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CREATING AN ATTENTIONAL BIAS IN CHILDREN WITH VARYING LANGUAGE ABILITIES

RACHEL MARIE MARODI
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Reviewed and approved* by the following:

Elina Mainela-Arnold
Assistant Professor
Thesis Supervisor

Carol Miller
Associate Professor
Honors Adviser

*Signatures are on file in the Schreyer Honors College.

ABSTRACT

This study examined whether or not children were able to track visual statistics given a novel set of exemplars and phonological word forms. The participants consisted of fourteen children, differing in age (6-14 years) and language abilities. All participants were volunteers from the State College community. Half of the participants were males and half were females. To test the link between attention and statistical learning, the Novel Bias Task (NBT) was created and a supplemental set of tasks were delivered: the Conners' ADHD DSM IV scale, the Expressive Vocabulary Test (EVT), the Peabody Picture Vocabulary Test (PPVT), the Wechsler Abbreviated Scale of Intelligence (WASI), and the Clinical Evaluation of Language Fundamentals 4 (CELF). Roughly half of the children exhibited learning during the task and results did not provide a correlation between the NBT and any of the other tasks. Thus, even though previous studies suggest that infants are able to learn statistical regularities on a similar task, not all older children did. Potential explanations for this are discussed.

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Chapter 1: Specific Language Impairment and Attention

Specific Language Impairment (SLI)

The majority of children with some form of language impairment fall into a population termed Developmental Language Disorders (DLDs). These children have relatively low IQs and other associated problems in addition to a language disorder. Concomitant deficits may be emotional or social, intellectual, neurological, etc. This population of children usually requires treatment from working speech-language therapists (Paul, 2007).

An important distinction in the terminology of language disorders lies in the description of Specific Language Impairment. Researchers generally try to study the nature of language disorders in children with “pure” language disabilities. “Pure” refers to those language disabilities that occur in the absence of mental retardation, serious emotional issues, sensory disorders, and environmental deprivation (Johnston, 1988; Leonard, 1991). Children in these researchers’ studies are referred to as having Specific Language Impairment (SLI), meaning that a marked language delay exists while non-verbal cognition, auditory-processing, emotional and neurological development are all within normal limits (Leonard, 1998; Paul, 2007). This population of children is relatively rare when compared to the population of children referred to as children with DLDs (Paul, 2007) as it only affects approximately 7.4% of children (Tomblin, Records, Buckwalter, Zhang, Smith & O’Brien, 1997).

Research investigating the causes of SLI has benefited from our knowledge of the brain regions significant for language and the observation that both written and spoken language impairments tend to be hereditary. Investigations into the brain basis of SLI stemmed from the early neurologists’ belief that difficulties in children’s learning language and the presence of focal lesions were comparable to the loss of language seen in adults with acquired aphasias, terming it a sort of “childhood aphasia”. “Aphasic” children often appeared quite bright and able in other aspects of development not related to language; they demonstrated normal affective bonds with the people around them and showed no signs of emotional disturbance. Thus, their inability to acquire language normally was attributed to some type of neurological mishap thought to be analogous to localized brain lesions that result in adult aphasia. The fact that children with focal lesions do not show long-lasting language impairments as seen in SLI suggests that neurological involvement in SLI is not similar to the localized pathology seen in adults with aphasia (Paul, 2007).

Rescorla and Lee (2001) have argued that it is not appropriate to diagnose SLI until age four. Younger children with language delays may “outgrow” their compromised start (e.g. Paul, 2000: Rescorla, Roberts, & Dahlsgaard, 1997). Thus, SLI should be restricted to those children who retain significant deficits after the age of 4 years. The best way to characterize the dimensions of communicative functioning that are impaired in the SLI population is to look at the linguistic, psychological, social, and behavioral deficits at different points in time.

Despite no frank neurological damage, the SLI population still lags behind peers in language development (Aram, Morris & Hall 1993; Leonard, 1998).

While early vocabularies are much smaller than typically developing children, early word usage in children with SLI is much like that of their normally developing counterparts at similar language levels with vocabulary issues typically resolved by 3 or 4 years of age (Paul, 1996; Rescorla, Mirak, & Singh, 2000). In addition to talking less than their peers, children with SLI use much simpler modes of production supported by phonological processes, late acquisition of CVC and multisyllable productions, and a limited amount of consonants. In *fast mapping* studies, children are provided with brief exposure to new words. Children with SLI tend to show deficits in both production and comprehension of the new words; production impairments are more profound (Alt, Plante, & Creusere, 2004; Dollaghan, 1987; Kiernan & Gray, 1998; Rice, Buhr, & Oetting, 1992; Weismer & Evans, 2002). Vocabulary in school-aged children with SLI lags behind that of peers (Rice, Warren, & Betz, 2005), maybe because of reduced experience through reading (Paul, 2007). The cause of these difficulties is uncertain however it may be related to a grammatical difficulty (Gopnik & Crago, 1991; Rice & Wexler, 1996), phonological and working memory deficits (Gathercole & Baddeley, 1990), auditory processing difficulty (Tallal, Miller, Bedi, Byman, Wang, Nagarajan, Schreiner, Jenkins, & Merzenich, 1996), or something more general (Bishop, 1997; Leonard, 1998).

While intellectual impairment is an exclusionary criterion of children with SLI, evidence shows problems in some areas of non-verbal cognition including: classification, symbolic play, figurative thinking, hypothesis formation, mental rotation of two- and three-dimensional objects, and identification of objects by touch (Bavin, Wilson, Maruff, & Sleeman, 2005; Johnston & Ramstad, 1978; Johnston & Weismer, 1983; Kamhi, 1981; Kamhi, Catts, Koenig, & Lewis, 1984; Rescorla & Goossens, 1992; van der Lely, 2005). All of these activities suggest some form of deficit in general representation that may affect symbolic functioning; indeed, as represented by Botting (2005), children with SLI lost 20 nonverbal IQ points between the ages of 7 and 14. Although these children will fall below age mates on tasks as mentioned above, they will still perform better than younger children with comparable language skills (Leonard, 1987).

As reported by Tallal et al. (1996), children with SLI are specifically impaired in their ability to process rapidly presented information. It has been proven that while a task’s length and complexity have a great effect on a child’s performance on the task, children with SLI will generally process information at a slower rate than typically developing children (Paul, 2007).

Commonly, children with SLI display mild neurological deficits such as clumsiness, poor attention (as mentioned with ADHD above), mild motor difficulty, and poor visual-motor integration (Rescorla & Lee, 2001).

