INVESTIGATING TO WHAT DEGREE INDIVIDUAL DIFFERENCES IN LANGUAGE AND EXECUTIVE FUNCTION ARE RELATED TO ANALOGICAL LEARNING IN YOUNG CHILDREN ACROSS SOCIO-ECONOMIC POPULATIONS

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DISSERTATION ABSTRACT

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Analogical reasoning is a foundational skill necessary for enabling learners to draw inferences about new experiences, to transfer learning across contexts, and to make abstractions based on relevant information from daily experiences. Linguistic and executive function (EF) skills may support analogical reasoning ability, as both these skill sets have previously been shown to influence other higher-order cognitive abilities, such as perspective taking. Outside influences such as socio-economic status (SES) backgrounds may also influence analogical reasoning, as they have been shown to affect other cognitive processes. At present, current research offers little information about developmental relations among SES, language, EF and analogical learning. The purpose of this dissertation research was to explore the extent to which the provision of relational language facilitates children's analogical reasoning, and to investigate the influence of SES, executive function and language skills in regard to such facilitation. Results indicate that the use of relational language indeed aids analogical reasoning. SES significantly predicted analogical reasoning, but interestingly, this was so only when relational language was absent. These findings support that relational language plays a key role in scaffolding analogical reasoning, and this support is particularly beneficial to children whose cognitive skills may be influenced by SES.

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DEDICATION

To Baby Coco for the final push - this was because of you.

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CHAPTER I

INTRODUCTION

As children grow and mature, they gain increasing sophistication at noticing and connecting similarities across situations and in engaging in analogical reasoning by transferring information from one context to another. This ability is imperative for higher-order functions that range from word learning, conceptualization, and making predictions, to creative thinking and persuasion (Genter, 2002; Gentner, & Colhoun, 2010; Holland, Holyoak, Nisbett & Thagard, 1986). Concurrently, developing processes of executive function and language emerge. The timing and simultaneous development of analogical reasoning, language and executive functions provide impetus for inquiry into their interactions in children's development. Little is yet known regarding relationships among these foundational skills or ways in which outside influences, such as home environment, might change their dynamics.

The present studies were designed to investigate children's ability to discover analogical relations, on the one hand, and possible relationships between children's analogical reasoning, language and executive skill, on the other. The possible outside influences measured in the study relate to differences in socio-economic status (SES) backgrounds and possible individual differences associated with the underlying mechanisms of language and executive function. Chapter 1 of this dissertation presents discussion elaborating on the significance of the questions guiding the research and what the existing literature has revealed on the topic. Chapter 2 reports on an effort to replicate previously documented benefits of novel language for enhancing analogical reasoning using a between-group design in the real-world setting of a children's museum. In this research I also asked whether analogical reasoning of children of varying SES differ in analogical reasoning ability. Chapter 3 reports research investigating a subsequent methodical question that arose in the museum-setting regarding the potential value of a within-subjects design in measuring effects of relational language on analogical reasoning. Chapter 4 considers the influence that individual differences in executive function and language skills have on analogical reasoning. Finally, Chapter 5 provides a general discussion of the overall findings across studies and potential implications for future research.

Why is analogical reasoning important?

Analogical reasoning is a foundational skill necessary for enabling learners to draw inferences about new experiences, to transfer learning across contexts, and to make abstractions based on relevant information from daily experiences (Gentner, & Colhoun, 2010; Richland, Morrison & Holyoke, 2006). This comparative process of analogical reasoning is imperative for higher-order functions that range from conceptualization, projection, induction, and making predictions, to creative thinking and persuasion (Genter, 2002; Gentner, & Colhoun, 2010; Holland, Holyoak, Nisbett & Thagard, 1986). Historically, analogies and analogical reasoning can be found in all domains. For example, in literature Dante compared living life to a journey (Alighieri, 1935); this analogy generated common phrases such as a career being "derailed" or "off-course." In some religions, the concept of God as Father is a prevalent analogy to make the deity more accessible and relatable to human existence. In science, analogies are often harnessed to communicate theoretical notions such as black holes and subatomic particles, concepts that refer to non-obvious entities. Similar examples exist in politics and law, dating back to the days of Socrates and Aristotle. Within cognitive science, there has been longstanding interest in understanding the cognitive processes underlying analogical reasoning, as well as the acquisition of this important skill in children's development. The focus of the current studies was on analogical learning in the field of cognitive development and how analogical reasoning develops over time, specifically in early childhood.

Beginning even in infancy, analogical reasoning is the process of comparison among stimuli or environmental input, including instances of words, pictures, etc., regardless of modality or domain. In this comparative process, a recognition of commonalities across two different entities occurs and produces a new level of understanding of each, but especially of the more novel item in the comparison. A classic illustration of analogy compares the solar system to an atom. Often in school children learn about the solar system beginning in elementary school. Later in schooling, children are introduced to subatomic structures of an atom. Constructing an analogy between the two domains demonstrates sensitivity to physical, perceptual similarities of round, central objects, such as the sun and the nucleus, as well as to relational similarities, such as laws of attraction in revolving planets and electrons (Gentner, 1983).

This process of comparing and aligning features has been investigated in some detail. Gentner and colleagues have articulated a theoretical account of the processes involved, which they refer to as Structure Mapping Theory (SMT; Forbus, Gentner & Law, 1995; Gentner, 1983;2005; Gentner, & Colhoun, 2010). SMT characterizes the subcomponents of analogical reasoning including: analogical retrieval (thinking of related events or items stored in long-term memory), analogical mapping (comparing two events while holding them in working memory), making inferences (evaluation of the analogy and its inferences) and, finally abstracting the common structure (what can be learned; Gentner, 2002; 2005; 2010; Gentner & Lowenstein, 2002). Analogical reasoning underlies higher-order cognitive functions which are the basis for acquiring new information and therefore vital for learning, cognitive development, and academic success (Holland, Holyoak, Nisbett & Thagard, 1986; Gentner, & Colhoun, 2010).

Structure Mapping Theory. According to structure mapping theory, while interacting with the environment and taking in information, elements and events in one's experience are compared and contrasted over time. Common features are attended to and, early on in development, similarities can be noted across multiple dimensions and at a variety of levels. Young children often are predisposed to note perceptual similarities but increasingly discover, or can be prompted to discern, deeper, relational similarities (Namy & Gentner, 2002; Gentner, Anggoro, & Klibanoff, 2011; Kurtz, Gentner & Boukrina, 2013). With enough consistency and highlighting of common features, structure mapping occurs and global alignment across analogical components is achieved, meaning the newly formed mental representations have enough structural stability to be deployed for future use (Gentner, 2005;2010; Gentner, & Colhoun, 2010; Gentner & Lowenstein, 2002), such as in projection, inference and prediction (Gentner & Christie, 2010; for a full account of a computational model (SME) inspired by Structure Mapping Theory, see Gentner 1983, 2005 and 2010).

Structural alignment is a key process within Structure Mapping Theory; it entails highlighting structural commonalities between two events and then drawing inferences based on the alignment of similar and different features (Gentner, 1983; 2010; Christie &

Gentner, 2010). For the alignment to take place there must be both one-to-one correspondence and parallel connectivity between events and objects being compared (Gentner, 1983; 2010; Christie & Gentner, 2010), meaning the feature of one object aligns with the feature of another leading to a connection between the two. Lastly, the structural alignment process elicits the formation of abstract commonalities based on inferences constructed during alignment, which in turn results in learning, in the sense that new, higher-order, relational knowledge has been achieved. In this sense, analogical reasoning generates learning, and for this reason the terms analogical reasoning and analogical learning are often used interchangeably, as will be the case in this dissertation.

Networks of connections. A final component of SMT is the systematicity principle. This principle is an internal bias for converting the connection of lower-ordered events (such as perceptual experiences) into higher-ordered structures (such as abstractions). The systematicity principle posits an implicit preference for coherence between lower- and higher-ordered events in that the alignment of the lower, local matches results in deeper, structurally consistent alignments. Then, the common systemic abstractions coming from the alignments can be used for projection, prediction, re-representation, difference-boosting and further inference (Gentner & Christie, 2010). Using comparison is a type of lens through which people learn by relating and recognizing new problems as an instance of a previously learned concept (Goldwater & Schalk, 2016). Learners align similarities amongst known concepts and match the new instance with the previously experienced ones resulting in more efficient learning. Matching multiple similarities simultaneously leads to stronger inferential power and more accurate conclusions, thus increasing knowledge over time (Gentner & Christie, 2010; Goldwater & Schalk, 2016). In particular, analogical reasoning can help children make connections between different concepts and link newly encountered knowledge to well-established prior knowledge (Gentner & Lowenstein, 2002). The power is, then, in the linking and networking of concepts that form the lens through which learners view the world.

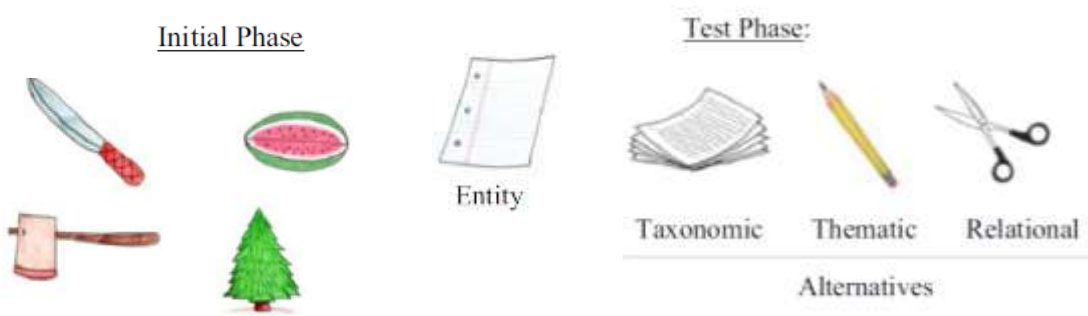
To summarize thus far, these theoretical foundations have established the important role that analogical reasoning in general, and structural alignment processes in particular, play in children's conceptual development and in human abstraction and learning more broadly. Interestingly, another body of research demonstrates that language is a powerful force for potentiating analogical reasoning. The principal idea here is that language provides a vehicle for encoding the relational structures derived through analogical reasoning; thus, for learners, the presence of a new word can invite discovery of relational structures not yet discerned in the absence of such language (Gentner, Simms, & Flusberg, 2009; Gentner, Anggoro & Klibanoff, 2011). As well, linguistic encoding of specific relational structures can be utilized by learners to scaffold the cognitively effortful deployment of these relational structures.

One study demonstrating the power of language in this regard presented children with novel relational nouns (Gentner, Anggoro & Klibanoff, 2011). Here it is worth noting that this research was conducted with a typically-developing, mid-to-higher SES population (Gentner, 2017). Relational nouns are more complex than object nouns in that they do not name a specific entity but rather a relation between objects; for example, the word *barrier*, which is relational in the sense that it refers to an object that stands between two other objects. Across three experiments, the authors tested 3-year-olds, 4-5-

year-olds and 6-year-olds on the effects of using relational language (RL; experiment 1), comparison with and without RL (experiment 2) and progressive alignment with and without RL (experiment 3). In experiment one, children were first shown two object picture cards that were perceptually dissimilar but conceptually related, for example a watermelon and a knife. One group had the addition of a novel relational vocabulary label. For example, children were told “The knife is the *dax* for the watermelon.” The other group simply heard “The knife goes with the watermelon.” Children were then asked to match a noun (paper) with four choices (baseball bat, scissors, pencil, pile of papers), one of which was the object:operator match (scissors). In experiment 2, which is the basis for my dissertation, the same procedure was conducted with one change in the addition of a second exemplar to allow more opportunities to compare (see Figure 1). In particular, children saw the knife and the watermelon as well as an ax and a tree. In the third experiment, structural alignment was further scaffolded in providing two pairs of the object:operator for a total of four exemplars.

Figure 1.

Analogical learning stimuli



The results of experiment 1 showed 6-year-olds were able to successfully make relational matches in every condition with and without RL. Four-to-five-year-olds performed better than the control group only in the relational language condition, thus confirming that the presence of relational language scaffolded children's abilities to reason analogically. In experiment 2, while comparing 2 exemplars, 4-5-year-olds were able to successfully make relational matches with and without RL, providing support for the idea that multiple opportunities to compare helps clarify the object:operator relation. Only in experiment 3 in the progressive alignment condition (4 exemplars) were 3-year-olds able to correctly identify the relational object:operator match with the use of RL. Overall, the pattern of findings confirmed that relational language and multiple opportunities to compare aid children most in making analogical connections.

