated (e.g., *BIRD - ROCK).* These associations *may* be associated to the target for the participant with autism spectrum disorders, although they are not associated in a typical fashion (e.g., *BIRD - FLY, BIRD - NEST).* However, based on the aforementioned analyses, one cannot determine whether these associates are indeed reliable associates for individuals with ASD (albeit idiosyncratic), or merely randomly selected responses. These results suggest that individuals with autism spectrum disorders may not associate words comparable to their chronologically age-matched peers.

Individuals with autism spectrum disorders demonstrated difficulty with cognitive flexibility and efficient search strategies. Further, they demonstrated organization of the lexicon that may either be immature or idiosyncratic, leading to responses that are either peripheral to the target (Dunn, et al., 1996) or unrelated, based on the findings in this study. This unique organization can explain why an individual with autism spectrum disorder may produce the associate *spider* in response to the target *LAMP* during a vocabulary task. This particular participant may have seen a spider on a lamp upon first learning the label *LAMP* and, therefore, stored both semantic referents as strong associates. Such association of labels to referents is indicative of fast mapping errors in individuals with ASD (Kanner, 1943; Baron-Cohen, Baldwin, & Crowson, 1997). If an individual with autism spectrum disorder is not engaging in joint attention bids, mapping of referents will inevitably be incorrect. Superimposed with rigidity characteristic of this disorder, these atypical referent-label relationships may be maintained over a lifespan, negatively impacting lexical organization.

In Experiment 1, the initial analysis of categorization of responses included identifying word association responses as either Association, Perseveration, Proper Noun, Phrase, or Other. Analysis of these responses revealed that individuals with ASD produced significantly more responses categorized as Perseverations and Other than both control groups. These responses reflect poor retrieval in the lexicon, are inefficient, and negatively impact acquisition and use of vocabulary. These responses were then collapsed into Association or Unrelated categories. Individuals with autism spectrum disorders exhibited significantly more Unrelated responses than both control groups. These results expanded the findings of the analyses of responses in relation to association norms and total number of typical associates. Individuals with autism spectrum disorders demonstrated altogether different underlying associative mechanisms than individuals who are developing language in a typical manner. Individuals with autism spectrum disorders may store semantic referents in their lexicons which are essentially unrelated in the typical population (e.g., *SPIDER – LAMP).* Such organization can cause vocabulary acquisition and subsequent organization to be continually compromised.

Two different (and conflicting) findings were observed with respect to word association responses labeled as Clusters and Switches. First, individuals with autism spectrum disorders produced significantly fewer Clusters and Switches than their chronologically age-matched counterparts. Second, they produced significantly more Clusters and Switches than the vocabulary-matched controls. The ability to perform similarly to chronologically age matched controls on words association (i.e., verbal fluency) tasks has been reported (Boucher, 1988). Turner (1999), however, reported that individuals with autism spectrum disorders produced a smaller proportion of semantic Clusters. Since neither of these studies used a control group matched for vocabulary age, one cannot draw firm conclusions based on the data presented in this study.

The fact that individuals with autism spectrum disorders did not perform similarly to their chronologically age-matched group may lead one to conclude that this population has a lexicon which is organized somewhat differently. However, since this same group produced more Clusters and Switches than their vocabulary-matched peers, this conclusion is not supported. Further investigation with more detailed analyses of Clusters and Switches may provide more conclusive information regarding lexical organization in individuals with ASD.

As observed by findings in Experiment 1, reaction time in a word association task may not be a reliable variable to analyze, particularly in an offline task such as semantic word association. More valuable analyses may be quantifying the nature of responses, as demonstrated in this study by analyses of responses in relation to association norms, number of typical responses, Clusters and Switches, and categorization of responses. Though all three groups produced responses within the same time frame, the quality of responses was clearly different in the group with autism spectrum disorders, as observed in the analysis of categorization of responses. These findings suggest language of individuals with autism spectrum disorder cannot be considered solely by a superficial analysis of vocabulary performance (i.e., quantity of responses in a word association task). If examined superficially, one's high expectation of semantic association may be inaccurate, given the gaping holes in the individual's lexicon. Rather, investigation of quality of semantic representation must be deep in nature, in order to obtain a valid estimate of vocabulary skills exhibited by this diverse population.

The differences in categorization of responses support the executive function hypothesis (Baddeley, 1986; Robinson, et al, 2009; Jurado & Roselli, 2007; Hill, 2004). Individuals with autism were unable to inhibit extraneous or idiosyncratic responses during this word association task. The associative hypothesis (Palermo, 1971; Oldfield & Wingfield, 1965; Humphreys, Riddoch, & Quinlan, 1988) does not apply to the findings in Experiment 1 for individuals with autism.

**Executive functions.** Executive function is defined as a cognitive construct describing goal-directed, future-oriented behaviors thought to be mediated by the frontal lobes. Executive function includes planning, inhibition of responses, flexibility, organized search, self-monitoring, and use of working memory (Baddeley, 1986; Robinson, et al, 2009; Jurado & Roselli, 2007). Pennington & Ozonoff (1996) discuss how executive functioning applies to individuals with autism spectrum disorders. Preschool children with ASD have been found to be deficient in set-shifting tasks (e.g., difficulty imitating a simple hand gesture after having been primed with a different hand movement) (Ozonoff, et al., 2005). Multiple repetitions of the target are examples of this compromised executive functioning (e.g., *dog, dog, dog, bone, dog, bite*). Evidence for executive function was found in the increased number of responses categorized as Perseverations in this study.

Response planning and inhibition are also components of executive function (Hill, 2004). The word association task in Experiment 1 investigates generativity. Turner (1997) defines generativity as the ability to spontaneously generate thoughts and behaviors. When compared to their chronological age- and vocabulary-matched counterparts, the individuals with autism spectrum disorders were able to produce the same quantity of responses as their peers. Upon initial examination of responses, one might infer that this outcome reflects intact executive function. When responses were examined more closely (i.e., categorization of responses), however, it became apparent that the *quality* of responses was fundamentally different.

Individuals with autism spectrum disorders produced responses that were unrelated to the target, relative to both control groups. Findings in Experiment 1 (i.e., increased number of Perseverations and Other responses) may therefore be explained by the lack of set shifting and generativity, ultimately resulting in poor executive function (i.e., dysfunction) in individuals with autism spectrum disorders (Happe, Booth, Charlton, & Hughes, 2006; Frith, 1989).