The cause of SLI remains unknown; however, various theories have tried to account for the deficits seen in children with SLI. After almost three decades of research surrounding processing capacity in SLI, Leonard and colleagues (2007) argued that the main cause of SLI may lie in a limited processing capacity. Studies have pointed toward limited phonological or verbal working memory capacity (Montgomery, 1995; Ellis Weismer, Evans, & Hesketh, 1999), a slow speed of both verbal and nonverbal processing (Miller, Kail, Leonard, & Tomblin, 2001), or a limited processing capacity overall (Johnston, 1994). The premise that children with SLI have particular limitations in computational resources available for language processing has been fundamental to these studies (Ellis Weismer et al., 1999; Gathercole & Baddeley, 1990; Johnston, 1994; Montgomery, 2000). Processing and storage of information is degraded when computational demands exceed available resources (Just & Carpenter, 1994; Shiffrin & Schneider, 1977), requiring children with SLI to encounter words and structures more times than typical in order to develop a mature linguistic system (Leonard et. al, 2007).

In addition, in some working memory models, working memory capacity primarily reflects the scope of attention, i.e. the processes that are attended to in a given task ((e.g. Cowan, 1999; Cowan, 2005; Engle, Kane, & Tuholski, 1999). Attention is emphasized in these models; evidence indicates that children with SLI exhibit difficulties with attention or inhibition in both verbal and non-verbal (including visual) tasks.

Genetics and SLI

The fact that SLI tends to run in families suggests that genetic factors may have some contribution to the acquisition of a language disorder. Unfortunately, while families share genes first, they also share environments; this idea alone requires solid evidence of a completely genetic effect that is not influenced by outside factors before determining any connection between genes and SLI. Twin studies have given researchers the ability to concentrate solely on the genomes of family members by comparing identical sets of twins. Where dizygotic, or fraternal, twins share the same home environment and only 50% of their genes, monozygotic, or identical, twins share the same home environment and 100% of their genes. This means that monozygotic twins are genetically identical. If through a twin study we can prove that identical twins resemble each other more in terms of language behavior than do fraternal twins, then the language similarities must be genetically mediated—this *is* the case. Further, certain language tasks such as non-sense word repetition and marking tense have been identified as highly heritable (Tomblin et. al, 2009).

Potential Causes of Specific Language Impairment

Procedural Learning Deficits

As gathered from above, SLI refers to a developmental condition that results in long-term restrictions in listening and speaking skills with no evidence of hearing loss or other neurodevelopmental disorders; progression of spoken language development is slow (Tomblin & Zhang, 1999). When focusing solely on linguistic impairments, elements of the abstract grammatical system are either impaired or absent (Gopnik & Crago, 1991; Rice & Wexler, 1996), and children have specific difficulties with grammatical morphemes (Bedore & Leonard, 1998; Cleave & Rice, 1997). There have been suggestions that such grammatical impairments seen in children with SLI are primarily due to general perceptual and/or cognitive processing deficits. Theories suggest that these general processing deficits have to do with auditory temporal processing (Tallal et al., 1996), limited working memory capacity (Gathercole & Baddeley, 1990; Weismer et. Al., 1999b) or slower general speed of processing (Miller et al., 2001).

Implicit learning is a diverse phenomenon that involves learning without awareness that includes: probabilistic learning of categories, prototype abstraction, statistical learning, and artificial grammar of learning (Ashby & Ell, 2001; Perruchet & Pacton, 2006; Reber, 1989; Reber, Stark & Squire, 1998; Squire & Knowlton, 2000; Squire & Zola, 1996). *Procedural learning*, a form of implicit memory, is identified as the learning and processing of rule-like relations in the context of real-time incremental, abstract, sensorimotor, or cognitive sequences (Eichenbaum & Cohen, 2001; Reber & Squire 1994; Schacter & Tulving, 1994; Squire, 1992; Squire and Knowlton, 2000; Squire, Knowlton, & Musen, 1993). In tasks that test procedural learning and implicit memories, learning of new cognitive and motor skills is believed to be unconscious and sequential. The realization of learning is demonstrated through generalization or increased speed of behavioral responses as the learned skills become more efficient and eventually automatic. The grammatical impairments seen in children with SLI may have a relation to a difficulty in learning regularities of patterns suggested by procedural learning, and may have a relation to abnormalities in brain networks associated with procedural memory; namely, cortico striatum (Ullman & Pierpoint 2005).

The Serial Reaction Time task (SRT; Jimenez, 2002) studies procedural learning of patterns by using visual materials and no obvious language. This test is viewed as evidence of implicit learning because it requires no awareness of having learned a pattern. On the SRT task:

Participants press a button based on the location of a visual stimulus over each trial. The task provides alternation between random orders of stimuli followed by a pattern of stimuli locations. Evidence of learning comes as participants learn to distinguish between a pattern and a random order of stimuli and acquire the ability to anticipate where the next stimulus will appear; if learning has occurred, response times will decrease. Such pattern learning is fast, robust, automatic, and general in nature for those who are able to “learn” (Cleeremans & Mcclelland, 1991; Cleeremans et al., 1998; Clegg et al., 1998; Saffran, 2003).

Given a few findings: 1.) Abilities to learn pattern regularities are implicated in language learning, 2.) Learning of regularities in sequences differs by language ability, and 3.) Individuals with SLI experience delayed language learning, it is reasonable to predict that individuals with SLI will be less proficient in procedural learning tasks than typical language learners. Tomblin and colleagues (2007) found that when compared to normal language peers, adolescents with SLI showed slower learning rates during pattern learning in comparison to controls. Specifically, we can predict that reaction times, and thus, learning rates, for children with SLI will be significantly slower than those without language difficulties. From this study, it may be reasonable to further conclude that differing abilities to track visual statistics may contribute to individual differences in vocabulary seen in children with SLI.

Statistical Learning

A paradigmatic measure of implicit learning during infancy and childhood is *statistical learning*. This type of learning involves the tracking of patterns of regularities over input such as syllables, tones, or shapes (e.g. Aslin, Saffran, & Newport, 1998; Kirkham, Slemmer, & Johnson, 2002; Saffran, Aslin & Newport, 1996; Saffran, Johnson, Aslin, & Newport, 1999). In such tasks, participants are exposed to a stream of elements that are ordered according to a set of straightforward statistical regularities following the notion that random events exhibit reliability when repeated enough times (e.g., the syllable /pa/ tends to be followed by the syllable /bi/). This is quite similar to the idea tested by the previously mentioned SRT task in which participants should anticipate order and demonstrate learning by their behavioral reactions. Infants and children have the ability to quickly decipher the regularities that link together elements in a given stream in the absence of instruction or reinforcement. This is supported by their ability to discriminate a familiar sequence from a novel sequence. Research concerned with implicit memory claims that adults, children, and infants can implicitly learn statistical regularities and that these patterns are useful for certain aspects of language learning (Saffran, 2003).