The contribution of language and multiple exemplars clearly support analogical learning but it is also important to consider what other possible contributing cognitive processes may be operating. There is evidence to suggest that analogical reasoning is cognitively effortful and requires executive skills, such as inhibition and selective attention, to keep high-order relations in mind while inhibiting attention to lower-order features (Richland, Morrison, & Holyoak, 2006). Language may enhance the ability to retain attention to higher-order relations, thereby easing the executive demand required. In what follows, I will review evidence bearing out the plausibility of these links between EF, analogical reasoning, and language.

What developmental processes may be at work during analogical reasoning?

Executive function includes skill sets such as self-regulation, working memory, attentional control, task initiation, task-switching/shifting, inhibition, planning and problem-solving strategy selection; collectively these skills are imperative for developing higher order function (Anderson & Reidy, 2012). For example, children utilize inhibitory control for more efficient analogical reasoning and conceptual integration (Richland, Morrison, and Holyoak, 2006). Because of their centrality to cognitive development, EF skills are critical for, and predictive of, school readiness and future academic outcomes (Anderson & Reidy, 2012; Pellicano, Kenny, Brede, Klaric, Lichwa & McMillin, 2017). Three core factors of EF development have been identified as central to school readiness -- working memory, shifting, and inhibition (Welsh, Pennington & Groisser, 1991; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000; Zelazno & Muller, 2002) and will be the focus of the current project.

During analogical learning, working memory may be utilized to keep relevant information active. Both the familiar information of prior knowledge and also the novel features of the new entity must be held in mind. During this process, mental shifting is activated to determine what features are relevant between incoming stimuli, and also between the prior and novel information. Finally, inhibition may be at work suppressing attention to superfluous information and the unrelated features of the novel stimuli. Children may also utilize inhibitory control for more efficient analogical reasoning and conceptual integration. Together, working memory, shifting, and inhibition may contribute to the process of analogical learning.

EF skills develop concurrently with vocabulary and there is a strong association between the two during the preschool and early school years (Weiland, Barata & Yoshikawa, 2014; Gooch, Thompson, Nash, Snowling, and Hulme, 2016). Both language and EF skills are crucial for learning, though the evidence is still developing on the intricacies of EF development. For example, EF skills at the beginning of preschool are significant predictors of later vocabulary but the reverse is not true (Weiland, Barata, & Yoshikawa, 2014). Relatedly, in a longitudinal study on both language and EF skills, EF skills predicted later attention while language skills did not (Gooch, Thompson, Nash, Snowling, and Hulme, 2016).

One central skill of both language and EF skills is processing speed. One line of thought is that processing speed subserves both skills, in that their roles are dependent on how processing speed functions (Tanner, 2009). Studies on the relation between processing efficiency and language demonstrate that more rapid processing correlates with more vocabulary growth (Fernald, Marchman & Weisleder, 2013). Gradual increases in processing speed lead to enhanced long-term cognitive and language functions (Salthouse, 1996). One proposed mechanism is that increased processing speed strengthens working memory, which in turn strengthens language and other higher-order cognitive skills (Fry & Hale, 1996).

Interestingly, SES has been shown to have implications for both language development as well as developing EF (Ursache & Noble, 2016). Thus, it is plausible to expect SES to affect children's developing ability to engage in analogical reasoning. As yet, however, to my knowledge this possible relationship has not as yet been directly investigated. In what follows, I make the case for investigating these issues directly.

What may be the influence of socioeconomic status on developing skills?

Roughly 43% of children in the United States live in low-income households and 21% of those children live in poverty (Jiang, Granja & Koball, 2017). Children from poorer households are disproportionately affected by factors that influence language, cognition, social and emotional processing (Hair, Hanson, Wolfe, & Pollak, 2015). For example, children of lower SES have less developed self-regulation that supports school readiness (Blair & Raver, 2015). Specific instances include less developed attentional control, reduced language skills, as well as reduced ability to regulate emotion and stress, and less engagement in positive social interactions. Additionally, children of lower SES reflect less on information, learning, and their experiences, which influences academic achievement (Blair & Raver, 2015). Of particular interest is that children of lower SES have less developed cognitive skills of language and executive function compared to peers of higher SES (for review, see Ursache & Noble, 2016).

SES and Executive Function. Several studies have demonstrated that children from lower SES perform worse on almost all aspects of EF relative to their higher SES peers (Noble, McCandliss, & Farah, 2007; Sarsour, Sheridan, Jutte, Nuru-Jeter, Hinshaw, & Boyce, 2011; Raver, Blair, Willoughby, 2013). Specifically, children who spend more years in low-income environments display reduced performance on tasks assessing working memory, attentional set shifting, and inhibitory control, making poverty itself a predictor of executive function (Raver, Blair, Willoughby, 2013). Additionally, race and SES have been shown to indirectly affect academic achievement through EF (Nesbitt, Baker-Ward & Willoughby, 2013). As such, the combination of EF and lower SES can influence the development of other cognitive skills, such as language.

SES and Language. Lower SES has been associated with less developed language skills including vocabulary size (Biemiller & Slomin, 2001; Lee & Kim, 2012), comprehension (Dickinson & Smith, 1994), processing efficiency (Fernald, Marchman & Weisleder, 2013), syntax use, conceptual knowledge and reading fluency (Dickinson, 2011). The SES achievement gap often reflects vocabulary and background knowledge differences over time (Bradbury, Corak, Waldfogel, & Washbrook, 2015). Children from less advantaged backgrounds have less-developed vocabularies and make fewer gains over time than children from more advantaged backgrounds (Biemiller & Slomin, 2001). Even when children from lower and higher SES begin school with the same language abilities, children of higher SES make more progress regardless of whether they began with high, moderate or low language in kindergarten (Bradbury, Corak, Waldfogel, & Washbrook, 2015).

SES differences have been seen in language processing from infants (Fernald, Marchman & Weisleder, 2013) to adults (Pakulak & Neville, 2010). Recent research has focused on investigating underlying mechanisms of vocabulary acquisition, such as processing speed. For example, starting as young as 18 months, significant differences in language proficiency and processing speed have been found between infants of lower and higher SES (Fernald, Marchman & Weisleder, 2013). Additionally, at 24 months, there was a six-month gap between the two groups. These differences and other cognitive differences are predictive of later academic achievement (Lee & Burkam, 2002; Blair & Raver, 2015). Yet despite the well-documented gap between children from poorer families and their higher SES counterparts, only small improvements have been made in supporting them academically. There has been a call to foster vocabulary in the early years to better support children of lower SES (Biemiller & Slomin, 2001). Supporting language development in children from lower SES background may have the added benefit of facilitating their cognitive development by helping to enhance their analogical reasoning skill.

Dissertation Aims

The overarching objective of this project was to assess children's analogical learning ability and explore its relation with their developing language and executive function skills. The primary goals of the dissertation were to 1) test for replication of Gentner's findings in the local community, and 2) investigate the extent to which individual differences in language and executive function correlate with children's analogical reasoning ability. A secondary aim was to explore the extent to which analogical learning differs for children from lower vs higher SES backgrounds in a socio-economically diverse sample.

To this end, the following specific aims included:

Study # 1 Aim: Does novel relational language aid analogical reasoning?

The primary goal of Study 1 was to replicate the previously documented benefit of relational language for enhancing analogical reasoning using a between-group design. In a museum setting, I compared the use of relational language (versus no label) on performance of analogical learning tasks in children between the ages of 4 and 6. It was hypothesized that relational language will aid analogical reasoning, as shown in past research (Gentner, Anggoro & Klibanoff, 2011), in that participants in the relational language condition of that research scored higher on analogical reasoning than participants in the no label, control group. A secondary prediction was that SES would be positively correlated to children's ability to provide relational matches, in that children from higher SES would make more relational matches.

Study # 2 Aim: Is there a potentially more powerful methodological design for studying analogical learning ability?

The primary aim of Study 2 was to test for replication of the Gentner, et al. (2011) findings in the context of a within-subjects design in order to ascertain whether this design would be appropriate to utilize in an individual differences context. In a museum setting, I compared the use of relational language versus no label on performance of the analogical learning tasks within the same children, targeting the ages of 4 and 6. It was predicted that there would be an overall effect of relational language and children would score higher on analogical reasoning in the relational language condition than when experiencing the no label condition.

Study # 3 Aim: What is the influence of executive function and language skills on individual differences in analogical learning?

The main objective of Study 3 was to explore relations between analogical reasoning, executive function and language skills. Thus, I analyzed individual differences among these factors for 4- and 5-year-olds in both a relational label and a no label condition within the same children. In the interest of examining SES to address the secondary aim, I incorporated SES into these analyses as a potential contributing factor. Consistent with past research, I predicted that children would benefit from relational language to guide analogical reasoning relative to when no label was available, due to the novel relational label highlighting relational commonalities. I also expected to find significant correlations among language, executive function and analogical learning in both conditions. At the same time, however, I expected stronger correlations in the relational language condition than in the no label condition; I hypothesized that EF and language skills would be more effectively engaged with the addition of relational language.

CHAPTER II

STUDY 1: A BETWEEN-GROUP EXAMINATION OF RELATIONAL REASONING IN THE MUSEUM CONTEXT

Previous research by Gentner et al. (2011) investigated the extent to which novel relational labels enhanced children's analogical reasoning relative to when no labels were provided. As stated in Chapter 1, one of the primary goals of Study 1 was to attempt to replicate the previously documented benefit of relational language for enhancing analogical reasoning. A second goal was to determine whether the effect would generalize to a broader socio-economic population. In past research, analogical reasoning typically has been studied in mid-to-highly educated populations, such as university students (Novick, 1988), or with children of well-to-do families living near university communities (Gick & Holyoak, 1983; Gentner, 2017). A final goal was to assess whether the relational language effect would persist outside of a lab setting. Research on analogical reasoning has typically been conducted in well-controlled environments, such as quiet laboratory settings. In recent years there has been a move to include a wider variety of settings for studying analogical learning, like classrooms (Vendetti, Matland, Richland, and Bunge, 2015) and children's museums (Gentner et al., 2015). In sum, the goals of the study were to replicate and extend current findings by including a more diverse sample in terms of socioeconomic background in the real-world setting of a children's museum. As in Gentner et al. (2011), I used a between-group design.

Methods

Participants

Children between 4 and 6 years of age participated in ten-minute sessions at the Eugene Science Center (formerly the Science Factory; ESC). Families were approached to participate in the study if there was a child who appeared to be in the appropriate age range but because of the guidelines of the ESC, any child who wished to could participate in the activity, meaning that parental consent was not needed in order for children to participate. However, data were retained for analyses only when a parent or guardian provided informed consent. The fact that all children interested would participate also meant that children from a wide range of ages completed the task. Overall, 60 children who were visiting the ESC with their families participated in the task but only data from 24 children in the targeted age range were analyzed. Because of another ESC guideline, completion of the parent survey was optional. As a result, data regarding children's age, SES, and even gender were in some cases missing.

Participants in the between-subjects design in the targeted age range (n = 24, F = 15) included 5 4-year-olds, 9 5- year-olds, and 10 6-year-olds. The between-subjects design included two conditions and two age groups. Similar to the Gentner et al. (2011) studies, children were grouped as 4-5-year-old and 6-year-olds. There were no significant differences in age ($F(1,23) = 0.47$, $p = .502$) or gender (X^2 $(1, N = 24) = 0.46$, $p = .831$) between the two conditions.

Table 1.

Study 1 Ages in Months in Between-Subjects Museum Study by Condition and Age Grouping

	No Label			Relational Language		
	n	*M*	*SD*	*n*	*M*	*SD*
4-5-year-olds	8	60.63	7.51	6	63.30	6.72
6-year-olds	5	77.00	4.30	5	77.00	1.64
Total	13	66.92	2.88	11	69.64	8.81

Materials and Procedure

Data collection followed the model advocated by the National Living Laboratory (http://livinglab.org/), whereby scientists recruit participants within the context of a local museum and conduct their interviews or experimental sessions among the exhibits on the museum floor in order to engage families in science and encourage one-on-one conversations with researchers. Thus, a Living Lab station was set up on the main floor of the ESC where I invited children to complete the analogical learning task. At the time of assent, research assistants asked parents to complete the consent form, a brief survey on socio-demographic information and the study vocabulary checklist. The museum's abbreviated testing time included the child Analogical Learning paradigm and the caregiver *MacArthur Sociodemographic Questionnaire* and study vocabulary checklist (parent surveys are available in Appendices C and D).

Child Measures.