**Associative hypothesis.** The associative hypothesis assumes that the frequency of co-occurrence of word pairs is the driving force of word association (Palermo, 1971; Oldfield & Wingfield, 1965; Humphreys, Riddoch, & Quinlan, 1988). Based on the nature of word association responses in individuals with autism, the associative hypothesis may not explain findings in Experiment 1. Individuals with autism spectrum disorder did not produce associates that were necessarily high in frequency. Furthermore, they produced a similar amount of associated and unrelated responses, unlike both control groups.

**Preferential acquisition principle.** An alternative principle proposed by Hills and colleagues (2009) may account for the responses produced by individuals with autism in Experiment 1. According to the preferential acquisition principle (Hills, et al., 2009), nouns that are better connected in a particular learning environment are learned earlier and more readily than nouns that are less well connected. Nouns that are not as well connected in individuals with autism spectrum disorders are those more strongly associated by typically developing individuals. These differences were observed in categorization of responses (i.e., the typical participants produced more typical associates than the participants with autism spectrum disorders). Given that individuals with autism spectrum disorders are reported to represent the world around them differently than typically developing individuals (Giagg, Gardiner, & Bowler, 2008; Grandin, 1996), the application of the preferential acquisition principle to these findings may be plausible.

The quality of semantic representation has been reported in other clinical populations (i.e., specific language impairment) (McGregor, et al., 2002). Although individuals with language disorders may be able to label a particular item, they may not possess a robust association network for that particular referent. Findings of Experiment 1 indicate that the *quantity* of responses is consistent across individuals with autism spectrum disorder and their typical counterparts. However, the *quality* of these responses may be ultimately compromised. Therefore, lexical organization in individuals with autism spectrum disorders may be immature.

**Experiment 2**

Experiment 2 was an investigation of cross-modal priming effects. With respect to accuracy of responses, there was a minimal number of errors (i.e., mean between 2 and 5) that were eliminated from analysis of picture naming in Experiment 2 (e.g., technical errors, false starts, incorrect responses). There were no significant differences in the number of errors across participant groups. These results replicate previous work (Seiger-Gardner & Schwartz, 2008; Gerenser & Schwartz, 2004), and contradict other work with children with specific language impairment (German & Simon, 1991; Lahey & Edwards, 1999; McGregor & Windsor, 1996; McGregor, 1997). Although individuals with autism spectrum disorders revealed a trend toward more incorrect responses and false-starts, these differences did not reach levels of significance, indicating that their ability to attend to the task, and respond correctly, was not necessarily compromised.

**Priming.** Multilevel analyses revealed priming in the Identity and Associated conditions. This observation indicated that priming occurred when a target was preceded by a prime that was either the same as the target or highly associated with it. The overall reaction times of the vocabulary-matched control group were generally slower, while the patterns were comparable to the autism spectrum disorders and chronological age-matched groups. The generally slower reaction time in younger individuals using cross-modal semantic priming tasks has been supported in the literature (Jescheniak, et al., 2006; Seiger-Gardner & Schwartz, 2008), explaining the reaction time in the group matched for vocabulary.

***Identity condition.*** Identity priming was found across all three groups. Strong identity priming has been well documented in the literature (Bruce, et al., 2000; Ballesteros, Gonzales, Mayas, Garcia-Rodriguez, & Reales, 2011; Gerenser, & Schwartz, 2004; Coane & Balota, 2010;

Feustel, Shiffrin, & Salasoo, 1983; Scarborough, Cortese, & Scarborough, 1977; Wheeldon & Monsell, 1992). Evidence of priming in this condition indicates that, even at a short interstimulus interval (i.e., 50 ms), individuals with autism spectrum disorders have the capability to name pictures when presented with matching auditory primes similar to both control groups. This finding is valuable, as it indicates that the underlying priming mechanism is similar in individuals with autism spectrum disorders as compared to their typical counterparts.

***Associated condition.*** Associative priming has been well documented in the literature (LeHeij, Dirks, & Kramer, 1993; Humphreys, Riddoch, & Quinlan, 1988; Alario, Segui, & Ferrand, 2000). There was a significant difference of Condition (i.e., faster reaction time in Associated versus Unrelated conditions). However, no Group x Condition interaction was observed. While significant differences in priming condition are promising, absence of an observed interaction is of concern. These results may be due to the fact that the differences were not very robust, unlike in the Identity condition. Lack of interaction in this condition warrants further investigation.

These findings may suggest a potential flaw in the stimuli used. In an effort to control for imageability, while minimizing confounding factors such as onset and rhyme, several compromises in stimuli selection were made. The first compromise was in frequency ratings (Kucera, & Francis, 1967). There was a wide range of frequency ratings for the primes used in the Associated condition (i.e., 10-591). Imposing greater control on the frequency ratings may have improved the strength of associated priming in this experiment. The second compromise was the association strength based on the University of South Florida Free Association Norms database (Nelson, et al., 1998). While all the primes used in this condition were identified as associates on this database, not all of them were the *first* associate, which is the associate most highly correlated to the target. The first associate on the University of South Florida database (Nelson, et al., 1998) may not have been able to be used as a prime due to attempts to minimize either phonological or categorical association. The third compromise may have been the SOA of 50 ms used in this experiment. This selection of SOA was used based on previous work that found semantic priming effects in both lexical decision and priming tasks (Hutchinson, Balota, Cortese, and Watson, 2008). Hutchinson and colleagues (2008) used a large number of prime-target pairs (i.e., 300), and found semantic priming effects. However, other literature suggests the contrary. At short SOAs, semantically related distractors produce interference (Sailor, Brooks, Bruening, Seiger-Gardner, & Guterman, 2009). Ultimately, the effects if these three compromises are speculative at this point and warrant further investigation.

***Individual semantic condition.*** The first responses in the word association task (Experiment 1) were used as semantic primes within the Individual Semantic condition. One hypothesis of this study was that individuals with autism spectrum disorders would demonstrate priming in the Individual Semantic condition while their typical peers matched by chronological age and vocabulary would not. The rationale for this hypothesis was that individuals with autism spectrum disorders are suspected to form associations that are idiosyncratic in nature and, therefore, may not demonstrate priming in the Associated condition, if associates are based on normative data. They could, however, demonstrate priming in the Individual Semantic condition, as these primes were proposed to be individualized, based on each participant's own word association responses in Experiment 1. There was no significant difference in this condition to the Unrelated condition across groups, indicating that all three groups did not differentiate primes that were obtained from their own responses in Experiment 1 versus Unrelated primes.