As expected, performance on each task presented to test implicit learning differs by participant. Performance on such tasks is central to the many aspects of language acquisition and thus, it makes sense that some individual differences could be correlated with naïve language abilities. In a study done to find if poor implicit learning may underlie aspects of the language impairments in SLI, researchers wanted to find whether children with SLI are impaired in their ability to keep track of sequences, and thus, word boundaries, heard in a stream of continuous speech—an implicit learning ability fundamental to the earliest stages of word learning. There is also debate regarding the extent to which language learned via implicit memory is because of a domain general mechanism or some mechanism specific to language modalities (Evans, 2009). Regarding statistical learning, there are many commonalities across modalities as well as important differences that suggest that statistical learning is constrained by modality and/or by our perceptual systems (Conway & Christiansen, 2005; Saffran, 2002; Saffran & Thiessen, 2007). If the characterization of SLI includes deficits in domain-general implicit learning abilities, there will be poor learning for both matched non-speech and speech stimuli in children with SLI (Evans, 2009).

While the assessment used for this study, the Novel Bias Task (NBT), is concerned with the ability to track patterns using visual stimuli, the study on Statistical Learning in Children with SLI sought to examine (a) whether children with specific language impairment (SLI) can implicitly compute the probabilities of adjacent sound sequences (Evans, 2009). Given this ability, and more applicable to the NBT, Evans (2009) also speculated: (b) if this ability is related to degree of exposure, (c) if it is domain specific or domain general, and (d) if this ability is related to vocabulary (Evans, 2009). Provided below is a synopsis of the methods and results of the two experiments conducted to further examine the four areas of interest:

Participants of the first experiment included typically developing children and children with SLI between the ages of 5 and 14 with an IQ of at least 85; all were monolingual English speakers. The group of typically developing children scored at or above age-level expectations on tests of core language and expressive and receptive vocabulary, while the SLI group was much lower (Evans, 2009).

Children were exposed to a tape of a continuous speech stream composed of *words* and *nonwords* (from an artificial language composed of 3 of 12 Consonant-Vowel (CV) pairs) while drawing a picture for a total of 21 minutes. Transitional probabilities between syllables within *words* were higher than transitional probabilities across *word* boundaries. The transitional probabilities within the *nonwords* were zero. The sets of *words* and *non-words* composed an alternative forced-choice test; half of the test items contained a *word* as the first member of a pair and half contained a *non-word* as the first member (Evans, 2009). Participants were asked to choose the sound in each pair of *trisyllables* (word + non-word) that sounded like the sounds they heard while drawing.

The children with Specific Language Impairment had a significantly poorer ability to attend to transitional probabilities than the NL group. Typically developing children were easily able to decipher transitional probabilities and discover words embedded in a speech stream. Thus, the ability to track sequential statistics may be related to lexical knowledge. If this is true, challenges in segmenting words from the speech stream would probably slow lexical development. This experiment indicated that the group with SLI was unable to use statistical information to discover word boundaries based on transitional probabilities after 21 minutes of exposure. Thus, the second experiment examined if given more exposure to the speech stream, children with SLI were able to compute the statistics (Evans, 2009).

Six months later, thirty children (with varying language abilities) who participated in the first experiment were split into two groups: children with SLI and a control group. Children participated in either one of two experiments (Evans, 2009). The stimuli and procedures of the first experiment mimicked those of the initial experiment with the exception that children listened to the same materials twice, without a break, for 42 continuous minutes (Evans, 2009). The second experiment utilized pure tone words that did not resemble anything close to a melody and were not constructed in accordance with rules of music composition. Transitional probabilities between tones within words were larger than transitional probabilities between tones spanning word boundaries (Evans, 2009). The tones were presented in a random ordered continuous stream; there were no acoustic markers of tone-word boundaries; transitional probabilities were the only cues to tone word boundaries. At the end of the 42 minutes, children were asked to select the sound sequence that sounded most familiar (Evans, 2009).

Again, the overall performance for children with SLI was poorer than that of their typical language peers. After double exposure to the speech stream, the SLI group's statistical word learning performance was not significantly correlated with the expressive vocabulary, age, or IQ, but was significantly correlated with receptive vocabulary. While some children with SLI performed at levels greater than 50% after double exposure (suggesting the ability to track *some* statistical information from input)—none were able to effectively use even the highest transitional probabilities to discover the word boundaries within the stream of speech. If the successful children with SLI were using transitional probability as a cue to discover word boundaries within the speech stream, then they should have been able to discover word boundaries for the words having the highest transitional probabilities. This suggests that with double the exposure, even if children with SLI are able to segment the speech stream to any extent, their knowledge of newly learned words (i.e. new vocabulary) might not contain enough phonological detail to enable differentiation between newly learned target words and highly phonologically similar words (Evans, 2009).

Results from both experiments demonstrate that increased exposure to the speech stimuli in the second experiment played the main role in the improved performance of the children with SLI (Evans, 2009). The findings from the group of studies support the notion that typically developing children have computational tools that can tie together statistical information to detect word boundaries, that this ability is related to measures of receptive and expressive word knowledge, and that it appears to be a domain-general ability (Evans 2009). The fact that differences in areas such as age, IQ, or receptive and expressive vocabularies did not account for dissimilarities in statistical learning ability suggests that children who perform differently must differ in some other fundamental way. Children may differ in their attentiveness or working memory capacities; word learning performance is significantly lower when these resources are reduced because they are not available to discover word boundaries (Ludden & Gupta, 2000). Overall, the implicit learning that describes a diverse collection of learning capacities to include: procedural memory, probabilistic learning of categories, statistical learning, artificial grammar learning, and prototype abstraction (Perruchet & Pacton, 2006; Squire & Zola, 1996), needs to be analyzed across all modalities in order to properly characterize children with SLI's learning challenges. The Novel Bias task aims to analyze the relationship between procedural memory, statistical learning and attention.

Genetics

In 2001, the *FOXP2* gene was discovered in a three-generational family (The KE family) as causing a severe speech and language impairment; *FOXP2* is important to the development and function of the cortico-striatal system (Lai et al., 2003), which regulates the output of the entire brain. *FOXP2* acts as a "chief executive officer" of the genetic programs of cells in humans as well as some animals and may be important in the embryonic development of brain structures associated with language (Paul, 2007).

15 members of the 37-member KE family had a *FOXP2* single-nucletotide mutation and all possessed a severe speech and language impairment (Lai et al., 2001) described as specific grammatical deficits involving rule-based morphological paradigms. Each member had abnormalities associated with gray matter density in the caudate nucleus, and integral part of the brain's memory and learning system. The caudate nucleus, a structure of the procedural learning system, is smaller in those affected with SLI than those who are not (Watkins et al., 2002). Knowing that the caudate nucleus has a large role in the cortico striatum, it is very likely that the striatum plays a significant role in procedural learning and implicit memory (Packard &

Knowlton, 2002). Thus, *FOXP2* may have an important role in the development of the frontostriatal network that supports procedural learning and its mutations may be hereditary. Procedural learning is generally believed to be rooted in the cortico-striatal system found to be functionally unusual in the KE family and based on Pullman's model of declarative and procedural learning apparatuses in language learning, the authors proposed that the morphological rule troubles of the family are rooted in procedural learning deficits (Liegois et al. 2003). Could it be possible that a mutation in *FOXP2* has led to the grammar difficulties that underlie procedural learning deficits? And if so, is language affected in general, or just speech? The KE family presented evidence of language and cognitive deficits, particularly in grammar. If *FOXP2* is involved in more than just speech, the KE family should demonstrate language impairments as well (Tomblin et al. 2009).