Analogical Learning paradigm – This task assessed children's learning of relational concepts (experiment 2 in Gentner et al., 2011). The task involved showing children two pairs of cards depicting familiar relations, such as the relation that holds between house to man, and nest to bird. To ensure children were familiar with the pictures, the researcher asked the child to point to each object picture as it was named. If they did not know a given object name, then the researcher would point to the correct item and repeat the word. Any unknown words were recorded (See Appendix A for the analogical learning record and Appendix B for a full list of stimuli). Then the children were shown a new object picture and asked to choose a match from one of 3 options. One option was the correct relational match while the other incorrect options were a perceptual match and a thematic match. For example, cards depicting a nest and bird as well as a house and a man (both depicting 'a home for') were shown to the child. The child would then be shown a dog and 3 options: a doghouse (relational), a bone (thematic), and another dog (perceptual). The particular wording of the question depended on the condition (Relational Language vs No Label). Children participated in a total of nine trials.

Children were randomly assigned to either the Relational Language group or the No Label group. Children in the Relational Language group received a novel label for the relation such as *dax*. For example, "The house is the *dax* for the man and the nest is the *dax* for the bird." Children in the No Label group heard "The house *goes with* the man and the nest *goes with* the bird". During test, when asked to find the (relational) match, children in the Relational Language group heard "What is the *dax* for the dog?"

(doghouse). Children in the No Label group heard “What *goes with* the dog?” during test. Following Gentner et al., (2011), the stimuli were presented in a fixed order with a set word list to decrease any variations in the procedure (See Appendices A and B for fixed set order and 9 sets of stimuli). For the original description, see Gentner, et al. (2011) supplemental materials. A relational match score in each condition was calculated for each child in terms of the percent of relational matches over the nine trials.

Caregiver Measures.

*MacArthur Sociodemographic Questionnaire (*MSQ*)* – This caregiver report measure consisted of 12 items that address socioeconomic status and subjective social status (Adler, Stewart, et al., 2007; See Appendix C). Of particular interest were 9 items on maternal education and occupation as factors for determining socioeconomic status on the Hollingshead scale. This measure yields scores that ranges from 8 – 66 (Hollingshead, 1975). Of the 24 child participants, 21 had SES data provided by parents which yielded a mean SES score of 47.93 (*SD* = 11.22; range = 25.00 – 66.00), and considered a mid-to-high-SES sample.

Demographic Information – These caregiver report questions asked about ethnicity, race, marital status, size of household and parental status.

Study vocabulary checklist – Children’s vocabulary knowledge for items included in the study was assessed with a parent checklist for two major reasons: a) to control for possible artifacts in SES differences that I might find with respect to analogical reasoning performance, and b) to utilize vocabulary knowledge as a covariate in analyses of children’s analogical reasoning. That is, I wanted to examine the degree to which children from lower and higher SES might differ with respect to familiarity with the items, because that might affect their relative success in choosing relational matches, rather than reflecting their a) analogical reasoning, per se, and/or b) their use of novel labels to facilitate analogical reasoning. Parents were given a list of the 60 words that were used in the study such as bird, nest, bone, etc. and were asked to indicate the words that were already familiar to their child (See Appendix D for the full list of study vocabulary).

Results

The primary question guiding Study 1's between-groups design was the degree to which replication would emerge with respect to Gentner et al.'s (2011) findings that relational labels facilitate young children's relational reasoning. As predicted, children indeed displayed an overall higher percentage of relational matches in the relational language condition (M = 61.61, SD = 34.20; n = 11) relative to the no label condition (M = 38.46, SD = 24.27, n = 13). The relational responses in the Relational Language condition were significantly above 33% chance ($t(10) = 2.76$, $p = .020$) while the No Label condition yielded no significant difference from chance ($t(12) = .812$, $p = .433$).

Age Differences

Similar to the original work on relational learning conducted by Gentner et al., the current study investigated age differences among 6-year-olds as one group and 4-to-5-year-olds as another. To do so, a 2 x 2 between-subjects ANOVA was conducted that examined the effect of age and condition on relational response. A significant main effect of condition, $F(1, 20) = 4.64$, $p = .044$, $\eta^2_p = 0.19$, 95% CI [0.0, .45], was revealed, and in looking at the table of means (Table 4) and Figure 2, both 4-5-year-olds and 6-year-olds displayed a higher percentage of relational matches in the Relational Language condition relative to the No Label condition. No significant main effect of age, $F(1, 20) = 0.81$, $p = .378$, $\eta^2_p = 0.04$, 95% CI [0.0, .27], nor a significant interaction was found, $F(1, 20) = 2.58$, $p = .124$, $\eta^2_p = 0.14$, 95% CI [0.0, .37]. Nonetheless, only 6-year-olds in the Relational Language condition were significantly above 33% chance ($t(4) = 3.54$, $p = .024$).

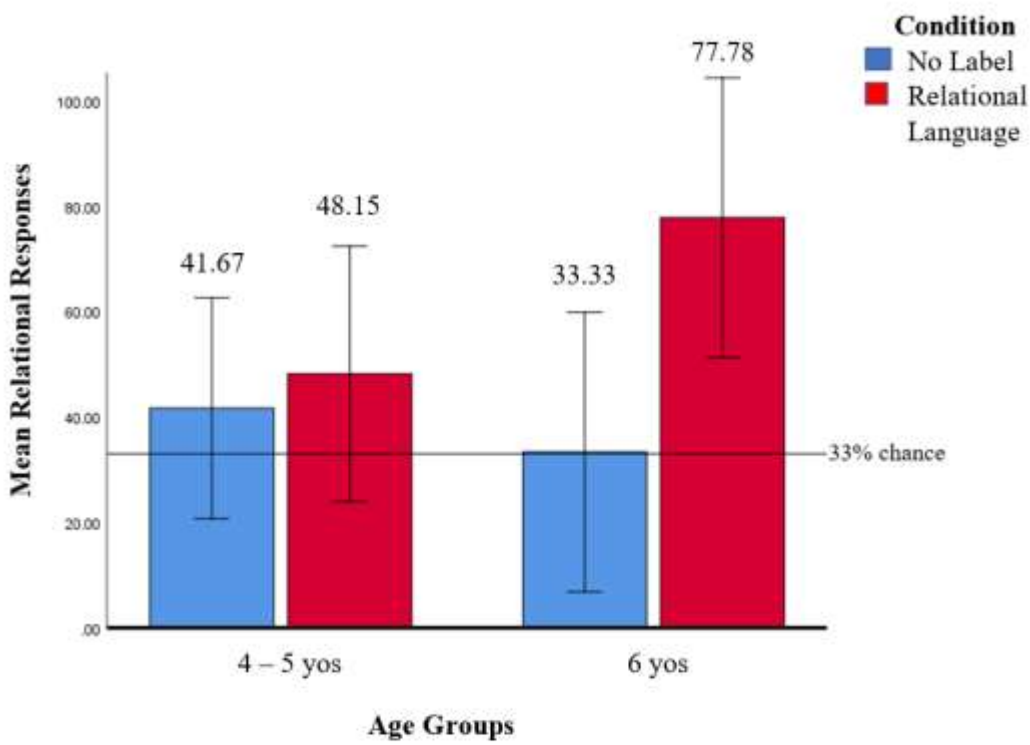
Table 2.

Means, Standard Deviations, and Sample Sizes for Relational Responses by Age and Condition

	No Label			Relational Language		
	n	*M*	*SD*	*n*	*M*	*SD*
4-5-year-olds	8	41.67	21.21	6	48.15	34.90
6-year-olds	5	33.33	30.43	5	77.78	28.33
Total	13	38.46	24.27	11	61.62	34.20

Figure 2.

Study 1 Distribution of Relational Responses from Children Across Age and Condition. Error bars represent 95% CIs.



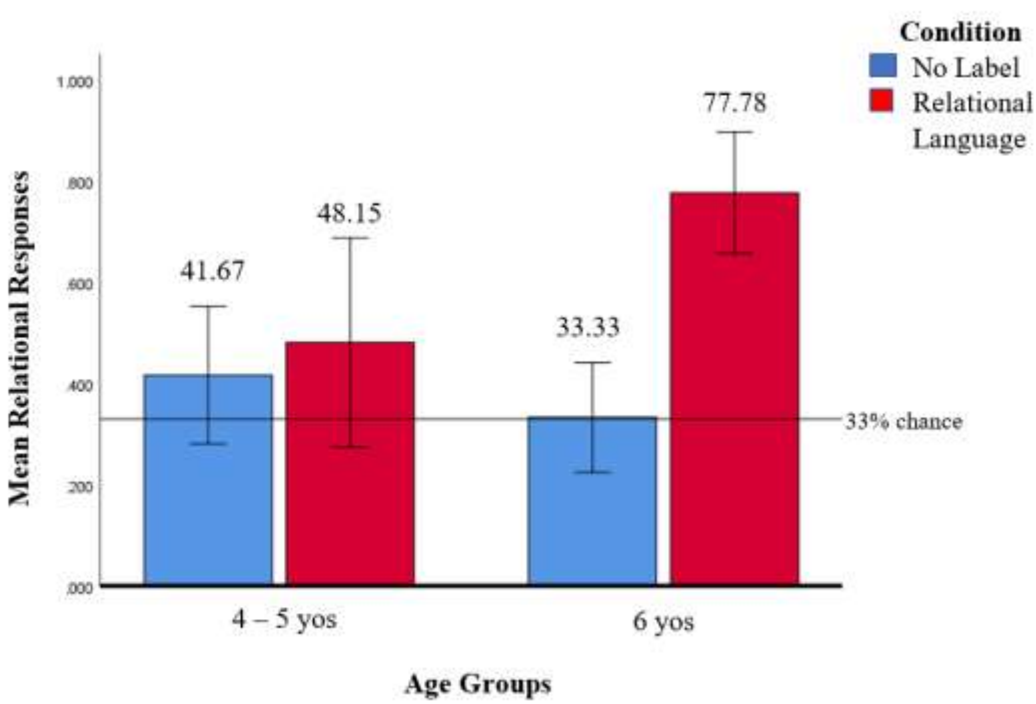
Item Analysis

Another question one could ask is the extent to which effects of relational language generalized across the stimulus sets (rather than across participants, as was the focus of prior analyses). A 2 x 2 within-subjects ANOVA was conducted that examined the effect of age and condition on relational responses across the 9 stimuli used in the experiment (collapsing across participants). The ANOVA revealed a significant main effect of condition, $F(1, 8) = 9.17$, $p = .016$, $\eta^2_p = 0.53$, 95% CI [.02, .75] with more relational matches in the Relational Language condition relative to the No Label condition, and a significant main effect of age, $F(1, 8) = 7.91$, $p = .023$, $\eta^2_p = 0.50$, 95%

CI [.01, .73] with 6-year-olds making more relational responses than 4-5-year-olds. There was also a statistically significant interaction between the effects of age and condition on relational responses, $F(1, 8) = 14.68$, $p = .005$, $\eta^2_p = 0.65$, 95% CI [.10, .81]. A follow-up analysis of simple effects showed that 6-year-olds scored significantly higher in the Relational Language condition compared to No Label condition ($p < .001$; See Figure 3). Among 4-5-year-olds, there were no significant difference between the two conditions ($p = .622$). Additionally, 6-year-olds scored significantly higher than 4-5-year-olds in the Relational Language condition ($p = .001$), but no significant difference was found between 4-5-year-olds and 6-year-olds in the No Label condition ($p = .240$).

Figure 3.

Study 1 Item Analysis Distribution of Relational Responses Across Age and Condition. Error bars represent 95% CIs.



When collapsed across age, subjects performed in the predicted directions on 8 out of 9 stimuli sets, (p = .020 one-tailed). 6-year-olds performed in the predicted direction on all 9 stimuli sets (p =.002) while 4-5-year-olds performed in the predicted direction on 7 out of 9 stimuli sets (p = .090). Even with the small sample sizes utilized in this study, these findings provide support for a relational language effect.

Is Socioeconomic Status Related to Analogical Learning?

Correlations between SES and the proportion of relational choices on the analogical learning task were also computed while controlling for vocabulary (of words found in the study as assessed in the parent interview) in both the Relational Language and No Label conditions. As it turned out, no systematic relations were found in either the RL condition (r = -.13, p = .763) or in the NL condition (r = -.47, p = .150). As well, the results indicated effects in the negative direction, contrary to the original prediction. It may be that the small sample size of 21 is not powerful enough to detect relations to SES.