Two explanations for these findings may be plausible. First, word association responses in Experiment 1 were highly variable. All participants were asked only once to provide an associated response. The chronologically age-matched group demonstrated more highly associated responses than the group with autism spectrum disorders, but the vocabulary matched group did not. Therefore, first responses may not have been a reflection of associative processes in the autism spectrum disorder- and vocabulary-matched groups, but rather a representation of one's attention at a given moment. A second explanation for this finding may be attributed to method. If any participants provided a first response that was already being used as an associate, the subsequent word association response was used as a prime. These secondary primes may not have been the most highly associated. The hypothesis that individuals with ASD would demonstrate priming in this condition while their chronologically age- and vocabulary-matched peers would not, was not supported.

**Participant characteristics.** The final analysis was conducted as a correlation between age and standardized test scores on task performance. Chronological age and CELF-4 scores were correlated with reaction time. As Chronological Age increased, reaction time decreased, indicating that participants responded more quickly as they matured. This was an anticipated correlation, which has been previously observed (Jescheniak, et al., 2006; Seiger-Gardner & Schwartz, 2008). As the CELF-4 score increased, reaction time increased, indicating that individuals with higher standard scores responded more slowly to prime-target pairs. This was an unanticipated observation, which warrants further investigation. When these variables were controlled for by conducting a re-analysis using a mixed-effects model, the findings of Experiment 2 did not change. While there was variability in participant groups and test scores, reaction times were not affected by these variables.

The findings in Experiment 2 indicate that individuals with autism spectrum disorders demonstrated priming patterns similar to their typically language-developing counterparts in all conditions. They demonstrated priming in the Identity condition, and absence of priming in the Associated and Individual Semantic conditions. The vocabulary-matched control group was generally slower than the autism spectrum disorder- and chronological age-matched groups, though the priming pattern of this group was ultimately similar.

These findings may be attributed to the fact that, in this study, individuals with autism spectrum disorders were very high functioning. TONI-3 scores were comparable in both control groups (i.e., mean standard score of 110 as compared to mean standard score of 115 in the chronologically age-matched group and mean standard score of 112 in the vocabulary-matched group). This information, paired with reduced scores on language testing in the experimental group, is consistent with the first linguistic profile phenotype described by Tager-Flusberg (2006) (i.e., autism language impaired). However, since the ultimate findings of Experiment 2 revealed no differences in priming patterns across groups, it is plausible that this group's cognitive level may have been too high to be sensitive to the hypothesis. As a result, these participants may not have been representative of individuals with autism spectrum disorders at large.

**General Discussion.** Experiment 2 examined semantic priming using cross-modal priming. Superficially, the participants with autism yielded similar reaction times as their peers matched by chronological age and vocabulary scores. There were no significant differences across groups. The high degree of variability and small subject numbers may have played a role in these results. These findings were consistent with previous work in reaction time data in children with autism spectrum disorders (Brian, Tipper, Weaver, & Bryson, 2003; Inui, Yamanashi, & Tada, 1995). The findings for the Identity condition was expected (i.e., performance comparable to both control groups), but the similarity between performance in the autism and chronologically age-matched and vocabulary-matched peers in the Individual Semantic condition was unexpected. Performance of all three groups in the Associated condition was similar, in that there were faster reaction times observed in this condition. Given the tendency toward systematization of language (Minshew, et al., 1995), the hypothesis of this study was that individuals with autism would demonstrate priming in Individual Semantic condition, while both control groups would not. This was not the case.

There were several instances where results revealed that the vocabulary-matched group exhibited unanticipated responses. In the word association task, this group exhibited significantly fewer responses overall, significantly fewer first responses, as well as fewer total number of responses identified on the USF database than the chronologically age-matched controls. In the priming task, this group demonstrated similar priming patterns, but the priming effects were significantly less than both the chronological age-matched group and the autism spectrum disorders group. The vocabulary-matched control group had a lower average age (11;1) than the autism and chronologically age-matched control groups (16;7 and 16;9, respectively). It is plausible that the vocabulary-matched group may still have been acquiring vocabulary at an increased rate, continually organizing and re-organizing semantic networks, suggesting malleability of the lexicon. Delays in reaction time in younger children (Kail, 1991), as well as increases in error rates (Jescheniak, et al., 2006, Seiger-Gardner & Schwartz, 2008), have been supported. However, the fact that the vocabulary-matched group in this study was approaching adolescence calls this explanation into question. Delays in lexical development have been reported in individuals with autism spectrum disorders (Charman, et al., 2003; Hobson, 1993;

Ozonoff, et al., 2005) and may also explain the similar performance between these two groups. The lexicons of the individuals matched by chronological age to the individuals with autism spectrum disorders appeared to be better established and stable.

**Summary.** Results obtained in Experiment 1 suggest that individuals with autism spectrum disorders have lexical organization that differs from their chronologically age-matched, typically developing peers. Specific areas of difference were found in frequency of atypical responses, answering the first specific research question of this study (i.e., whether individuals with autism spectrum disorders exhibit different lexical organization than that of their typically developing peers). Further, findings from Experiment 1, with respect to Associated versus Unrelated responses, as well as typicality of the first associative response produced, and number of Clusters and Switches, support the hypothesis of the second research question of this study (i.e., do individuals with ASD provide different word associations than their typically developing peers).

The priming results for the Identity condition in Experiment 2 indicate that individuals with autism spectrum disorders exhibit the same basic priming mechanism as their typically developing peers. Individuals with autism spectrum disorders did not demonstrate priming patterns in the individual semantic condition nor did their typical counterparts. Therefore, the response to the third research question (i.e., do individuals with ASD respond differently to self-generated versus typically associated primes, as compared to their typical counterparts) is that individuals with autism did not respond to primes generated from their own initial word associations differently from their typical peers.

***Implications for individuals with autism spectrum disorders.*** The following question remains; How do these findings contribute to clinical application when working with individuals with autism spectrum disorders? Depending on the learning context, word associations may at first appear to be typical, while underlying associations may not be so. In-depth analyses of the word associations (i.e., responses categorized as Association, Perseveration, Proper Noun, Phrase, and Other) of clients with autism spectrum disorders provides robust information regarding lexical organization. If individuals with autism spectrum disorders have limited exposure to the world around them, their word associations will inevitably be affected. Individuals diagnosed with autism spectrum disorders can indeed fast map new vocabulary. The specific label-referent relationship, however, remains in question. Establishing typical associations in this population is critical in vocabulary instruction and language intervention.

***Limitations.*** Some limitations of the study include the lack of robust priming in the Associated condition across groups, exclusion of participants with cognitive deficits, and the type of primes used. When taken as a complete model of reaction time, the fact that significance across Identity and Associated priming conditions was observed is promising. Lack of observed Group x Condition interaction in the Associated condition warrants further investigation. Targets used in this study were early acquired basic nouns, which may not have been sensitive enough to the effects in question. While we described trends in the data, the fact that significant differences were not found may be a methodological limitation and warrants more investigation. A further limitation is that subject selection carefully excluded individuals with cognitive deficits. Therefore, findings can be generalized only to individuals with nonverbal IQ scores within the range of normal. Finally, the inherent nature of the Individual Semantic condition did not control for the specific type of prime. As a result, individual prime-target pairs may have been phonologically related. The number of Individual Semantic primes that had the same phonological onset of the target, however, was 6%, so findings reported can be maintained with confidence.