After breakpoint locations were discovered in mutated strains of *FOXP2*, studies were conducted to find if language impairment is likely a part of the phenotypic profile of *FOXP2* irregularities and if the discovered language impairment is similar to those found in the KE family.

In comparison, mother (B) and daughter (T) have mutations in *FOXP2* (that originated with B) and are healthy individuals with no clinically significant deficits other than marked long-term developmental speech and language problems. This particular study sought to descriptively compare the profiles of the TB and KE families (Tomblin et al. 2009).

The mutations in *FOXP2* of a mother and daughter (T and B) and their demonstration of significant speech impairments consistent with reports of others with *FOXP2* abnormalities were confirmed. Within the Words-and-Rules (WR) model that uses either a rule- or lexical- based solution to tense marking, B's performance may be evidence of a productive morphological rule system for regular tense marking. Additionally, words may be acquired and stored in a declarative system and rules may be learned in a procedural system. If so, B's performance is evidence of an intact morphological rule system and an intact procedural system (Tomblin et al. 2009). On the contrary, T's performance is consistent with impairment in a rule-based procedural learning system—the same *FOXP2* chromosomal rearrangement in T and B would thus be implicated in two very different patterns. If regular forms can be stored in memory and learners have the ability to generate regularization to novel forms based on phonological similarity, then B could over-regularize tense on novel words that may take an irregular form despite having an impaired procedural system. In this case, B's tendency to over-regularize and T's to under-regularize can be explained by the WR model. Overall, a key feature of the learning system is that it would allow for a protracted learning process, as individual lexical items could be learned and continually incorporated into the mental lexicon over the course of one's life (Tomblin et al. 2009).

In general, the functional consequences of *FOXP2* mutations are similar between the TB and KE families, but not identical. The overall cognitive and language profiles for the two families were similar: both had language problems, particularly with grammar, both had strong vocabularies. Such similarities are support for a role of *FOXP2* in the neurodevelopmental pathways involved with speech and language (Lai et al., 2003). However, it is important to recognize that genes are a single element in complex interactions; the identification of a specific gene that plays a role in such interactions will help to constrain the space of the complex system (Tomblin et al., 2009).

Why the Novel Bias Task?—Evidence from The ALA

As previously discovered in experimental tasks, children as young as 2 years of age show systematic attentional biases; specifically attending to different properties for different classes – the many similarities of animals, the materials of substances, the shapes of artifacts, and the various colors of foods (Smith & Samuelson, 2006). The Attentional Learning Account (ALA) of word learning makes three claims regarding the cognitive mechanisms involved in vocabulary building and the corresponding lexical-semantic representations characteristic of typical development:

> 1.) The *first claim* affirms that *the learning environment provides correlations among object properties, linguistic devices, and perceptual category organization*. When studying the statistical nature of nouns, among early noun categories, the ALA discovered that artifacts tend to be angular, solid, rigid things in grouped into categories by shape (i.e. animals have eyes, legs, and heads that are in categories organized by similarities, substances are usually nonsolid and categorized by material). From this evidence, correlations are seen between perceptual properties of individual things much like the similarities seen in a common noun category (Smith & Samuelson, 2006).
>
> 2.) The *second claim* of the ALA suggests that *children are empowered with the ability to learn lexical categories rapidly; as their knowledge of lexical categories increases, statistical regularities and higher order generalizations emerge*. In a particular experiment, 15- to 19- month old children were taught lexical categories organized by shape that were generalized into novel categories. In the real-world, the training led to acceleration in the rate of vocabulary growth, demonstrating that the attention to object shape in learning names for artifacts is relevant to vocabulary development in young children (Smith & Samuelson, 2006).
>
> 3.) The *third claim* realizes that *the application of children's learning of statistical regularities in a real-time task of generalizing a name to a new case is mechanistically recognized through learned associations yielding contextually cued attention shifts*. Cued attentional biases are created via a system of learned associations. Automatically, in any particular instance of learning, a child's attention is directed to similarities that are consistent with perceptual and linguistic contexts of the child's past. This suggests that past knowledge has top-down control of attention (Smith, 2000, 2003, 2005; Yoshida & Smith, 2003a, 2003b). Underlying this assumption is the idea that automatic processes use cues in the current context of learning to rapidly activate past learning; this is because past education, and thus, overlearned associations, have the ability to modulate attention (Smith, Jones, & Landau, 1996). As such, the context vigorously binds attention,

> enabling a child to focus on the correct associations for the current perceptual and linguistic task (Smith & Samuelson, 2006).

The power of this learning mechanism is admired by the ALA for three reasons: (a) its connection to and ability to integrate various contextual cues at a specific moment, (b) it enables a child to pay different ways of attention to the same perceptual object depending on current context, and (c) the history of regularities in a learner's past have the ability to guide attention and learning in the moment (Smith & Samuelson, 2006).

In reference to SLI, the concepts of (1) children extracting correlations among visual perceptual features when learning semantic categories, and (2) children's attention being shaped by extraction of statistical associations between perceptual category organization and lexical forms, provide a potential explanation for lexical-semantic deficits characteristic of SLI.

Why the Novel Bias Task? – Evidence From Earlier Studies

Experiments have previously been conducted to investigate infants' use of structural relations (i.e., correlated attribute values) to segregate items into specific categories. Although values of attributes have the potential to vary continuously across objects, some combinations will be more likely to occur than others, forming discontinuities between clusters of correlated values. Using artificial categories and a standard infant-recognition memory procedure, the experiments demonstrated 10-month-old infants' sensitivity to structural information and their ability to divide items into categories on the basis of clusters of correlated attribute values (Younger,1985).

Segregation of items into categories was examined by manipulating the covariation between dimensional values. The stimuli were artificially constructed schematic animals that varied along four quantitative dimensions: leg length, tail width, neck length, and ear separation. Each dimension varied along five distinct values. Two conditions were examined over the course of the study. In one condition, the full range of values on any given dimension occurred with the full range of values on other dimensions.   Younger (1985) predicted that the broad range of variation across dimensions would result in the formation of a single broad category that encompassed the full extent of variation experienced among the set of exemplars.   In the second condition, restricted ranges of values were correlated across dimensions. The scaling of values on the different dimensions was arranged so that the animals in each of the two "categories" were roughly of the same average size (e.g. long legs were paired with short necks, and short legs were paired with long necks).   It was expected that infants in this category would form two narrow categories to reflect the experienced pattern of correlation (Younger, 1985).