Discussion

Relational Language Support

The between-subjects patterns of responses in Study 1 generally replicated results from the original Gentner, et al. (2011) work on the power of relational labels to facilitate children's ability to make deeper-level relational matches rather than relying on more superficial features such as in thematic or perceptual relations. A significant condition effect found in analyzing participant data controlling age supported the beneficial use of relational labels versus no labels. We found a stronger effect in 6-year-old children in the Relational Language group who performed significantly above chance, while 4- to 5-year-old children did not. Perhaps with a larger sample than the one collected in the museum study, the predicted result in 4-5-year-olds would reach significance. Even with small sample sizes, robust findings of the item analyses supported the effect of labels versus no labels in making relational matches. Again, 6-year-olds performed better in the Relational Language condition than in the No Label condition, supporting the use of relational labels. Thus, the initial hypothesis of Study 1 predicting an overall effect of relational language was supported. Further, the study extended the original findings to a non-lab context (museum setting) and to a broader SES population.

In contrast, the prediction that SES would be related to children's ability to provide relational matches was not supported; that is, no systematic relationship between SES and percentage of relational matches emerged in either of the two conditions. Of course, sample sizes in this museum study were small, smaller than the original studies, making the lack of systematic relationship between SES and relational matches difficult to interpret. Further examination of possible relations will be important in future research with larger sample sizes, such as in Study 3.

CHAPTER III

STUDY 2: INVESTINGATING A POTENTIALLY MORE POWERFUL METHODOLOGICAL DESIGN FOR STUDYING ANALOGICAL REASONING IN A MUSEUM SETTING

A methodological research aim for Study 2 arose during initial data collection regarding the design of the analogical learning paradigm. As described in the introduction section, the Gentner, Angorro and Klibnaoff (2011) study employed a between-subjects design with two conditions: relational language support and no label. My committee and I discussed taking advantage of the fast pace of data collection at the museum to test for replication of these findings with both a between-subjects design, as reported on in the previous chapter, as well as with a within-subjects design. Within-subjects designs have the benefit of greater statistical power than between-subjects designs (given the same sample size) and are thus highly advantageous for developmental research given the challenge of achieving large samples in research with children.

As well, given my goal to examine individual differences in analogical reasoning, it was thought beneficial to employ a within-subjects design to obtain a measure of individuals' tendency to respond to relational language support. Thus, the primary aim of Study 3 was to test for replication of the Gentner, et al. (2011) findings in the context of a within-subjects design in order to ascertain whether this design would be appropriate to utilize in an individual differences context. Results from the within-subjects design in the museum setting helped to shape Study 3, the in-lab study on individual differences (reported on in Chapter 4).

Methods

Participants

Participants in the within-subjects design in the targeted age range (n = 17) included 9 4-year-olds (*M* = 51.89 months, *SD* = 0.89), 7 5- year-olds (*M* = 65.29 months, *SD* = 1.63), and 1 6-year-old (*M* = 64.00 months). Given just one 6-year-old participant, the 6-year-old's data were not included in analyses. While consent was provided for each child, only 10 out of 17 parent surveys included SES data due to parents skipping the relevant questions or declining to answer the entire survey; therefore, no statistical analyses were conducted with SES.

Materials and Procedure

Identical to the between-subjects design in Study 1, the museum's abbreviated testing included the child Analogical Learning paradigm and the caregiver *MacArthur Sociodemographic Questionnaire* and study vocabulary checklist. The general procedures and stimuli of Study 2 were similar to Study 1 with the main differences being that 1) children received <u>both</u> the Relational Language and No Label conditions in the within-subjects design, and 2) each condition included 4 trials, instead of 9. I counter-balanced order of condition across participants such that roughly half of the children (n = 7) experienced the No Label condition first and roughly half (n = 9) experienced the Relational Language condition first. The four trials in each condition were presented in a prearranged, randomized order (see Appendix E for an example). From the original set of 9 stimuli in the between-subjects design, one stimulus set was removed in order to have an equal number of trials in each condition.

The decision regarding which stimulus set to remove was based on examination of results midstream through data collection in the between-subjects design. Inspection of grand means for all stimulus sets displayed a ceiling effect in the majority of children making a relational match with the stimulus set comprised of the train, car and boat (see Appendix F for midstream, item response totals). Thus, this stimulus set offered little opportunity for a condition difference to emerge, and was selected for elimination,

Results

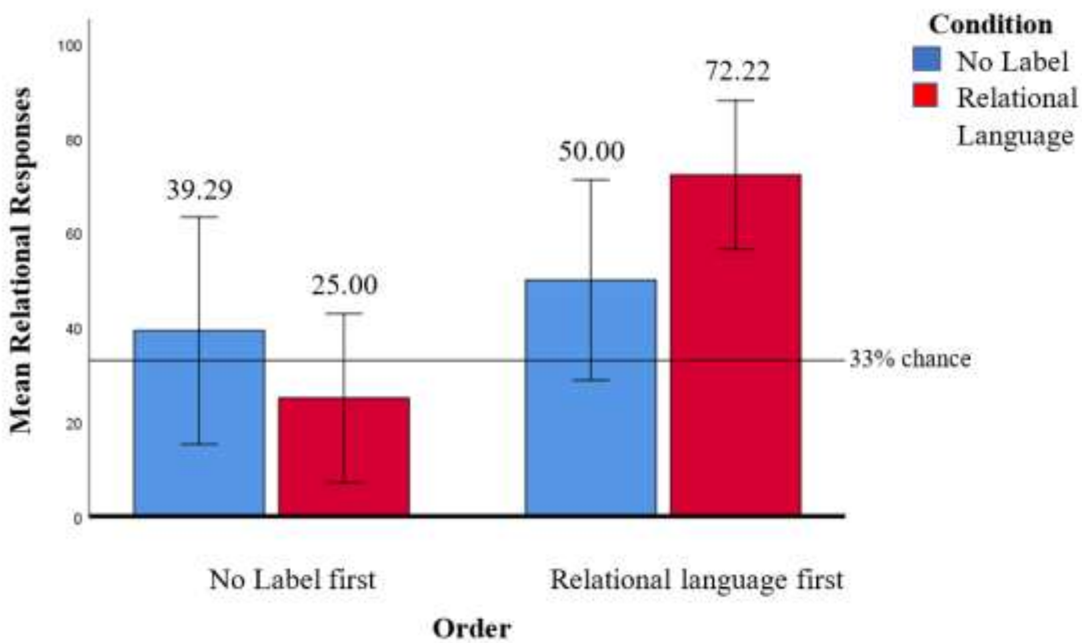
To recap, in Study 2 I investigated whether the Gentner et al. 2011 findings would replicate when a within-subjects design was utilized, with children participating in both the Relational Language and No Label conditions. The conditions were counter-balanced across subjects yielding a factor of condition and a factor of order. A mixed factorial ANOVA was conducted with order as the between-group factor and condition as the within-subjects factor. The ANOVA revealed a significant main effect of order, $F(1, 14) = 6.95$, $p = .020$, $\eta^2_p = 0.33$, 95% CI [.01, .59] with children displaying a significantly higher percentage of relational choices when the Relational Language condition came first ($M = 72.22$, $SD = 19.54$) than when it came second ($M = 25.00$, $SD = 25.00$). The ANOVA also revealed a non-significant main effect of condition, $F(1, 14) = 0.30$, $p = .593$, $\eta^2_p = 0.02$, 95% CI [0.0, .28]. However, a significant interaction between condition and order emerged, $F(1, 14) = 6.32$, $p = .025$, $\eta^2_p = 0.31$, 95% CI [0.0, .57] indicating that the pattern of results differed depending on the order of conditions that each child received.

A follow-up analysis of simple effects showed the percentage of relational choices differed significantly between orders for the Relational Language condition (*p* =

.001), but not for the No Label condition (p = .485; see Figure 4). Furthermore, there was a significant difference in percentage of relational choices between the Relational Language and No Label conditions when the Relational Language condition came first (p = .036), but not when the No Label condition came first (p = .211).

Figure 4.

Study 2 Mixed-design Relational responses in the Relational Language and No Label conditions by Order. Error bars represent 95% CIs.

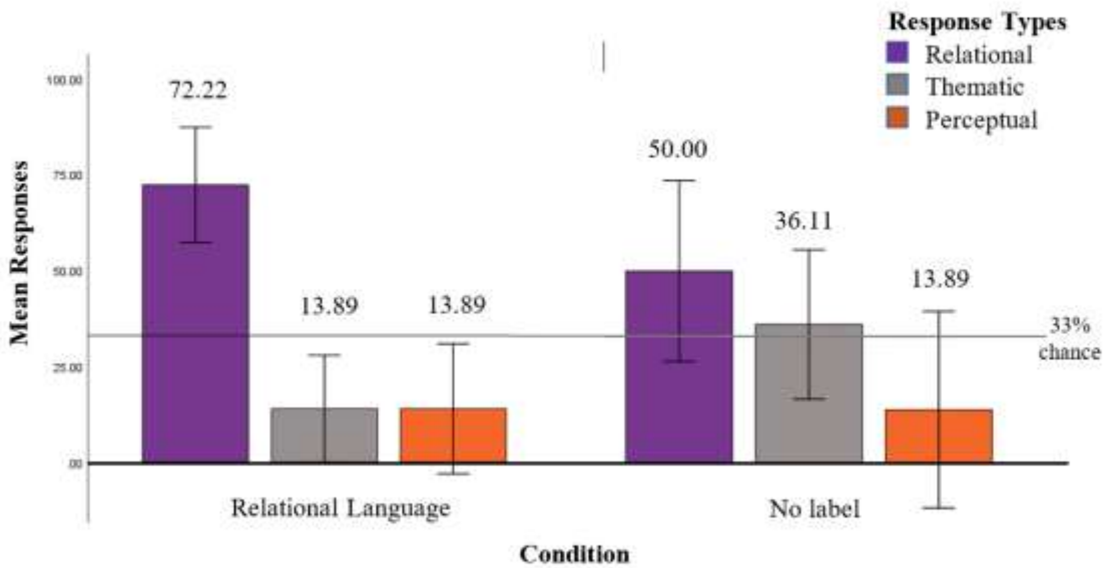


Relational Language Condition First

Given the significant carry-over effect of order revealed by the first ANOVA, it was of interest to examine the pattern of choices children made when relational language support occurred first in their experience, versus when it occurred after the no label condition, and whether these response patterns significantly differed from chance. As seen in Figure 5, when children received the Relational Language condition first, they made more relational matches (72%) than either thematic (14%) or perceptual (14%) matches in that condition. Relational responses were significantly above 33% chance ($t(8) = 6.02$, $p < .001$). In looking at the following No Label condition, these same children also displayed more relational (50%) matches than thematic (36%) or perceptual (14%) matches. However, relational matches in this condition did not significantly exceed chance levels, ($t(8) = 1.67$, $p = .134$).

Figure 5.

Study 2 Within-subjects All Response Types in Relational Language then No Label condition. Error bars represent 95% CIs.