**Directions for future research**

In Experiment 1, a detailed analysis of age of acquisition for target responses in the word association task should be conducted. Correlational analyses between age of acquisition of target and number of responses produced may yield information regarding lexical organization in individuals with autism spectrum disorders. In addition, a follow-up study should be conducted with the same participants, as a second presentation of Experiment 1. A comparison of response types across multiple presentations of the same stimuli may yield valuable information regarding stability of semantic organization. Such an analysis would provide information as to whether associative responses are truly idiosyncratic but stable associations, or whether responses are random or unrelated.

The stimuli in Experiment 2 should be re-evaluated. Controlling for a higher frequency rating according to Kucera and Francis (1967), may strengthen the findings in the Associated condition. Increasing the number of conditions by varying SOA may answer the question regarding the potential flaw in this experiment. If robust priming effects are obtained at -150 SOA, and *not* at -50 SOA in the Associated condition, one could infer that SOA was the reason for inconsistent findings in Experiment 2. Experiment 2 should be modified, imposing greater control on the Individual Semantic condition for primes that may be phonologically related. While controlling for this confound, the addition of a phonological condition would be helpful to expand the breadth and depth of our knowledge in priming and autism. Further, the addition of a phonological condition in a follow-up experiment would allow for generation of preliminary assumptions of overall lexical access.

Finally, Experiment 2 should be replicated with younger children with autism spectrum disorders. Inclusion of another clinical population (e.g., specific language impairment) may yield robust information regarding the uniqueness of the lexicon in individuals with autism spectrum disorders versus other clinical populations. When considering additional participants with autism spectrum disorders, creating subgroups for additional participants with different profiles would impose greater control of behavioral and/or linguistic characteristics.

**Conclusion**

Word associations were observed to be qualitatively different in individuals with autism spectrum disorders compared to their chronologically age- and vocabulary-matched peers (i.e., significantly more responses categorized as Unrelated than Associated). In addition, significantly more responses categorized as Perseverations and Other in the autism spectrum disorders group than in both control groups was observed. Though these word associations are not as rigid as had originally been proposed (as observed by lack of priming in the Individual Semantic condition from Experiment 2), strengthening co-occurrence of typical associates may have positive implications for vocabulary instruction in this population. Individuals with autism spectrum disorders performed comparably on a semantic priming task to their chronologically- and vocabulary-matched peers, providing further support for priming in this population. In conclusion, while individuals with autism spectrum disorders may initially be lexically disadvantaged, they have the ability to learn and organize semantic networks, as measured by behavioral paradigms such as this one.

Appendix A

Experiment 1: Word association stimuli (40 words).

| # | TARGET | # | TARGET |
|---|---|---|---|
| 1 | Arm | 21 | Foot |
| 2 | Ball | 22 | Hand |
| 3 | Barn | 23 | Horse |
| 4 | Bear | 24 | House |
| 5 | Bed | 25 | Key |
| 6 | Belt | 26 | Knife |
| 7 | Bird | 27 | Moon |
| 8 | Book | 28 | Mouse |
| 9 | Cake | 29 | Nose |
| 10 | Car | 30 | Pen |
| 11 | Chain | 31 | Ring |
| 12 | Chair | 32 | Saw |
| 13 | Cloud | 33 | Sheep |
| 14 | Corn | 34 | Shirt |
| 15 | Cow | 35 | Skirt |
| 16 | Cup | 36 | Snake |
| 17 | Dog | 37 | Star |
| 18 | Door | 38 | Swing |
| 19 | Eye | 39 | Tree |
| 20 | Fish | 40 | Wheel |

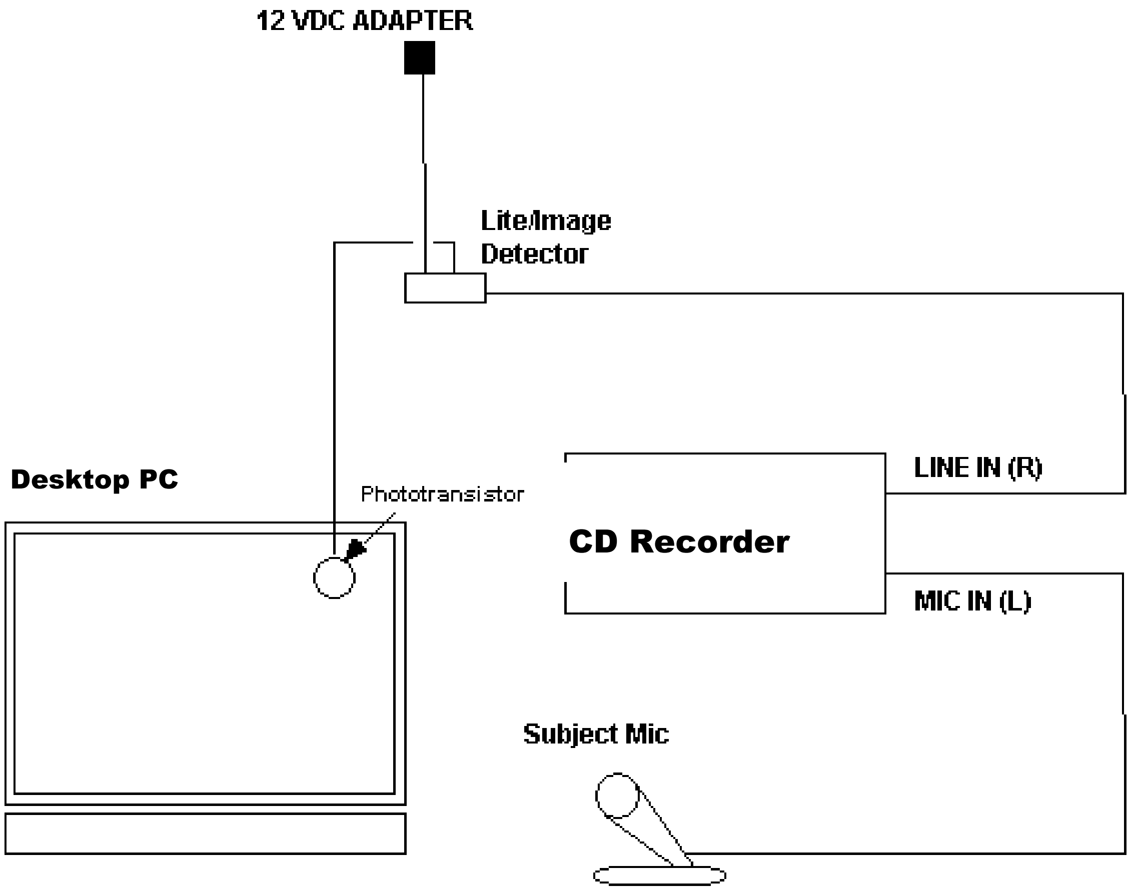
Appendix B

Experiment 1: Four pseudorandomized target lists (All forty original words are listed).