Overall, the findings add to the understanding of infants' ability to process and characterize category information.   Results from the experiments contribute to evidence indicating that, with quantitative variation among attributes, instances near to the category "average" are recognized as most familiar by 10-month old infants (Strauss, 1979, 1981). In addition, findings demonstrate 10-month-olds' sensitivity to attribute relations occurring in categories.   In an earlier experiment, Younger and Cohen (1983) used a habituation-dishabituation procedure to show that infants' attention would recuperate after being shown stimuli that violated previously experienced patterns of correlation among qualitatively different features. In the 1985 Younger studies, it was demonstrated that the pattern of novelty preferences shown by infants was influenced by the manipulation of dimensional values and also that the infants had the ability to use clusters of correlated qualities to form categories (Younger, 1985).

All three studies support that two crucial categorization functions are supplied by two very different processes: (1) constructive processes have an important role when representing variability found in categories and (2) while it is a different role, the discernment of structural constants-correlated properties has an equally important role in categorization. Taken together, the ability to perceive correlated attributes or invariants is critical to being able to discriminate between and divide objects into categories (Younger, 1985).

Current Study

As mentioned in the discussion above, children may differ in their attentiveness or working memory capacities (Evans, 2009). Common of SLI is the characteristic of poor attention abilities. Children with SLI also have difficulty with determining auditory patterns (as in the Evans-Saffran task) and the ability to track visual statistics (as in the Tomblin study) relates to a domain general difficulty with extracting statistics. In addition, *FOXP2* may have an important role in the development of the frontostriatal network that supports procedural learning and its mutations may be hereditary. Given these difficulties in attention, statistical learning and vocabulary, the current study focused on developing a task that could be used to study the relationships between these deficits.

To execute the Novel Bias Task, a general inquiry is addressed and investigated further via the use of two hypotheses. Motivated by previous studies and claims from the Attentional Learning Account, the Novel Bias Task investigates whether or not a task that was adopted from babies' that examined looking time can apply to older children who are required to explicitly answer and asks:

Are children within this age range readily able to pick up the statistics presented by the Novel Bias Task?

If they are, the NBT is structured to further study lexical-semantic deficits seen in children with low level language abilities and whether or not prior lexical and statistical learning shapes children’s attention: First, it could be used to study if *extraction of visual correlations underlying lexical-semantic categories is slowed by difficulty with extracting visual statistics*, and second, *that attention is shaped by prior extraction of statistical associations between perceptual category organization and statistical associations, perhaps resulting in deficits in attention characteristic of children with low language abilities.*

Chapter 2: Method

Participants

The included adolescents met the following criteria: (1) nonverbal brief intelligence quotient above 85 as measured by the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), (2) normal oral and speech motor abilities, (3) monolingual English speaking homes, and (4) a within normal score on Conners' ADHD DSM IV scale (Conners, 1991).

The study excluded any children who, by parent report, met any of the following conditions: (1) intellectual disability, (2) behavioral or emotional disturbances, (3) motor deficits or other frank neurological signs, (4) seizure disorders or use of medication to control seizures, or (5) clinical diagnosis or use of medication to treat attention deficit hyperactivity disorder (ADHD).

Per session protocol, children completed the Clinical Evaluation of Language Fundamentals 4 (CELF 4, Siemel, Wiig, & Secord, 2003), a measure of core language skills. Receptive and expressive vocabularies were examined using the Peabody Picture Vocabulary Test 4 (PPVT 4, Dunn & Dunn, 2007) and the Expressive Vocabulary Test 2 (EVT 2, Williams, 2007). Scores for each participant are indicated in the **Table 2.1** below.

Table 2.1 Participant Background

	Age[a]	***WASI***[b]	***CELF***[c]	***EVT***[d]	***PPVT***[e]
Mean		110.7143	112.2143	118.0714	118.0000
SD		10.7018	11.34208	11.83518	11.79961
Range	6;6 – 14;8	-1.20 SD-1.9 SD	-0.67 SD-1.53 SD	-0.27 SD-2.33 SD	-0.40 SD-2.67 SD

[a] Years;Months
[b] Wechsler Abbreviated Scale of Intelligence, Performance IQ (Wechsler, 1999)
[c] Clinical Evaluation of Language Fundamentals 4, Core Language (Semel et al., 2003)
[d] Expressive Vocabulary Test 2 (Williams, 2007)
[e] Peabody Picture Vocabulary Test 4 (Dunn & Dunn, 2007)

The ages of participants ranged from 6 years, 6 months to 14 years, 8 months. Children's WASI performance IQ scores ranged from 1.2 SD below the mean to 1.9 SD above the mean.

The CELF 4 Core Language Scores fell between 0.67 SD below the mean to 1.53 SD above the mean. On the EVT, children's expressive vocabulary ranged by 0.27 SD below the mean to 2.33 SD above the mean. According the PPVT, receptive vocabulary scores varied between 0.40 SD below the mean to 2.67 SD above the mean.

General Procedure

Instrumentation. The Novel Bias Task (NBT) utilizes the E-Prime computer testing system. Pictures to be used for the task were measured and drawn by a single individual to ensure consistency and avoid error. Responses to the task were recorded on score sheet by an assistant clinician as seen in **Figure 2.1** in Appendix A**.**

Animals were classified into 2 different categories depending on specific variables (which changed according to the desired target finding) for 2 different tasks. The general procedure involved children looking at the stimulus pictures on a computer screen. Each stimulus was associated with a corresponding novel phonological form (e.g. "This is a rif," presented at the time a "rif" was on the screen). Every fourth stimulus, children were asked a test question (e.g. "Is this a rif?") to which they responded "yes" or "no" based on learning during the task. One entire trial of the NBT consisted of 128 total pictures allowing 96 stimuli for learning and 32 for testing. Children's learning rates throughout the task, as evidenced by their responses to the 32 test questions, were examined. Modifications in the task and the stimuli between two separate tasks were used to investigate the contributions of visual statistical and attentional learning during a lexical semantic task in children with varying language abilities. Subsequent to each task, the following questions were asked to monitor each child's process of shaping their learning:

1. How could you tell what was a RIF and what was a DAX?
2. How sure are you?

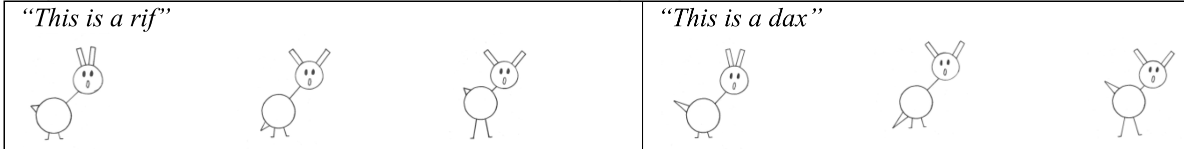
3. Did you think that way the whole time?
4. (If answer to #3 was "No") What did you think at first?