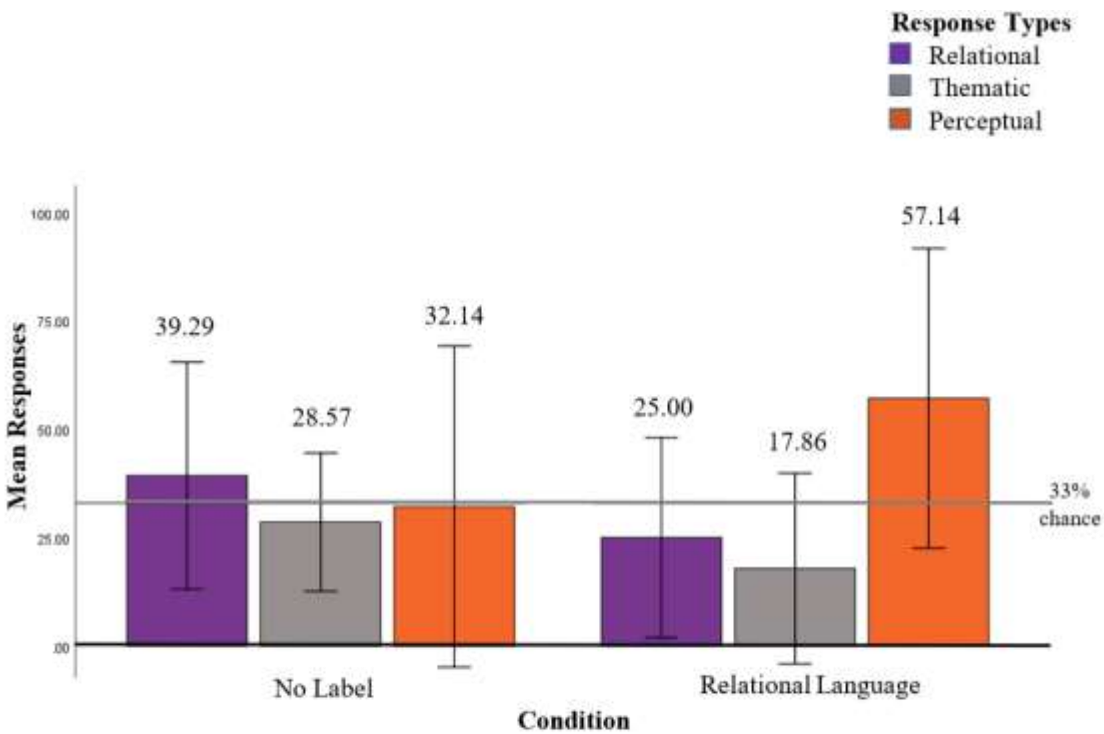
No Label Condition First

In contrast, when children participated in the No Label condition first (see Figure 6), a quite different pattern of responses emerged. The distribution of responses in the No

Label condition was relatively even among relational (39%), thematic (29%) and perceptual matches (32%), as is consistent with past research and the between-subjects results of the No Label condition in Study 1 discussed in the previous chapter. In this condition, the relational matches did not differ from chance, ($t(7) = 0.13$, $p = .899$). When relational labels were subsequently introduced, children displayed 25% relational matches, 18% thematic matches, and 57% perceptual matches. As in the No Label condition, relational matches in the Relational Language condition did not differ from chance levels, ($t(7) = -0.98$, $p = .361$). In sum, children who experienced the No Label condition first seemed to have generally persisted in their initial pattern of responding which did not favor relational choices, even when they later experienced the Relational Language condition. In contrast, children who experienced the Relational Language condition first showed a strong tendency to favor relational matches when they had the support of relational language; but losing that support in the No Label condition undercut their ability to focus on relational matches.

Figure 6.

Study 2 Within-subjects All Response Types in No Label then Relational Language condition. Error bars represent 95% CIs.



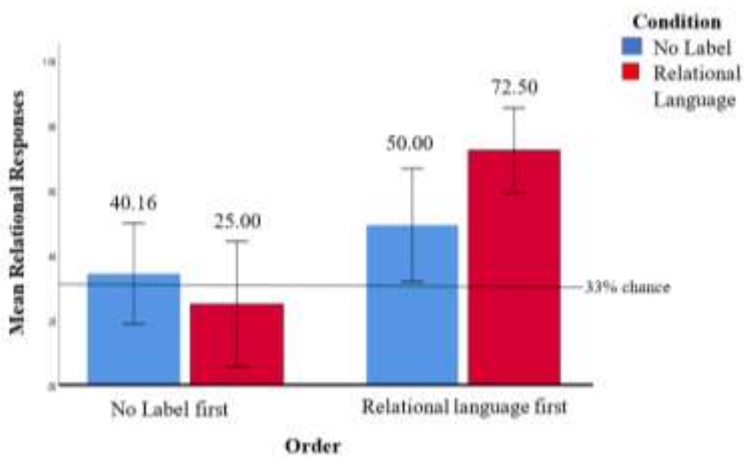
Item Analysis

To assess whether the order difference generalized across items as well as participants, an item analysis was conducted. Since all eight items were used across both conditions and orders, a 2 x 2 within-subjects ANOVA examined the effect of order and condition on relational responses across the 8 stimulus sets used in the experiment. Similar to the participant results reported above, the ANOVA revealed a significant main effect of order, $F(1, 7) = 5.14$, $p = .058$, $\eta^2_p = 0.42$, 95% CI [0.0, .69] with children displaying a significantly higher percentage of relational choices when the Relational Language condition came first than when it came second (see Figure 7). The ANOVA also revealed a non-significant main effect of condition, $F(1, 7) = 0.76$, $p = .412$, $\eta^2_p = 0.10$, 95% CI [0.0, .47]. As well, there was a statistically significant interaction between order and condition on relational responses, $F(1, 7) = 42.07$, $p < .001$, $\eta^2_p = 0.86$, 95% CI [.43, .92] indicating, similar to the analyses reported above, that the pattern of results differed depending on the order of conditions that children experienced.

Simple effects tests showed a significantly higher percentage of relational choices in the Relational Language condition when this condition came first (72%) rather than second (25%; $p = .001$), but order of condition had no significant effect on percentage of relational matches in the No Label condition ($p = .096$). More importantly, the percentage of relational choices in the Relational Language condition was significantly higher than that in the No Label condition both when the Relational Language condition came first ($p = .002$) and when the No Label condition came first ($p = .048$). However, the only case in which relational matches significantly exceeded chance levels was when children experienced the Relational Language condition first, $t(7) = 7.17$, $p < .001$.

Figure 7.

Study 2 Item Analysis Distribution of Relational Responses by Order and Condition. Error bars represent 95% CIs.



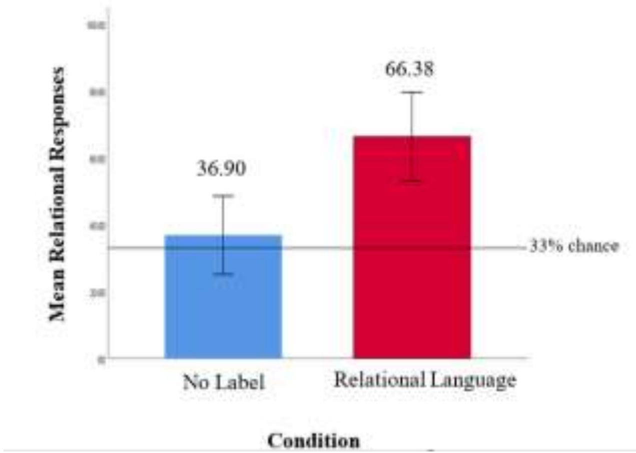
Combined Analysis of Participant Data

In looking only at the condition children received first in Study 2, a statistically significant difference was found between relational responses (72% in Relational Language first vs 39% in No Label first) in the two conditions, $t(15) = -3.14$, $p = .007$). These first condition-only results of the within-subjects design replicated findings from both the Gentner et al. (2011) results and the between-subjects design I presented in Study 1 (Chapter 2). In this next section I compared and combined the first conditions of the within-subjects design of Study 2 with the between-subjects results in Study 1.

In order to increase the sample size and statistical power of combined responses between the within-subjects first condition and the between-subjects study, response percents were utilized to aggregate the data, similar to what was used in previous analyses. Raw values were not used since there were different numbers of trials used in the two studies. The within-subjects first condition consisted of four trials and the between-subjects study was 8 trials. Therefore, a response percent was used as the dependent variable. As predicted, in the combined dataset children indeed displayed a higher percentage of relational matches in the Relational Language condition ($M = 66.38$, $SD = 28.38$; n = 20) relative to the No Label condition ($M = 36.90$, $SD = 25.81$, n = 21; see Figure 8). The relational responses in the Relational Language condition were significantly above 33% chance ($t(19) = 5.26$, $p < .001$) while the No Label condition yielded no significant difference from chance ($t(20) = .69$, $p = .496$). Since there were no 6-year-olds in the within-subjects design, a 2 x 2 between-subjects ANOVA could not be conducted as in Study 1. Instead, a one-way between-groups ANCOVA with age as the covariate and percent relational matches as the dependent variable revealed a significant main effect of condition ($F(1, 38) = 11.85$, $p = .001$; $\eta^2_p = 24$, 95% CI [.04, .43]), indicating that relational language provided a systematic boost to children's analogical reasoning relative to how they performed when no label was offered (see Figure 8).

Figure 8.

Study 2 Combined Between-subjects and First Condition of Within-subjects Responses. Error bars represent 95% CIs.



Discussion

Both a within-subjects and a between-subjects design were tested at the Eugene Science Center to gauge the appropriateness of a within-subjects design for investigating children's use of relational language to support analogical reasoning. The findings from the within-subjects design replicated prior findings based on a between-subjects design (e.g., Gentner, et al. 2011 and my Study 1 reported in Chapter 2) when the order included the relational language condition first. That is, children displayed an overall higher percentage of relational choices when relational language was provided relative to when no relational language was offered. As well, when findings from children's first trial from the within-subjects design were combined with the findings from the between-subjects design – thus boosting overall power – analyses revealed that relational language provided a systematic boost to children's relational reasoning relative to when no label was provided.

However, a clear carry-over effect also emerged in the within-subjects design of Study 2: A significant benefit of relational language only emerged when children experienced the relational language condition first. When they experienced the no label condition first, they did not display increased choice of relational matches when subsequently hearing relational labels in the relational language condition. Thus a "cognitive set" established in the no label condition seemed to carry over to shape their responding in the relational language condition. Similar results were found in the item analysis in that more relational matches were made in the Relational Language condition when the Relational Language condition came first. Thus, a within-subjects design seems to be somewhat problematic as a vehicle for investigating children's reliance on relational language to support their relational reasoning.

As described, only one order of conditions (the Relational Language condition first followed by the No Label condition) replicated past patterns of results reported by Gentner, Anggoro & Klibanoff (2011). As a result of this, I opted to give all children the Relational Language condition for the individual differences-oriented Study 3 (in-lab sessions). I also decided to include the No Label condition after a short break in which another behavioral measure, the Head-Toes-Knees-Shoulders activity, occurred, in the hope that this break would interrupt any possible "cognitive set" already established in the Relational Language condition. The focus of Study 3 was to investigate the extent to which individual variability on other factors (e.g., SES, executive function skills, processing speed, general language ability) might correlate with children's ability to utilize relational language to support relational reasoning. Thus, it was important to assess children’s performance in both the Relational Language and No Label conditions in Study 3, The findings from this individual differences study are reported in the following chapter.

CHAPTER IV

STUDY 3: INVESTINGATING INFLUENCES OF SES, EXECUTIVE FUNCTION AND LANGUAGE ON INDIVIDUAL DIFFERENCES IN ANALOGICAL REASONING

In Study 3, the primary goal was to build on the findings of the within-subjects design from the previous chapter in a more extensive study investigating factors affecting individual differences in analogical reasoning for 4- and 5-year-olds in both a relational language and no label condition. Specifically, the research is the first to explore the extent to which individual differences in language skills and executive function correlate with children's analogical learning ability. By considering potential contributors to analogical reasoning, such as language, processing speed, and executive function skills (including working memory, inhibition, and task switching) the research may inform theory concerning, and future studies regarding, the development of analogical reasoning.

Specifically, I predicted that children would benefit from relational language to guide analogical reasoning relative to when no label was available consistent with past research, due to the novel relational label highlighting relational commonalities. I also expected to find significant correlations among language, executive function, SES, processing speed and analogical learning in both conditions. At the same time, however, I expected stronger correlations in the relational language condition than in the no label condition; I hypothesized that EF and language skills would be more effectively engaged with the addition of relational language.

Methods

Participants

A power analysis calculated in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) suggested a sample size of 84 with desired power of .80 (Cohen, 1969). The full battery of behavioral tests and surveys described below was administered to 92 four-to-five-year-olds and their caregivers who were recruited from both the Team Duckling database and Head Start sites in Lane County in order to collect a sample of varying SES for in-lab behavioral testing sessions. Of the 92 children who participated, two were involved in pilot testing and three were excluded due to either refusal to complete the tasks, or behaviors that interfered with task completion, such as hyper-activity or severe speech impediments. For the 87 child participants whose data were satisfactorily collected (see Table 3 for age and gender statistics), one set of parent data was not saved due to human error so 86 parent surveys were collected.

81.6% of parents identified their child's race as Caucasian, 2.3% as Asian, 1.1% as American Indian or Alaska Native, 1.1% as Native Hawaiian or other Pacific Islander, 10.3% as Other, and 3.4% Not provided. As well, 7% of the total sample identified their child's ethnicity as Hispanic or Latino.

Table 3.

Study 3 Age and Gender of Child Participants

Age	*M (SD)*	F	M	Totals
4	*52.89 (3.57)*	28	29	57
5	*65.40 (3.62)*	18	12	30
Totals	*57.21* (6.96)	46	41	87

Note. Mean ages in months within each group are presented in italics and standard deviations are presented in parentheses.

Materials

Child Measures. Both computerized and pencil-and-paper tasks were utilized during child assessments. Some measures were conducted on an Ipad using the *Early Childhood Cognition Measures* Toolbox from the National Institute of Health (NIH; http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox) with data saved on a secure server and then transferred for analysis purposes. Other assessments were non-computerized and recorded on paper by the researcher. Both types of assessments are as described below.