| # | List 1 | List 2 | List 3 | List 4 |
|---|---|---|---|---|
| 1 | Barn | Tree | Saw | Moon |
| 2 | Fish | Chain | Corn | Tree |
| 3 | Ball | Bird | Ring | Hand |
| 4 | Cake | Mouse | Bed | Star |
| 5 | Belt | Book | Mouse | Bird |
| 6 | Foot | Sheep | Bear | Pen |
| 7 | Wheel | Ball | Door | Arm |
| 8 | Chair | Shirt | Horse | Snake |
| 9 | Corn | Cow | Key | Wheel |
| 10 | Pen | Cake | Belt | Shirt |
| 11 | Door | Skirt | Cloud | Cow |
| 12 | Eye | Dog | Eye | Belt |
| 13 | Ring | Bed | Knife | Car |
| 14 | Bed | Wheel | Nose | Swing |
| 15 | Cup | Bear | Chair | Sheep |
| 16 | Nose | Cup | Sheep | Eye |
| 17 | Sheep | Fish | Hand | Chain |
| 18 | Hand | Barn | Star | Skirt |
| 19 | Cloud | Nose | House | Chair |
| 20 | Mouse | Snake | Wheel | House |
| 21 | Chain | Car | Bird | Nose |
| 22 | Arm | Moon | Pen | Bed |
| 23 | Snake | Key | Fish | Mouse |
| 24 | Car | Saw | Chain | Ring |
| 25 | Dog | Cloud | Arm | Barn |
| 26 | Key | Arm | Moon | Door |
| 27 | Swing | Corn | Car | Cup |
| 28 | House | Hand | Swing | Book |
| 29 | Skirt | House | Cake | Saw |
| 30 | Cow | Star | Tree | Knife |
| 31 | Shirt | Knife | Cup | Key |
| 32 | Bird | Eye | Snake | Horse |
| 33 | Saw | Ring | Ball | Corn |
| 34 | Moon | Foot | Cow | Cake |
| 35 | Bear | Belt | Book | Bear |
| 36 | Knife | Chair | Shirt | Foot |
| 37 | Book | Pen | Dog | Dog |
| 38 | Tree | Horse | Barn | Ball |
| 39 | Horse | Swing | Skirt | Fish |
| 40 | Star | Door | Foot | Cloud |

Appendix C

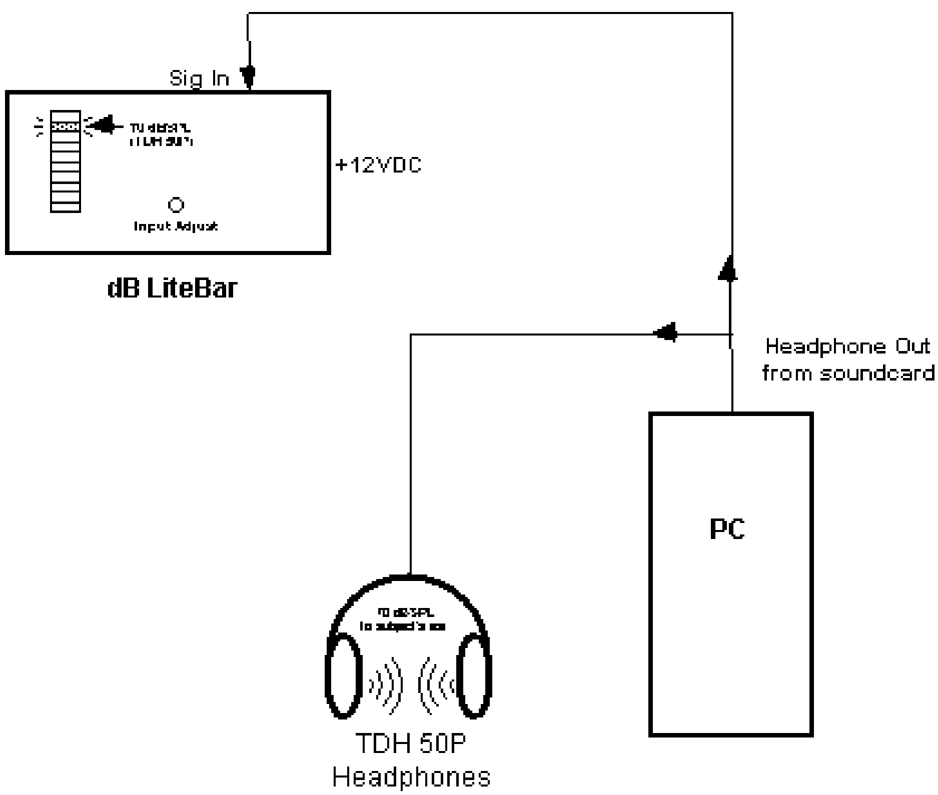
Diagram of light detector.



Appendix D

Setup for dB LightBar.