Stimuli. Artificial lexical-semantic learning tasks were used to investigate the role of visual statistical and attentional learning during lexical learning. The stimuli for these experiments were modifications of Younger's (1985) initial cartoon pictures. Younger's cartoon animals present visual features including: a tail, a neck, legs and ears. In the NBT, the neck, leg, and ear features vary on a scale of 1 to 5 for a single dimension (length, length, and placement, respectively), while the tail varies on 2 dimensions (length and placement). Children were exposed to different variations in the visual stimuli and a novel phonological form. The measurements used for length can be seen in **Table 2.2**. Provided in **Figure 2.2** are examples of the animals to illustrate the varying dimensions of length and placement.

Table 2.2 _Length Variations_ – For use with neck, legs, and tail

Dimension	Measurement
1	0.25 in.
2	0.50 in.
3	0.75 in.
4	1.00 in.
5	1.25 in.

Figure 2.2 _Example Stimuli_ – Varied dimensions of **length** (neck, legs, and tail) and **placement** (ears and tail)



"This is a rif"			*"This is a dax"*		
Tail length 1, *tail placement 2, ear placement1, neck length 4, leg length 1*	***Tail length 2,*** *tail placement 5, ear placement 2, neck length 4, leg length 2*	***Tail length 1***, *tail placement 1, ear placement 2, neck length 1, leg length 5*	***Tail length 4***, *tail placement 2, ear placement1, neck length 4, leg length 1*	***Tail length 5,*** *tail placement 5, ear placement 2, neck length 4, leg length 2*	***Tail length4***, *tail placement 1, ear placement 2, neck length 1, leg length 5*

Coding. One clinician administered the NBT via EPrime software while another clinician recorded the children's yes/no responses on the score sheet with paper and pencil. The variable of interest was the number of exposure trials needed for the child to reach 10 consecutive correct responses to the "test" stimuli. Correct responses were marked "√" and incorrect responses were marked "—." Up to three trials can be run in the event a child does not reach 10 consecutive correct in the first or second trial. Thus, if needed, the 128 stimuli can be viewed three times, providing 96 "test" exemplars.

It should be noted that the number of trials to reach the target criteria was recorded based on test questions. Thus, if a participant answered the first 10 test questions correctly, this would be recorded as achieving the desired criteria after 10 exemplars. However, the child has been exposed to 30 example stimuli and 10 test questions.

Category 1

Category 1 first examined if the NBT task can be used to study children's abilities to track visual regularities when learning meanings of novel word categories.

Procedure. Children were presented with a novel picture stimulus on a computer screen accompanied by a novel phonological word form (e.g. "This is a rif.") presented by a recording. Overall, two sets of stimulus pictures categorized by two novel words were represented (rif and dax). Exemplar picture-word combinations, chosen randomly from both categories, were presented in a controlled order. For purposes of consistency, the order remained the same for each participant. For every fourth stimulus picture, children were presented with a test question (e.g. "is this a rif?"). The following sets of directions will be presented on the computer screen and read verbally by the clinician prior to exposing the children to stimuli. Before beginning the experiment children will be advised: "You will see some cartoon animals on the screen. I will give you some clues on what they are called. Let's start!" After being exposed to three stimulus items, immediately before exposure to a test exemplar, children will be exposed to: "Let's take a guess." The computerized recording will then ask, "Is this a ____?" (Insert *rif, dax, mek, sim*). Intermittently throughout the task, children will be presented with: "Let's look at more cartoon animals!" The purpose of this statement is to keep the children motivated and engaged in the task as much as possible.

Children responded either "yes" or "no" to the test questions and responses were recorded by a second clinician on the score sheet (Figure 2.1).

Stimuli. The stimuli were the cartoon animals described in the general procedure above. For this particular study, the two categories are denoted "rif" and "dax." **Note:** In this study, the defining characteristic between the two categories (rif and dax) was tail length. A rif has a tail length from dimensions 1-2 and a dax will has a tail length from dimensions 4-5. Dimension 3 was unused in order to create some separation between the two categories. All other features (neck length, leg length, ear placement) varied among dimensions 1-5.

Category 2

We then investigated if the category learning that previously developed in Category 1 has an effect on the ability to re-direct attention and track new visual regularities (i.e. learn something different). In accordance with the ALA, the attentional bias formed in Category 1 should work to the child's advantage in Category 2 by helping to learn a new set of categories.

Procedure. Presentation of the stimulus items was identical to that in Category 1. However, children were exposed to new names for the stimuli they had already viewed, creating the need to establish two new categories (mek and dim). This manipulation allowed for the examination of if having previously learned that the feature essential for category inclusion had to do with a particular feature (e.g. tail properties) transferred to learning a new category boundary for which that feature was still essential but on a different dimension. In other words, did prior lexical learning teach children what perceptual cues to attend to in a novel learning situation?

Stimuli. Again, the stimulus items were those described in the general procedure. For this study, the two categories were denoted “mek” and “sim.” **Note:** In this study, the defining characteristic between the two categories (mek and sim) was tail placement. Thus, a characteristic that had no effect on the categorization in the first study then became the critical characteristic for categorization. A mek had tail placement in the upper two dimensions, while a sim will had tail placement in the lower two dimensions. Again, all other features varied among dimensions 1-5.

Chapter 3: Results

Category 1

The results of Category 1 are provided in **Table 2.3** below.

Table 2.3 Average number of exemplars needed to reach the criterion

	# Correct Participants[a]	Mean[b]	SD[c]
Category 1	7	19.1429	10.0404

[a] Number of participants who reached the criterion
[b] Average number of exemplars to reach criterion
[c] Standard deviation

Based on the original criterion of 10 consecutive correct, 7 out of 14 participants correctly completed the task in the first set of exemplars. The average number of exemplars to reach the criterion was 19.1429 with a SD of 10.0404.

To further examine the ability to extract visual patterns in relation to semantic learning, a comparison between participants who did and did not exhibit learning the category was prepared. **Table 2.4** provides the Mean scores and P-values that the children who completed NBT achieved on supplemental background tests.

Table 2.4 Participant Comparison

	Average for Participants Who Correctly Completed NBT	Average for Participants Who Incorrectly Completed NBT	P-value, T-test
Conners’[a]	49	51.4286	0.6199
WASI[b]	114	107.4286	0.2669
EVT[c]	121.8571	114.2857	0.2463
PPVT[d]	119	117	0.7649

[a] Conners’ ADHD DSM IV scale (Conners, 1991).
[b] Wechsler Abbreviated Scale of Intelligence, Performance IQ (Wechsler, 1999)
[c] Expressive Vocabulary Test 2 (Williams, 2007)
[d] Peabody Picture Vocabulary Test 4 (Dunn & Dunn, 2007)

As can be seen in Table 2.4. Children who learned the category did not have significantly different Conners, WASI, EVT or PPVT scores when compared to children who did not learn the category. This suggests that learning on the NBT task was not explained by attention, IQ or language abilities.