Analogical Learning paradigm – This task, the same described in Chapter 2, was used to assess children's learning of relational concepts (experiment 2 in Gentner, et al., 2011). As a reminder, the task involved showing children two pairs of picture cards depicting familiar relations, like bird and nest, and man and house. To ensure children were familiar with the pictures, the researcher asked the child to point to each object as it was named. If they were not familiar with the object picture, the researcher pointed to the correct item and repeated the word. Any unknown words were recorded. The children were then shown a new object picture and asked to choose a match that shows the same relation. The researcher then recorded the child's response.

Given the findings from Study 2, children first received the Relational Language condition and then the No Label condition in that order. One difference from the museum procedure as reported in Chapter 3 was a brief intermediary break with the HTKS activity (see below) between the two analogical conditions to attempt to alleviate any carry-over effects.

Executive Function

NIH Toolbox Flanker Task is an attention/inhibition test that contributed to an overall measure of executive function (EF). The task asked children to pay attention to a central focus on an iPad screen, in this case the center fish. The screen displayed a row of five fish in a horizontal row in which the center fish is the focus. Children were expected to inhibit the direction of the four, peripheral fish and report the direction of the center fish, as either left or right, by touching a left or right arrow. Some trials were congruent with all fish facing the same direction while on other trials the fish direction was incongruent with the middle fish pointing the opposite direction of the four, peripheral fish. Children completed a familiarization phase in which the tester demonstrated 6 trials. Then children completed 4 practice trials independently with corrective feedback. Finally, they completed 20 fish test trials. This measure yielded a raw accuracy score for correctly choosing which direction the middle fish is pointing. For participants who scored more than 80% correct, response time was calculated and combined with an accuracy score. If participants answered 90% of trials correctly, then they advanced to 20 trials of a more abstract arrow-only stimuli (selecting the direction of the center arrow among 4 peripheral arrows). The task generally lasted 5-7 minutes.

NIH Toolbox Dimensional Change Card Sort (DCCS) is a task that contributed to an overall measure of EF in measuring mental switching/shifting. Participants simultaneously viewed one central image displayed on the top half of the iPad screen and were asked to chose one of two options displayed on the bottom half of the screen to make a visual match based on a specific dimension (color or shape). For example, participants may have seen a white rabbit as the target and were asked to match either a brown rabbit or a white sailboat. In one phase, participants were asked to match based on shape (i.e., Touch the one which…). Then in the next phase, they were asked to match based on color. They completed a familiarization phase in which the tester demonstrated 2 trials of each dimension. Then participants completed the practice phase of 4 trials of each dimension, and finally completed a test phase of 5 trials of each dimension. If participants completed both the color and shape trials successfully, then they completed a test phase of 20 trials in which both dimensions were intermixed. This measure yielded a raw accuracy score for correct matches. As in the Flanker task, for participants who scored more than 80% correct, response time is calculated and combined with the accuracy score. This task generally lasted 3-5 minutes.

Head-Toes-Knees-Shoulders (HTKS) – This task measured inhibitory control and contributed to an overall measure of EF. Children were asked to follow the researcher's directions to touch a body part, such as touching their toes or head (McClelland & Cameron, 2012). After following the directions for 4 trials, children were then instructed to do the opposite of the stated directions. This change was explained in detail by the researcher. For example, children were told to touch their toes but expected to touch their head. Participants completed 6 practice trials with the "opposite" directions. During the test phase, children completed 10 tasks of (opposite) head or toes. Next children were asked to (normally) touch their shoulders and knees. After following the (normal) directions for 4 familiarization trials, children were then instructed to do the opposite of the stated directions. They completed 6 practice trials of the "opposite" directions with shoulder and knees. In the second test phase, children were asked to continue doing the opposite of the given instructions with either head, toes, knees or shoulders as options.

Children completed 10 items in this test phase. Overall, children completed the task until either all 20 items were completed or 3 errors were made in a row. Scores were calculated based on the 6 practice trials from the first phase and the 20 test items, earning 0-2 points with a possible high score of 52. Zero points were earned if a child touched the incorrect body part, 1 point was earned if a child self-corrected an initial mistake, and 2 points were earned for a correct response. This task generally lasted 4-7 minutes.

Corsi Block Tapping Test – This task is a measure of visuo-spatial working memory, another contributing component of EF. In the first Forward phase, children were asked to tap blocks in a pattern that was modeled by the researcher. Children began with two trials of a familiarization phase in which the tester demonstrated tapping one block and the child copied the action. Next, children completed a practice phase with corrective feedback in which they copied two blocks that the tester had just demonstrated. Finally, during test children began with two blocks and increased in number to a maximum of nine, unless 2 or more consecutive errors were made. Children had two attempts on any given trial. In the following Backward phase, children were asked to reverse the pattern demonstrated by the tester. Similar to the first phase, children completed a practice phase with corrective feedback in which they touched two blocks in the reverse order that the tester had just demonstrated. During the test phase children began with two blocks and increased in number to a maximum of nine, unless 2 or more consecutive errors were made. Children had two attempts on any given trial. Working memory span is defined as the highest level at which the child correctly reproduces at least one sequence with a possible range of 0 to 9 for forward span and 0-7 for backward span (Farrell Pagulayan, Busch, Medina, Bartok, & Krikorian, 2006). Forward span is typically a measure of short-term memory while Backward span is thought of as a measure of working memory. Therefore, the backward span scores were utilized in the analyses. This task generally lasted 3-5 minutes.

Language measures

NIH Toolbox Picture Vocabulary Test (PVT) contributed to an overall language measure. The task is an adaptive vocabulary and verbal IQ test in which four images at a time are displayed on an Ipad screen as a word is said aloud. Children are asked to touch the picture that represents the announced word. Children received two practice trials before starting the testing period. Correct answers were followed by increasingly difficult words and incorrect answers were followed by easier words until 25 items were completed. This measure yielded a raw accuracy score for correct matches. The task generally lasted 3-5 minutes.

Clinical Evaluation of Language Fundamentals (CELF) *Preschool 2* – This assessment is designed to measure children's language and communication skills and contributed to an overall language measure. For this study, I used the Language Content scale composed of three different subscales: Expressive Vocabulary, Concepts & Following Directions and either Basic Concepts (4-year-olds) or Word Classes-Total (5-year-olds) to fully assess semantic knowledge including vocabulary, concept and category development, understanding of associations among words, and interpretation of information (Wiig, Secord & Semel, 2004). For each task, participants completed a familiarization phase, practice phase with corrective feedback and then test as described below. The CELF generated a raw total score. Each task generally lasted 3-5 minutes.

Expressive Vocabulary is a task in which children looked at a picture and responded to questions such as ‘What is this?’ or ‘What is the _____ doing?’ to identify an object, person or activity in an image. Children completed 1 familiarization demonstration, 2 practice trials and 20 test trials. Children earned 0-2 points based on the thoroughness of their answers for each item.

Concepts & Following Directions is a task in which children identified objects in response to given directions asking them to interpret, recall, and execute given commands of increasing length and difficulty that contain concepts of functional language. For example, when looking at a group of 5 animals, children were asked to point to the monkey. A more difficult example is among a group of 6 animals, children were asked to point to the big monkey, the little bear and the second fish, in that order. Children completed 2 familiarization trials, 2 practice trials and 22 test trials. Scores were either 0 or 1 for accuracy in the responses on the test trials.

For the third CELF subscale of the Language Content Index, children received either the Basic Concepts task, if they were 4-year-olds, or the Word Classes-Total task, if they were 5-year-olds.

Basic Concepts is a task in which 4-year-old children identified objects in response to given directions about dimension/size, direction/location/position, number/quantity, and equality concepts. For example, researchers pointed to each picture and said “Look at these children. This is a baby. The baby is little. This is a girl. She is little, too. And this is a boy. The boy is big. Look at the children again. Point to the one who is big.” Children pointed to their response. Children completed 1 familiarization trial, 2 practice trials and 18 test trials. Scores were calculated as either 0 or 1 for accuracy in the responses on the test trials.

Word Classes Total is a task in which 5-year-old children chose a picture that best represented a given relationship between words that are a variety of part–whole and semantic class relationships in order to assess categorization skills and the ability to associate word meanings. For example, children were shown three images: bread, shoe, and apple. The tester asked “Which two pictures go together?”. The child pointed to two pictures, in this case the correct answers were bread and apple. Then the child was asked “How do the words bread and apple go together?”. A correct answer would include descriptions about things people eat or types of food. Children completed 1 familiarization demonstration, 2 practice trials and 20 test trials. Answers were scored as either 0 or 1 for accuracy in the responses on the two questions of the test trials.

Processing Speed.

NIH Toolbox Processing Speed - This task is an assessment used to measure mental processing speed via response time when participants identify two pictures as same or different. Participants viewed two images simultaneously displayed on the Ipad screen and chose a smiley face if the images were the same or a frown face if the images were different. They completed a familiarization phase consisting of 2 trials as demonstrated by the tester. Next, they completed 5 practice trials independently with corrective feedback. Finally, children completed the test phase. Participants were given 90 seconds to make as many responses as possible, up to 130 possible responses.

Caregiver Measures.

*MacArthur Sociodemographic Questionnaire (*MSQ*)* – This caregiver report measure consists of 12 items that address socioeconomic status and subjective social status (Adler, Stewart, et al., 2007). Of particular interest are 9 items on maternal education and occupation as factors for determining socioeconomic status on the Hollingshead scale. This measure yields scores that ranges from 8 – 66 (Hollingshead, 1975).

Demographic Information – This caregiver report questionnaire asked about ethnicity, race, marital status, household quantity and parenthood.

Behavioral Rating Inventory of Executive Function (BRIEF) *Preschool* – This caregiver report measure consists of 63 items and targets observations of children's behavior, emotion and cognitive regulation abilities related to executive function (Gioia, Andrews, & Isquith, 1996). Reports of this survey will not be discussed in the current study because it is outside the scope of the targeted research questions.

Children's Social Understanding Scale (CSUS) – This caregiver report measure included the short form of 18 items, which targets observations of children's theory of mind development (Tahiroglu et al., 2014). Reports of this survey will not be discussed in the current study because they are outside the scope of the targeted research questions.

Study vocabulary checklist – Identical to that used in Study 1 and 2, a parent checklist of children's vocabulary knowledge was included in the study to control for possible artifacts in language differences that we might find with respect to analogical reasoning performance. Parents were given a list of the 60 words, such as bird, nest, bone, etc., and asked to indicate the words their child was familiar with.

Procedure

Data collection for Study 3 occurred in the Acquiring Minds lab at the University of Oregon. Families were welcomed to the lab and given a brief tour of the child space and caregiver space where they were able to find each other during the visit, if need be. A researcher or research assistant then explained the details of the project and obtained informed consent from the caregiver and assent from the child. Children were then led to the study room and parents to an interview room.

In the study room, children were directed to a table and chair. Depending on the comfort and openness of the child, a brief warm-up period with explanations about the expected activities was given. The Relational Language condition of the Analogical Learning task was administered first. Then the HTKS task was completed as an intermediary between conditions. Next, the second phase of the Analogical Learning task, the No Label condition, was administered. Children then completed the Corsi Block Tapping Test on a wooden board with blocks. Then children played a series of the NIH Toolbox activities on the iPad, specifically the PVT, Flanker task, DCCS task, and a Processing Speed task. Children were then allowed a short stretch or free play break. During the second half of the testing appointment, children completed the CELF Language Content measure, which consisted of the Expressive Vocabulary, Concepts and Following Directions, and either Basic Concepts (4-year-olds) or Word Class (5-year-olds) tasks. The total appointment lasted 50 minutes on average.

In the interview room, the researcher or research assistant read the questionnaires to caregivers and recorded their answers on an Ipad via secure storage on a Qualtrics application. Caregivers were first asked to answer a short demographic survey followed by the MSQ, the BRIEF-P, the study vocabulary checklist, and finally the CSUS. The total caregiver interview time lasted on average 35 minutes. Once completed, caregivers were allowed to view their children completing testing. When requested, parents could watch their child at the beginning of the appointment with the interview portion taking place after the observation. At the conclusion of testing, children from higher SES families (generally recruited from the Team Duckling database) were offered a book or t-shirt as compensation. Caregivers from lower SES (generally recruited from Head Start centers) received financial compensation of $40 to help alleviate financial barriers to participation in the study, and children received stickers.