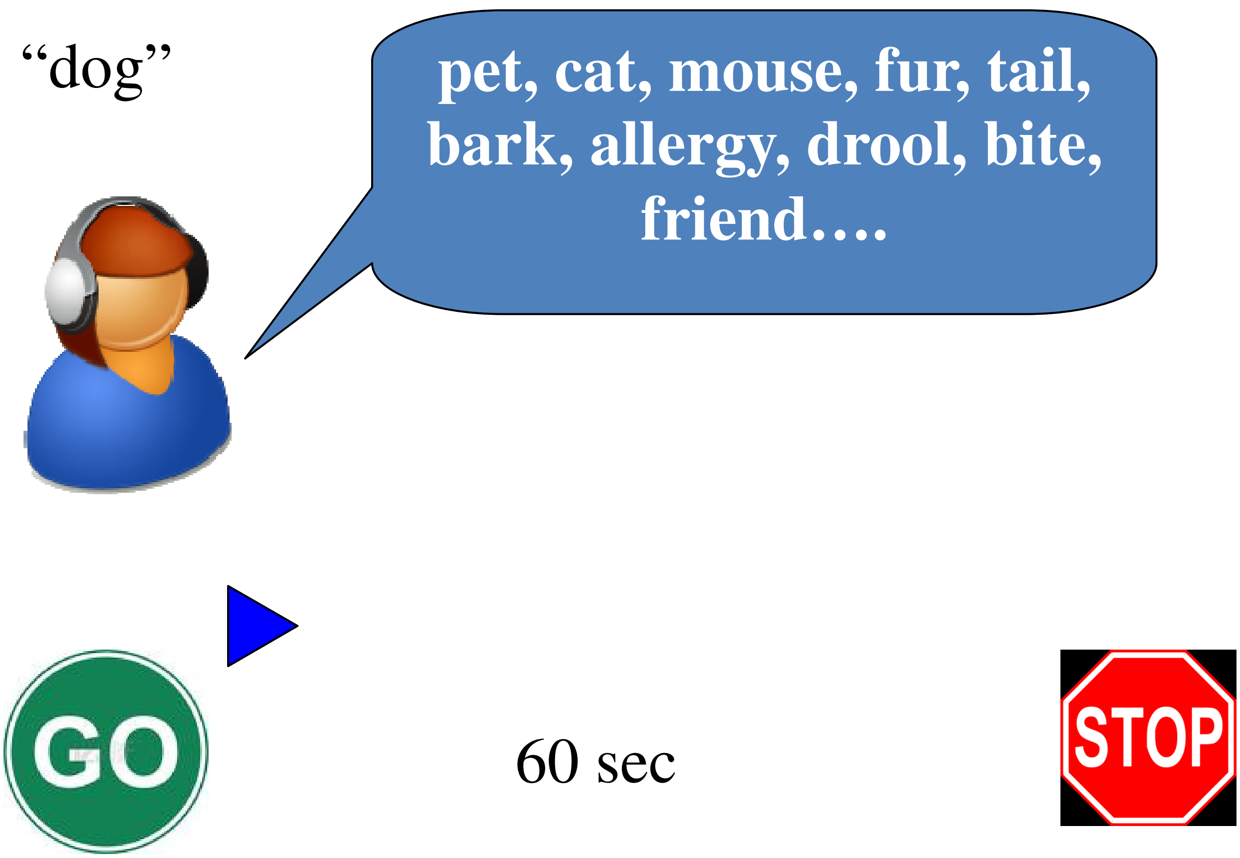
ar



Appendix E

Visual display of one trial and directions for Experiment 1.

Trial:




Directions:
"Welcome!  You will see a go sign. Get ready.  You will also hear a word. When you hear this word, tell me all the words you can think of.   You will use this microphone (pointing in direction of microphone).  Do this as fast as you can.  Do you have any questions?  Press the spacebar when you are ready to begin."

Appendix F

Prime-Target pairs for Experiment 2.

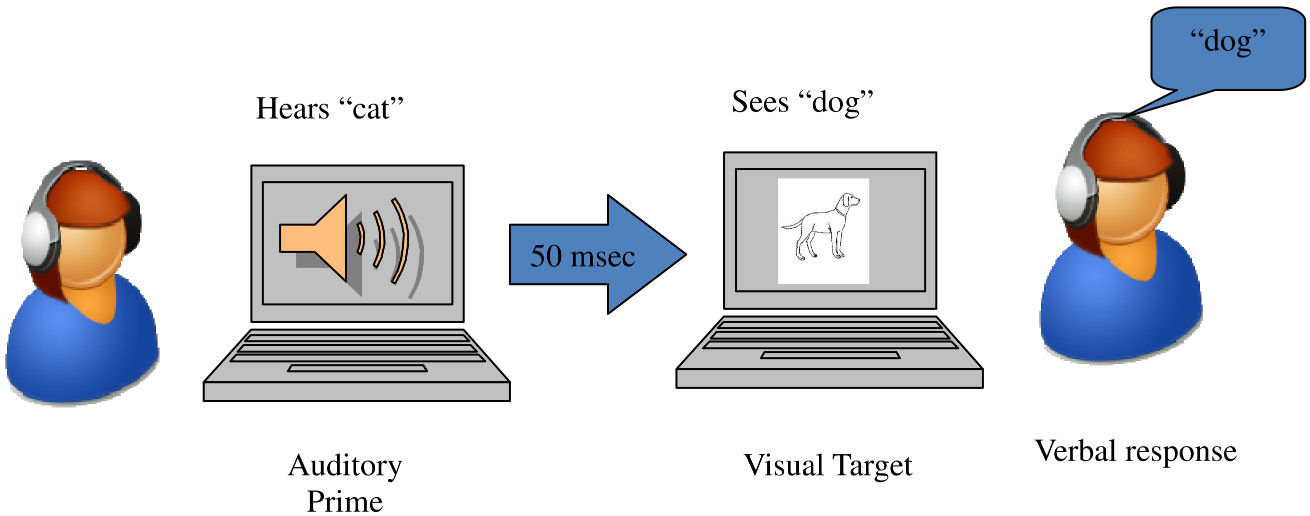
(ID)= Identity, (AS) = Associated, (UN) = Unrelated, (IS) = Individual Semantic
TBD = To Be Determined by response to target in Experiment 1

| # | **Target** | **ID** | **AS** | **UN** | **IS** |
|---|---|---|---|---|---|
| 1 | Arm | Arm | Leg | Shelf | TBD |
| 2 | Ball | Ball | Game | Knob | TBD |
| 3 | Barn | Barn | Hay | Candy | TBD |
| 4 | Bear | Bear | Grizzly | Wire | TBD |
| 5 | Bed | Bed | Mattress | Dish | TBD |
| 6 | Belt | Belt | Buckle | Paper | TBD |
| 7 | Bird | Bird | Nest | Vase | TBD |
| 8 | Book | Book | School | Rock | TBD |
| 9 | Cake | Cake | Ice Cream | Boat | TBD |
| 10 | Car | Car | Gas | Mouth | TBD |
| 11 | Chain | Chain | Link | Spider | TBD |
| 12 | Chair | Chair | Table | Seed | TBD |
| 13 | Cloud | Cloud | Sky | Baby | TBD |
| 14 | Corn | Corn | Husk | Train | TBD |
| 15 | Cow | Cow | Milk | Paper | TBD |
| 16 | Cup | Cup | Glass | Plug | TBD |
| 17 | Dog | Dog | Cat | Carrot | TBD |
| 18 | Door | Door | Knob | Beach | TBD |
| 19 | Eye | Eye | Sight | Brick | TBD |
| 20 | Fish | Fish | Water | Toothbrush | TBD |
| 21 | Foot | Foot | Shoe | Dinner | TBD |
| 22 | Hand | Hand | Finger | Cap | TBD |
| 23 | Horse | Horse | Saddle | Square | TBD |
| 24 | House | House | Roof | Circle | TBD |
| 25 | Key | Key | Lock | Grass | TBD |
| 26 | Knife | Knife | Sharp | Mud | TBD |
| 27 | Moon | Moon | Night | King | TBD |
| 28 | Mouse | Mouse | Cheese | Bag | TBD |
| 29 | Nose | Nose | Face | Wing | TBD |
| 30 | Pen | Pen | Ink | Belt | TBD |
| 31 | Ring | Ring | Wedding | Truck | TBD |
| 32 | Saw | Saw | Wood | Neptune | TBD |
| 33 | Sheep | Sheep | Wool | Yellow | TBD |
| 34 | Shirt | Shirt | Pants | Jungle | TBD |
| 35 | Skirt | Skirt | Dress | Fruit | TBD |
| 36 | Snake | Snake | Rattle | Pluto | TBD |
| 37 | Star | Star | Bright | Cookie | TBD |
| 38 | Swing | Swing | Park | Juice | TBD |
| 39 | Tree | Tree | Leaf | Letter | TBD |
| 40 | Wheel | Wheel | Tire | Stick | TBD |