Category 2

The results of Category 2 are provided in **Table 2.5** below.

Table 2.5 *Average number of exemplars needed to reach the criterion*

	# Correct Participants[a]	**Mean**[b]	**SD**[c]
Category 2	8	17.375	5.153

[a] Number of participants who reached the criterion
[b] Average number of exemplars to reach criterion
[c] Standard deviation

Based on the original criterion of 10 consecutive correct, given the second set of exemplars, 8 out of 13 of participants correctly completed the task (One participant did not complete the second set). The average number of exemplars to reach the criterion was 17.375 with a SD of 5.1530.

Table 2.6 *Significance between the studies*

	Category 1	**Category 2**	**P-Value, T-test**
Mean to reach criterion	19.1429	17.3750	0.668591

As can be seen in Table 2.6, having learned a category before did not significantly improve learning of a second category**.**

Investigating a More Lenient Criteria

A subsequent investigation examined if whether or not the original criteria of 10 consecutive correct for the NBT was too stringent. Using the same participants, procedure, stimuli, and coding, the children's performance was rescored. **Table 2.6** presents the results of rescoring performance on the NBT given a more lenient criterion of 6 consecutive correct rather than 10.

Table 2.7 *Average number of exemplars needed to reach the criterion*

	# Correct Participants[a]	**Mean**[b]	**SD**[c]
Category 1	8	13.625	6.4794
Category 2	11	22.6364	21.3835

[a] Number of participants who reached the criterion
[b] Average number of exemplars to reach criterion
[c] Standard deviation

Based on the more lenient criterion of 6 consecutive correct, 8 of 14 participants correctly completed the task in the first set of exemplars. The average number of exemplars to reach the criterion was 13.625 with a SD of 6.4794. Given the second set of exemplars, 11 of 13 participants correctly completed the task (One participant did not complete the second set). The average number of exemplars to reach the criterion was 22.6364 with a SD of 21.38351.

Chapter 4: Discussion

This study set out to create a task where children extract visual correlation among features when learning novel word categories. Roughly half of the children exhibited learning of the category, half did not. Learning did not seem to be associated with attention, expressive and receptive vocabulary, and IQ. The results of the Novel Bias Task maintain that subsequent areas such as attention, expressive and receptive vocabulary, and IQ, have no effect on children's performance on tracking statistical regularities in the given task. In a comparison of the two different studies that exposed children to separate trials of different animals, there is no conclusive trend to signify whether or not learning has occurred from one study to the next.

As supported by the Novel Bias Task studies, it cannot be reasonably concluded that children are readily able to track the statistics presented by the NBT. Thus, through the previous experiments, it is not possible to ascertain our two hypothesis of first, *whether or not extraction of visual correlations underlying lexical-semantic categories is slowed by difficulty with extracting visual statistics* and further, *if attention is shaped by prior extraction of statistical associations between perceptual category organization and statistical associations.*

While in previous studies with babies, the ability to track visual statistics was evident via the looking time, the results from the NBT were not as conclusive. Given abundant exposure to stimuli and numerous attempts to correctly identify the exemplar, evidence does not support adolescents' collective ability to track the pattern presented by the NBT and explicitly respond correctly. In the results provided, an overall total of 8 of 14 children were tracking statistical associations during either the first or second task. In addition, children's performance on supplemental tasks (i.e. IQ, attention, expressive and receptive vocabulary), did not significantly correlate with those who did complete the task correctly.

A lower P-value on IQ comparisons between the groups who completed the task correctly and who did not complete it correctly may suggest the need for a larger sample of kids; those who completed the task correctly had slightly higher IQ's. However, a difference in IQ would not support the initial hypothesis that tracking visual statistics underlies lexical-semantic categories the way a difference in vocabulary would have. If this hypothesis were to be true, a significant P-value would exist between expressive and receptive vocabulary scores of the groups who did and did not complete the task correctly. As noted in the results, this is not the case.

Discounting the second hypothesis was the notion that only two children who correctly completed Category 1 improved on Category 2. Thus, it cannot be concluded that attention is shaped by prior extraction of statistical associations between perceptual category organization and statistical associations. While some children completed both tasks, and some were able to complete the second but not the first, evidence of learning can only be seen in the two individuals who correctly completed Category 1 and required lower amounts of exposure to the second set of exemplars to correctly complete Category 2.

To test the possibility that the original criterion of 10 consecutive correct was too stringent and as a result, unnecessarily prolonged the task, a more lenient criterion of 6 consecutive correct was used to re-score the participants performance. Performance on this follow-up study significantly improved: overall learning occurred for 12 of the 14 participants and 7 of 14 improved between the two tasks. The less stringent criterion allowed for more participants to complete the task, suggesting a possible flaw in the assessment as a whole.

Hypotheses were made to address the possible reason for the participants' trouble with the task. Most notably, the realization of misrepresented stimuli is concerning. While children were presented with three exemplars, each matched with its phonological novel word form, before each test stimuli, the presentation of test stimuli may present a critical issue. As claimed by the ALA, the learning environment provides correlations among object properties, linguistic devices, and perceptual category organization (Smith & Samuelson, 2006). In addition, children are empowered with the ability to learn lexical categories rapidly; as their knowledge of categories increases, statistical regularities and higher order generalizations emerge (Smith & Samuelson, 2006). Thus implicit statistical learning relies on the consistent and correct representation of the categories to be formed unconsciously. By presenting a particular test stimulus and pairing it with a test question that referred to the opposite stimulus, implicit statistical learning may be affected and children are perplexed (i.e. Showing a picture of a "rif" but asking the question, "Is this a dax?"). Unless the stimulus picture and word form correctly match, it cannot be assumed that children will pick up on the pattern and correctly sort the animals into categories.