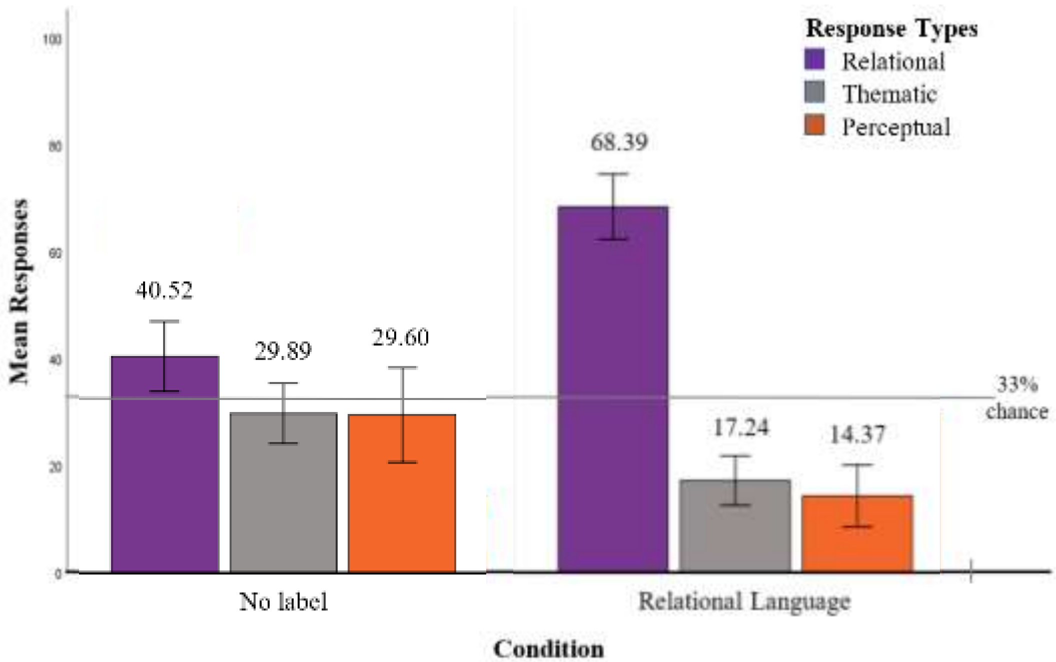
Results

Condition Comparison

To recap, in Study 2, I investigated what would arise from a within-subjects design when children received both the Relational Language and No Label conditions. Only one order replicated original results: Relational Language first, then No Label. In this study, children received the Relational Language condition and then, after a break with the HTKS, received the No Label condition. A one-way repeated-measures ANOVA was conducted to compare percent of relational matches in the Relational Language and No Label conditions. The ANOVA revealed a significant condition difference between the Relational Language (*M*=68.39, *SD*=28.65) and No Label (*M*=40.52, *SD*=30.56) conditions; $F(1, 86)= 66.99$, $p < .001$, $\eta^2_p = 0.44$, 95% CI [.28, .56] (see Figure 9). This result suggested that the addition of novel labels increases relational matches, in line with what was found in both studies 1 and 2, and thus supporting one hypothesis of Study 3.

Figure 9.

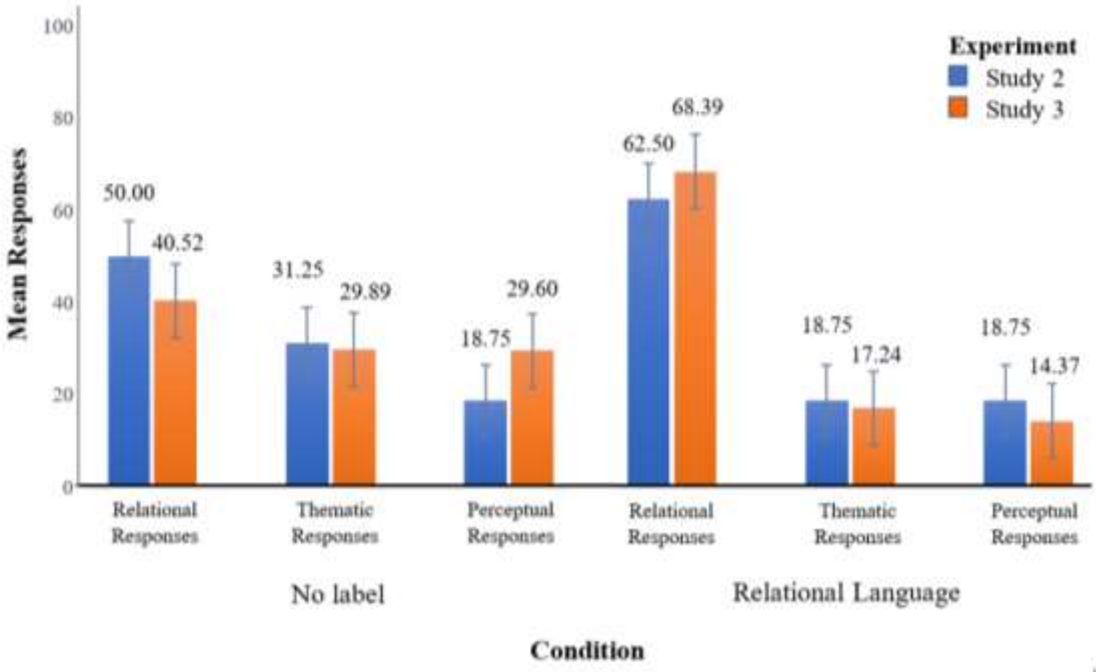
Study 3 Relational, Thematic and Perceptual Responses across both conditions. Error bars represent 95% CIs.



One of the goals of Study 3 was to reduce the likelihood of order effects by separating the two conditions with an intermediary task (HTKS). To assess that I compared patterns of choices of relational, thematic and perceptual matches for this study, when the break occurred, and Study 2, when the conditions occurred sequentially. In the Relational Language condition, which was presented first in both studies, similar patterns were found across studies (See Figure 10). In the No Label condition, in contrast, we found a more evenly distributed spread of choices in the current study (40%, 30%, and 30%) that may indicate less of a carry-over effect of having the Relational Language condition first compared to the museum study (50%, 31%, 19%), and more in line with past research of the No Label condition. That said, the difference across studies is not large.

Figure 10.

Comparison of Responses for Study 2 and Study 3. Error bars represent 95% CIs.



Item Analysis

In order to assess whether the condition difference generalized across items as well as participants, an item analysis was conducted. Since there were no overlapping stimuli used in the two conditions, an independent samples t-test was employed. As in the participant analysis, there was a statistically significant difference between conditions in relational responses, $t(6) = 2.64$, $p = .038$, $d = 1.87$, 95% CI [.02, .54]. Relational matches numbered 68% in the Relational Language condition and 41% in the No Label condition. The relational responses were significantly above 33% chance for the Relational Language condition ($t(3) = 10.22$, $p = .002$) but not for the No Label condition ($t(3) = 0.75$, $p = .506$).

Individual Differences

I next investigated the extent to which individual differences in SES, language, processing speed, and executive function correlated with children's analogical reasoning ability. (Means and standard deviations of behavioral measures are available in Table 4). As a reminder, SES data was not recorded for one participant, so the following analyses are based on a sample size of 86 participants.

Table 4.

Study 3 Means and Standard Deviations of Behavioral Tasks for Individual Differences

Measure	*M*	*SD*
CELF language content	*61.64*	*14.44*
Corsi block	*3.41*	*0.69*
DCCS	*25.84*	*13.58*
Flanker tests	*32.05*	*9.69*
HTKS	*35.83*	*13.03*
Picture vocabulary test	*65.28*	*7.09*
Processing Speed	*21.99*	*6.02*
SES	*47.41*	*12.81*

Aggregate Variables

Raw and partial correlations controlling for age were computed among the four EF measures: Flanker task, DCCS task, HTKS and Corsi block task. As Table 5 shows, the interrcorrelations among the EF measures were all in the expected direction and either significant or near significance (raw rs > .26, ps < .05; partial rs > .22, ps < .05). Scores from these executive function measures were thus z-scored and aggregated to create a composite EF value.

Table 5.

Study 3 Intercorrelations Among Executive Function Measures

	1	2	3	4
1. Corsi block	1.00			
2. HTKS	.40** (.33**)	1.00		
3. DCCS	.29** (.21†)	.31** (.24*)	1.00	
4. Flanker	.26* (.19)	.28** (.22*)	.25* (.20)	1.00

Note: Partial correlations controlling for Age in months are in parenthesis.
*$p < .05$, **$p < .01$, †$p = .06$

Similarly, raw and partial correlations were computed for the two language measures: picture vocabulary test and CELF language assessment. The intercorrelations among the language measures were all in the expected direction and significant (raw $r = .61$, $p < .01$; partial $r = .39$, $p < .01$). Thus, scores from these two language measures were z-scored and aggregated to create a composite language value. 5 outliers for the EF aggregate (defined as outside more than 1.5 times the interquartile range) were winsorized, such that the next most extreme remaining value was utilized in their place. The same process was used for 2 outliers in the Language aggregate. The pattern of findings remained the same whether or not winsorization was conducted.

Finally, a General Cognitive Ability aggregate was calculated, separate from the SES individual difference factor. Raw and partial correlations were computed for the 3 cognitive components: the EF aggregate, Language aggregate and Processing Speed. As Table 6 shows, the interrcorrelations among the cognitive measures were all in the expected direction and statistically significant (*r*s > .44, *p*s < .01). In creating the composite, scores from the individual difference measures were z-scored and aggregated.

Table 6.

Study 3 Intercorrelations among Individual Difference Factors for General Cognitive Ability

	1	2	3
1. EF aggregate	1.00		
2. Language aggregate	.58**	1.00	
3. Processing Speed	.46**	.52**	1.00

***p* < .01

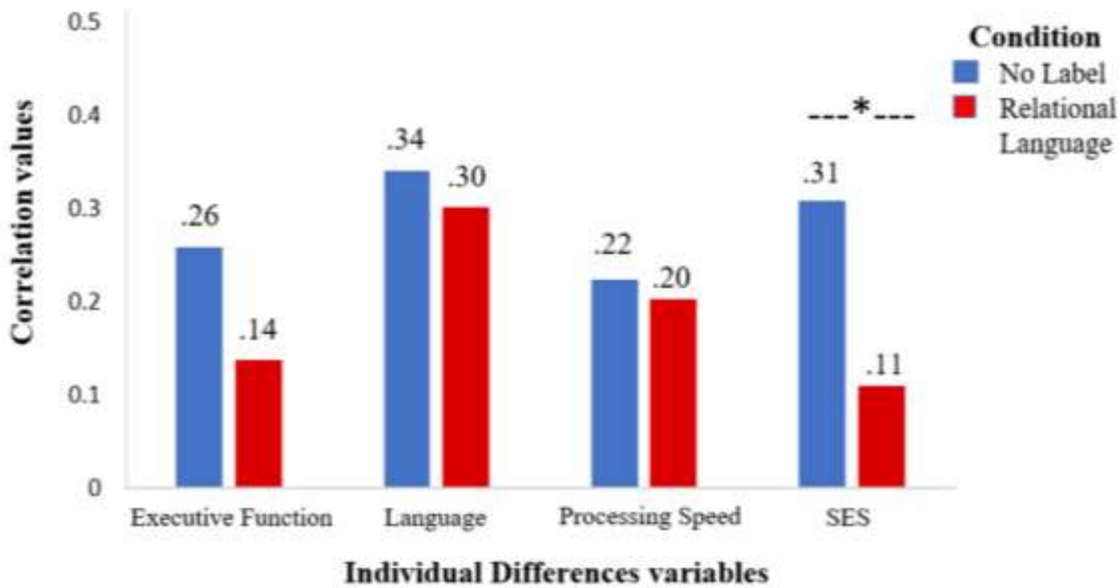
Correlation Comparison

The next steps were, first, to examine correlations between the aggregate variables and relational matches in each condition, and, second, to test the significance of the correlations across the two conditions. In the No Label condition all correlations between the individual difference variables (EF, Language, Processing speed, and SES) and relational matches were significant and positively correlated (*r*s > .22, *p*s < .05). However, in the Relational Language condition, only the Language aggregate and relational matches were significantly correlated ($r = .30$, $p < .01$).

In order to further assess the difference between conditions, I tested the significance of the difference between the two correlation coefficients across the two conditions for each individual difference variable from the within-subjects sample. As seen in Figure 11, the only significant difference that emerged between conditions involved correlations between SES and relational matches (Z = -1.76, p = .039; two-sided).

Figure 11.