Appendix G

Visual display of one trial and directions for Experiment 2.

Trial:




Directions:
"Welcome! You will see a "go" sign. Get ready. You will see a picture. Tell me the name of the picture as quickly as possible. You will use this microphone (pointing in direction of microphone). Do this as fast as you can. Press the spacebar when you are ready to begin."

# Appendix H

37 targets included in analyses for Experiments 1 and 2.

| # | TARGET |
|---|---|
| 1 | Arm |
| 2 | Ball |
| 3 | Bear |
| 4 | Bed |
| 5 | Bird |
| 6 | Book |
| 7 | Cake |
| 8 | Car |
| 9 | Chain |
| 10 | Chair |
| 11 | Cloud |
| 12 | Corn |
| 13 | Cow |
| 14 | Cup |
| 15 | Dog |
| 16 | Door |
| 17 | Eye |
| 18 | Fish |
| 19 | Foot |
| 20 | Hand |
| 21 | Horse |
| 22 | House |
| 23 | Key |
| 24 | Knife |
| 25 | Moon |
| 26 | Mouse |
| 27 | Nose |
| 28 | Pen |
| 29 | Ring |
| 30 | Saw |
| 31 | Sheep |
| 32 | Shirt |
| 33 | Skirt |
| 34 | Snake |
| 35 | Star |
| 36 | Swing |
| 37 | Tree |

Appendix I

Experiment 1: Means (M) and Standard Deviations (SD) of Reaction Time (RT) in milliseconds (ms) per target, across groups.

*Participant*

| *TARGET* | *ASD* | *CAM* | *VM* | *TOTAL* |
|---|---|---|---|---|
| ARM | 4362 (3775) | 3925 (4180) | 3391 (1431) | 3914 (3358) |
| BALL | 2953 (2989) | 1934 (568) | 2339 (721) | 2412 (1801) |
| BEAR | 2552 (1073) | 2888 (2479) | 2686 (1004) | 2710 (1657) |
| BED | 2479 (1052) | 2437 (1475) | 1981 (542) | 2312 (1108) |
| BIRD | 2714 (1959) | 3289 (3082) | 2401 (1646) | 2819 (2317) |
| BOOK | 2630 (935) | 2220 (1115) | 2357 (1568) | 2405 (1203) |
| CAKE | 3127 (2004) | 2602 (2516) | 2503 (965) | 2754 (1948) |
| CAR | 4061 (4991) | 2027 (1098) | 2670 (1408) | 2930 (3169) |
| CHAIN | 7435 (13759) | 2913 (1986) | 3553 (2221) | 4681 (8370) |
| CHAIR | 3846 (3994) | 1981 (676) | 2474 (870) | 2780 (2520) |
| CLOUD | 2547 (775) | 2704 (2833) | 3030 (1600) | 2748 (1912) |
| CORN | 4462 (6398) | 3091 (2674) | 2215 (784) | 3301 (4131) |
| COW | 2915 (1929) | 3193 (3906) | 3025 (2533) | 3045 (2862) |
| CUP | 2542 (1117) | 2100 (1020) | 3631 (4920) | 2720 (2857) |
| DOG | 3180 (1586) | 3082 (2347) | 2933 (1156) | 3052 (1752) |
| DOOR | 3130 (2253) | 2160 (910) | 3259 (3851) | 2832 (2550) |
| EYE | 4868 (8714) | 3117 (3933) | 3397 (1455) | 3811 (5630) |
| FISH | 5143 (5758) | 3327 (3207) | 2775 (1426) | 3790 (4014) |
| FOOT | 3769 (3190) | 2400 (956) | 3112 (1522) | 3093 (2168) |
| HAND | 5130 (6068) | 2466 (874) | 2770 (1040) | 3485 (3786) |
| HORSE | 3612 (3561) | 2506 (1161) | 4319 (4797) | 3443 (3448) |
| HOUSE | 4055 (3190) | 2608 (1091) | 2791 (1391) | 3167 (2187) |
| KEY | 6463 (9227) | 3014 (2199) | 5811 (5986) | 5065 (6535) |
| KNIFE | 3645 (3068) | 2218 (1738) | 3914 (4097) | 3231 (3093) |
| MOON | 2902 (1262) | 2667 (1498) | 3391 (2419) | 2947 (1743) |
| MOUSE | 2891 (1584) | 2588 (1394) | 2497 (1017) | 2666 (1346) |
| NOSE | 3740 (1967) | 4598 (9849) | 5861 (7581) | 4684 (7140) |
| PEN | 2253 (1297) | 1816 (545) | 2339 (743) | 2127 (934) |
| RING | 5073 (4176) | 2422 (1597) | 3863 (2921) | 3783 (3222) |
| SAW | 3566 (2111) | 2547 (1134) | 3861 (2100) | 3301 (1874) |
| SHEEP | 2898 (1526) | 4020 (5638) | 2789 (1195) | 3255 (3479) |
| SHIRT | 4300 (4127) | 2944 (3448) | 2625 (1065) | 3318 (3241) |
| SKIRT | 4322 (4899) | 4651 (9866) | 3588 (2488) | 4213 (6514) |
| SNAKE | 3103 (1644) | 3346 (2695) | 2465 (574) | 2994 (1885) |
| STAR | 5281 (6418) | 6271 (13983) | 4761 (4204) | 5467 (9141) |
| SWING | 4222 (3246) | 3682 (4893) | 3420 (1359) | 3790 (3484) |
| TREE | 2744 (793) | 2702 (2001) | 2574 (1117) | 2678 (1382) |