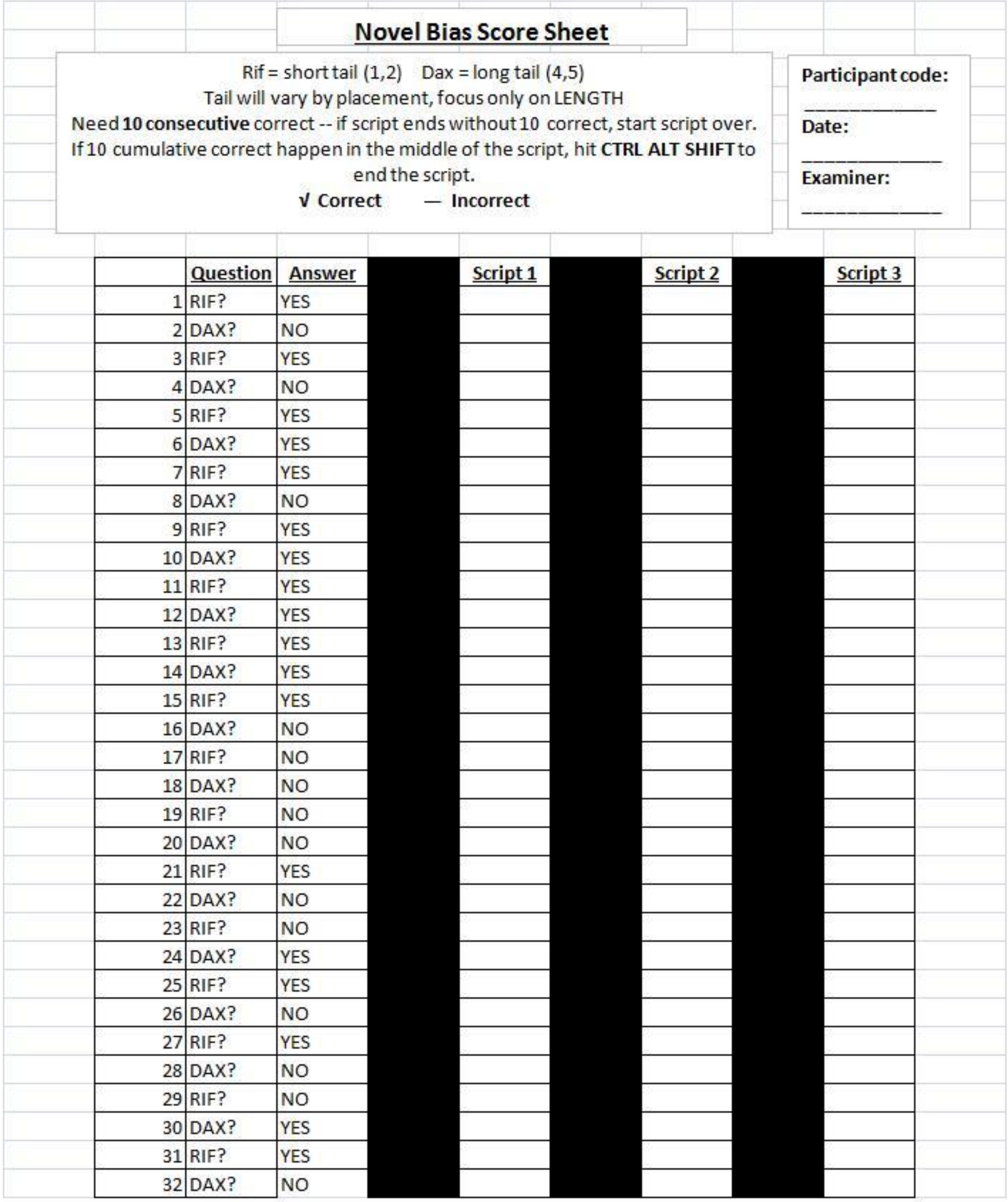
A potential way to correct this error is to present the child with a larger number of exemplars at the start of the task (i.e. 12 in a row) that are novel pictures each matched with the correct phonological word form. When a test exemplar is presented (i.e. a *rif)*, instead of asking if the picture *is* or *is not* a specific type of exemplar, the child should be asked: "What is this?" A clinician can record the child's answer to see if it matches the target answer. In this way, the child is able to formulate their own idea of the stimulus rather than focus attention on the picture and the potentially un-corresponding name given to it in the presented question as was previously the case.

A more general hypothesis to account for error could be the sample size used for the study. While the group who correctly completed the NBT also had slightly higher averages on all supplemental tests, no difference was large enough to be statistically significant. If completed over a longer period of time and given the ability to collect more participant data, results may present differently. Lastly, a variety of confounding variables may be somewhat responsible for performance on the NBT. It should be noted that all children came into the lab after the work-day and many came after school or other activities. Thus, undesirable performance may be contributed to lethargy and resistance to the tasks. Many children were uneager to complete the tasks and some flat-out guessed. Responses to the questions asked at the end of each study provide evidence for this claim. When asked if he used the same thinking throughout the task, one participant said, “No I guessed randomly.” Other participants were unwilling to complete the task and the session had to be cut short. Again, this may be due to the stringent criteria and its ability to either make children feel unsure of themselves and perhaps get bored.

While the results from the Novel Bias Task are not conclusive among a variety of variables, it cannot be proven that children in this age range are unable to track visual patterns similar to those used in this particular task. Subsequent tasks should consider the ideas presented in this discussion and make efforts to present the task, and especially the exemplars, in the clearest manner possible. By approaching this task differently, results may or may not answer the questions presented in this paper.

APPENDIX A: Instrumentation

Figure 2.1 *The Novel Bias Task Score Sheet*



Novel Bias Score Sheet

Rif = short tail (1,2)   Dax = long tail (4,5)
Tail will vary by placement, focus only on LENGTH
Need **10 consecutive** correct -- if script ends without 10 correct, start script over.
If 10 cumulative correct happen in the middle of the script, hit **CTRL ALT SHIFT** to end the script.
√ Correct   — Incorrect

Participant code: ____________
Date: _____________
Examiner: _____________

	Question	Answer		Script 1		Script 2		Script 3
1	RIF?	YES						
2	DAX?	NO						
3	RIF?	YES						
4	DAX?	NO						
5	RIF?	YES						
6	DAX?	YES						
7	RIF?	YES						
8	DAX?	NO						
9	RIF?	YES						
10	DAX?	YES						
11	RIF?	YES						
12	DAX?	YES						
13	RIF?	YES						
14	DAX?	YES						
15	RIF?	YES						
16	DAX?	NO						
17	RIF?	NO						
18	DAX?	NO						
19	RIF?	NO						
20	DAX?	NO						
21	RIF?	YES						
22	DAX?	NO						
23	RIF?	NO						
24	DAX?	YES						
25	RIF?	YES						
26	DAX?	NO						
27	RIF?	YES						
28	DAX?	NO						
29	RIF?	NO						
30	DAX?	YES						
31	RIF?	YES						
32	DAX?	NO						

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ACADEMIC VITA

Rachel Marie Marodi

Education

Bachelor of Science in Communication Sciences and Disorders, May 2011
Biology Minor
Schreyer Honors College
College of Health and Human Development
The Pennsylvania State University, University Park, PA

Research

Child Language and Cognitive Development Laboratory
Undergraduate Thesis: Creating an Attentional Bias in Children with Varying Language Abilities
Thesis Supervisor: Elina Mainela-Arnold, Associate Professor of Communication Sciences and Disorders.

Leadership

Teaching Assistant (2009-2010) for Mammalian Anatomy (BIOL 129)
CIU#10 Development Center for Adults, State College, PA. Literacy Corps *Certified ESL Tutor*
Treasurer (2009-2010) of *Vole*--the Penn State Ballet Club

Awards

Dean's List for all completed semesters
Health and Human Development Honors' Society