Appendix J

Experiment 1: Means (M) and Standard Deviations (SD) of responses per target, across groups.

| | *Participant* | | |
|---|---|---|---|
| *TARGET* | *ASD* | *CAM* | *VM* |
| ARM | 15 (8) | 19 (11) | 8 (4) |
| BALL | 15 (9) | 20 (8) | 10 (5) |
| BEAR | 17 (10) | 19 (7) | 12 (6) |
| BED | 17 (7) | 18 (7) | 10 (6) |
| BIRD | 20 (5) | 20 (9) | 10 (4) |
| BOOK | 19 (8) | 20 (8) | 12 (6) |
| CAKE | 16 (5) | 18 (8) | 11 (6) |
| CAR | 19 (6) | 24 (10) | 12 (6) |
| CHAIN | 16 (12) | 14 (7) | 7 (3) |
| CHAIR | 14 (10) | 16 (8) | 9 (5) |
| CLOUD | 16 (10) | 18 (8) | 10 (4) |
| CORN | 15 (7) | 16 (7) | 8 (4) |
| COW | 19 (8) | 18 (7) | 9 (4) |
| CUP | 16 (8) | 17 (8) | 10 (6) |
| DOG | 16 (8) | 21 (9) | 13 (7) |
| DOOR | 16 (9) | 18 (8) | 11 (7) |
| EYE | 17 (9) | 19 (9) | 9 (4) |
| FISH | 17 (9) | 19 (8) | 12 (6) |
| FOOT | 14 (8) | 20 (9) | 10 (6) |
| HAND | 14 (8) | 19 (9) | 8 (4) |
| HORSE | 16 (8) | 19 (7) | 12 (7) |
| HOUSE | 20 (8) | 22 (9) | 12 (7) |
| KEY | 13 (8) | 16 (8) | 6 (3) |
| KNIFE | 15 (7) | 18 (8) | 9 (6) |
| MOON | 16 (10) | 16 (7) | 9 (5) |
| MOUSE | 17 (8) | 17 (7) | 9 (4) |
| NOSE | 14 (7) | 16 (8) | 7 (4) |
| PEN | 16 (10) | 17 (8) | 8 (5) |
| RING | 14 (7) | 18 (9) | 9 (6) |
| SAW | 14 (7) | 16 (7) | 7 (5) |
| SHEEP | 14 (8) | 16 (7) | 7 (3) |
| SHIRT | 16 (10) | 19 (8) | 12 (6) |
| SKIRT | 13 (11) | 17 (8) | 9 (5) |
| SNAKE | 16 (8) | 18 (8) | 11 (5) |
| STAR | 15 (11) | 15 (7) | 7 (3) |
| SWING | 11 (7) | 15 (8) | 8 (5) |
| TREE | 16 (6) | 22 (8) | 11 (5) |

Appendix K

Experiment 1: Sample of word association responses for one target across groups.

| Participant | "MOON" |
|---|---|
| ASD | Sun, Earth, Pluto, Mercury, Venus, Mars, Saturn, Rings, Magician, Bird, Dove, Dog, Poodle, Mix, Terrier, Doberman, Shitzu, Laberdog, Schnauzer, Cardinal, Book, Cat, Timer, Clock, Calendar, Bottle, Water, Germex, Bird, Sunglasses, Truth, Dragon, Dog, Cat, Cow, Chicken, Cat |
| CAM | Big, White, Sky, Space, Astronomy, Physics, Gravity, Air, Weightless, Astronauts, Flag, Spaceships, Aliens, Theories, Craters, Pulling, Waves, Night, Stars, Outer, Satellite, Surrounding, Dust |
| VA | Crescent, Circle, White, Craters, Space, Bright, Night |

| Participant | "CUP" |
|---|---|
| ASD | Brown, Drink, Eat, Water, Water, Brown, Orange, Blue, Green, Blue, Orange, White, Pink, Brown, Blue, Green, Orange, Brown, Black, White, Purple, Violet, Indigo, Teal, Black, Orange, Red, Yellow, Green |
| CAM | Drinking, Round, Hole, Liquid, Cereal, Fruit, Glass, Plastic, Ceramic, Drinking, Hot, Cold, Paper, Disposable, Reusable, Holding, Handle, Meals, Silverware, Plates, knives, Forks, Thirsty |
| VA | Drink, Plastic, Colorful, Mug, Water |

| Participant | "BEAR" |
|---|---|
| ASD | Roar, Ears, Nose, Mouth, Growl, Cold, Paws, Legs, Feet, Nose, Mouth, Cheek, Fur, Brown, White, Blue, Pink, Yellow, Grey, Fur, Orange, Cold, Polar Bear, Panda Bear, Grizzly Bear, Sloth, Ears, |
| CAM | Animal, Forest, Aggressive, Dominant, Protective, Young, Furry, Large, Black Bear, Brown Bear, Grizzly Bear, Mountains, Streams, Fish, Eat, Predator, Hunters, Panda Bear, Polar Bear, Endangered, Variety, Furry, Cute |
| VA | Polar Bear, Grizzly Bear, Sun, Bear, Panda, Cub, Mammal, Paw, Hybernation. |

## Appendix L

Experiment 1: Example of Clusters and Switches example across groups.

All clusters are indicated in bold. Adjacent clusters adjacent noted by change in color from black to blue.

Switches are indicated with slashes ( / ).

| **Target** | **"MOON"** |
|---|---|
| ASD | round / nighttime **/ yellow, green** / dark / skies / stars / black / backyard / cold / dark **/ yellow, white, blue, yellow, orange, blue, green, red, yellow / crescent, full / big, small /** stars / dark |
| CAM | **sun, star /** rain / night **/ white, black, dark / grass, field /** rural / cows / crater / face / light **/ circle, round** / ball / smooth / man / flag / astronaut **/ space, galaxy, universe** |
| VA | night / eclipse / shapes / large **/ outer space, craters /** lights **/ astronaut, rocket** |

Appendix M

Experiment 2: Significance values for item analysis for partial multilevel model.

| Model | Description | Significance value |
| --- | --- | --- |
| 1 | Full master file | $p = .02$ |
| 2 | Omitting *WHEEL, BELT* | $p = .01$ |
| 3 | Omitting *WHEEL, BARN, BELT* | $p = .009$* |

NOTE: Only the models demonstrating significantly different priming in Associated versus Unrelated conditions are shown.

* Model 3 was selected as the final model to continue with a full scale multilevel analysis.

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