Study 3 Test of Correlation Comparison between No Label and Relational Language conditions



*p < .05

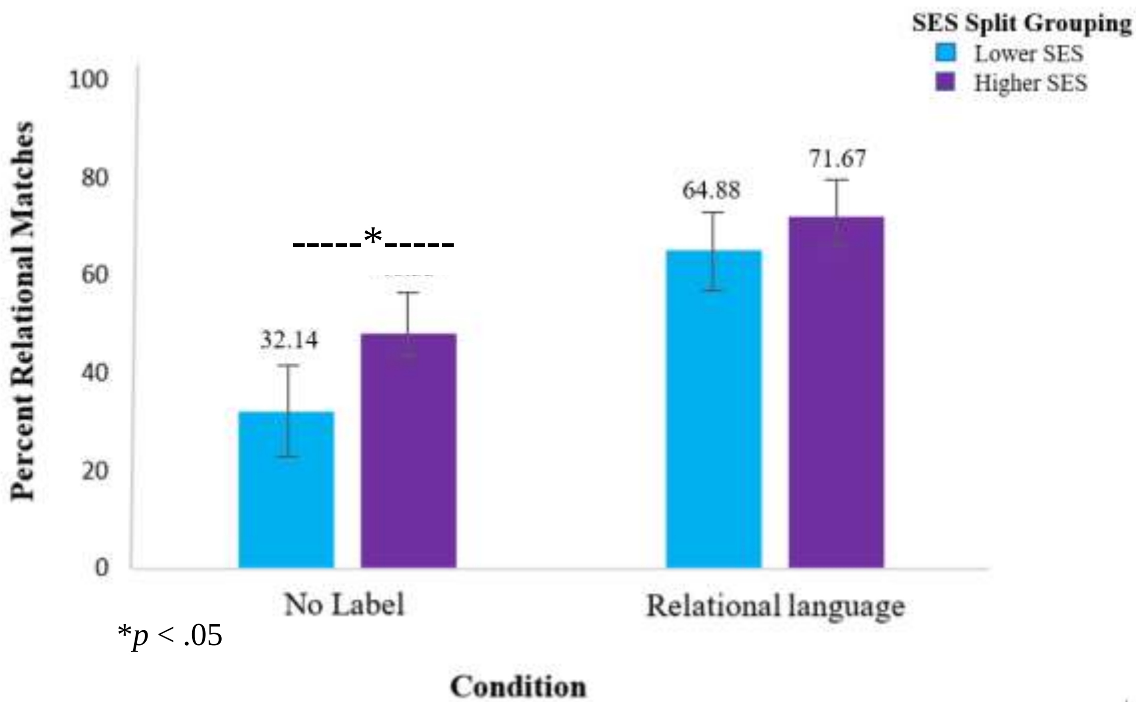
The results from the correlations between the Relational Language condition and the individual difference variables were in contrast to the original predictions of Study 3, where it was predicted that all variables would correlate with relational matches and that there would be stronger correlations in the Relational Language Condition than in the No Label condition. It may be that the presence of relational language is scaffolding analogical reasoning in that the label may serve as a support, guiding children to match analogically. If so, enhanced EF and processing skills may not be required to make relational matches when the label is present. Conversely, it may be that when the support structure of the label is lacking in the No Label condition, the general processing demands of the task are increased such that children now must rely on their general cognitive abilities to succeed. The correlation test of significance results support the notion that SES may be the individual difference variable capturing the difference between the two conditions.

Median Split Analyses

To further explore the differential relation across conditions for SES, I created a median split for SES into lower and higher SES. One caveat in this analysis is the mean SES for this sample was relatively high, M = 47.41 (SD = 12.81). Thus, the lower and higher SES groups were more comparable to what we colloquially refer to as middle class (lower SES in this sample) and upper class (higher SES). A one-way ANOVA revealed a significant difference in relational matches in the No Label condition between lower and higher SES, ($F(1,85) = 6.49$, $p = .013$; $\eta^2_p = 0.07$, 95% CI [.00, .19]; see Figure 13). In contrast, in the Relational Language condition there was no significant difference between children from lower and higher SES, ($F(1,85) = 1.22$, $p = .272$; η^2_p = 0.01, 95% CI [.00, .10]), with the lower SES children performing almost as well as the higher SES children. These results further support the notion that the presence of the relational language scaffolds analogical reasoning for children from both SES groups. Relational Language appears to improve performance such that SES differences are greatly diminished. The label may be aiding the comparative process of analogical reasoning, and when there is no label, children have to rely on other cognitive abilities (for which SES may be a proxy).

Figure 12.

Study 3 Median Split of SES in the No Label and Relational Language conditions, Error bars represent 95% CIs.



Individual Differences and General Cognitive Ability Predicting Relational Matches

As noted in the previous SES analyses, in the No Label condition the general processing demands of the task were increased such that children may have needed to rely on their general cognitive abilities to succeed. To explore this possibility further, I analyzed the relationship between analogical reasoning in both conditions and the potential contributing individual differences factors by computing raw and partial correlations between relational matches in each condition, the General Cognitive Ability aggregate and SES. Consistent with the earlier results, in the Relational Language condition, relational matches were not correlated with SES (with or without controlling for age) (see Table 7). Yet in the No Label condition, relational matches were positively correlated with SES (with or without controlling for age). General Cognitive ability was correlated with both conditions, though not in the Relational Language condition when controlling for Age.

Table 7.

Study 3 Intercorrelations among Relational Matches, General Cognitive Ability and SES by condition

	No Label	Relational Language
General Cognitive Ability	.33** (.25*)	.27* (.14)
SES	.31** (.29**)	.11 (.09)

Note: Partial correlations controlling for Age in months are in parenthesis.
*p < .05, **p < .01

Next, a hierarchical linear regression was conducted to assess the predictive power of the individual difference factors with regard to relational matches. In these analyses, relational match was the dependent variable, age was entered into the first step of the model, General Cognitive Ability was entered into the second step of the model, and SES was entered in the final step to specifically assess how SES contributed over and above general cognitive abilities and age.

No Label Condition with SES and General Cognitive Ability

In the No Label condition, the full regression model was significant, $R^2 = 0.16$, $F(3,82) = 5.19$, $p = .002$, as well as the R^2 change from model 2 to model 3, $R^2\ \Delta = .05$, $p = .031$, indicating SES accounted for an extra 5% of the variance in relational matches in the No Label condition, over and above the General Cognitive Ability composite and Age (see Table 8). In looking at individual predictors, results indicated that SES was the only significant predictor in the full model ($\beta = .24$; $t(85) = 2.19$, $p = .031$).

Table 8

Coefficients Table for Relational Match with SES and General Cognitive Ability in the No Label Condition Regression Model

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Constant	-0.66	1.07		1.86	1.51		.27	1.64	
Age	0.04	0.02	.23*	-.004	0.03	-.02	.01	.03	.03
General Cog				0.21	0.09	.35*	.14	.09	.24
SES							.02	.01	.24*
R^2 statistic (%)	0.05*			0.11*			0.16*		
F statistic	4.68*			5.14**			5.19**		
Df for F statistic	1, 84			2, 83			3, 82		

**$p < .01$

*$p < .05$.

Relational Language Condition with SES and General Cognitive Ability

In the Relational Language condition, the full regression model was not significant, $R^2 = 0.08$, $F(3,82) = 2.33$, $p = .080$, indicating SES did not account for any extra variance in relational matches in the this condition (see Table 9). As well, there were no significant predictors besides Age in Model 1.

Table 9

Coefficients Table for Relational Match with SES and General Cognitive Ability in the Relational Language Condition Regression Model

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Constant	0.45	1.01		1.77	1.45		1.47	1.63	
Age	0.04	0.02	.24*	0.02	0.03	.10	.02	.03	.11
General Cog				0.11	0.09	.19	.10	.09	.17
SES							.004	.01	.05
R^2 statistic (%)		0.06*			0.08			0.08	
F statistic		5.25*			3.44*			2.33	
Df for F statistic		1, 84			2, 83			3, 82	

*$p < .05$.

Partitioned General Cognitive Ability Measures

In order to thoroughly investigate the individual difference relations, I repeated the correlation and regression analyses above with the General Cognitive Ability aggregate partitioned back into the original individual difference variables: EF, Language and Processing Speed. I conducted these analyses in both conditions, as presented below, and also with a Change Score variables across condition but no significant results were found with this variable and, therefore, are omitted from the results.

Individual Difference Variables Partitioned in the No Label condition

To explore the relationship between analogical reasoning in the No Label condition and the same partitioned factors, correlations were conducted between the number of relational matches in the No Label condition, the language aggregate, the executive function aggregate, and processing speed. Similar to correlation results with the General Cognitive Ability composite, in the No Label condition, all contributing factors of SES, processing speed, executive function, and language were moderately positively correlated with relational ability (see Table 10).

Table 10.

Study 3 Intercorrelations Among Relational Choices and Partitioned Behavioral Measures in the No Label Condition

	1	2	3	4	5
1. Relational matches	1.000				
2. EF Aggregate	.26** (.18)	1.00			
3. Language Aggregate	.34** (.26*)	.56** (.40**)	1.00		
4. Processing Speed	.22* (.11)	.46** (.28**)	.51** (.14)	1.00	
5. SES	.31** (.29*)	.23* (.21)	.36** (.41**)	.14 (.10)	1.00

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

Similar to the prior analyses, a hierarchical regression was conducted predicting relational matches from age, EF, language and processing speed was conducted. Relational match in the No Label condition was entered as the dependent variable and age was controlled for and therefore entered into the first step, then the predictor variables were entered as a set in the second step of the model. In the No Label condition the regression model was significant, $R^2 = 0.16$, $F(5,80) = 3.14$, $p = .012$, as was the $R^2 = 0.11$ increment from Model 1 to Model 2, $F(4,80) = 2.66$, $p = .038$ When the individual predictors were examined further, the results indicated that none of the factors were significant predictors for the model although SES was close to significance ($t = 1.90$, $p = .061$; see Table 11).

Table 11

Coefficients Table for Relational Choices and Partitioned Behavioral Measures in No Label Condition Regression Models

	Model 1			Model 2		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Constant	-.66	1.07		0.32	1.69	
Age	0.04*	0.02	.230	.002	0.03	0.01
EF Aggregate				0.15	0.24	.08
Language Aggregate				0.26	0.24	.19
Processing Speed				0.01	0.03	.06
SES				0.02†	0.01	.22†
R^2 statistic (%)		0.05			0.10*	
F statistic		3.14*			1.73*	
Degrees of freedom for F statistic		1, 84			5, 80	

$^*p < .05$.
$^\dagger p = .06$

Individual Difference Variables Partitioned in the Relational Language Condition

To explore the relationship in the Relational Language condition between analogical reasoning and the same potential individual difference factors, correlations were computed among relational matches in the Relational Language condition, the language aggregate, the executive function aggregate, SES, and processing speed. In the

Relational Language condition, relational match was significantly, positively correlated with processing speed and language, whereas SES and Executive function were not (see Table 12).

Table 12.

Study 3 Intercorrelations among Relational Choices and Partitioned Behavioral Measures in the Relational Language Condition

	1	2	3	4	5
1. Relational matches	1.00				
2. EF Aggregate	.14 (.04)	1.00			
3. Language Aggregate	.30** (.19)	.56** (.40**)	1.00		
4. Processing Speed	.20 (.07)	.46** (.28**)	.51** (.14)	1.00	
5. SES	.11 (.09)	.23* (.21)	.36** (.41**)	.14 (.10)	1.00

$^*p < .05$, $^{**}p < .01$

Similar to the prior analyses, a hierarchical regression was conducted predicting relational matches in the relational language condition from EF, language, SES and processing speed. Relational match was entered as the dependent variable as age was controlled for and therefore entered into the first step, then the predictor variables were entered as a set in the second step of the model. The full Relational Language regression model was not significant, $R^2 = 0.10$, $F(5,80) = 1.73$, $p = .138$, nor was the $R^2\,\Delta = .039$ significant from model 1 to model 2, $F(4,80) = 0.86$, $p = .493$. Table 13 displays the coefficients with only Age as a significant predictor of relational ability in the first step of the model.

Table 13.

Coefficients Table for Relational Choices and Partitioned Behavioral measures in Relational Language Condition Regression Models

	Model 1			Model 2		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Constant	0.45	1.01		2.12	1.66	
Age	0.04*	0.02	.242	0.01	0.03	.03
EF Aggregate				-0.12	0.24	-.07
Language Aggregate				0.37	0.24	.28
Processing Speed				0.01	0.03	.07
SES				.001	0.01	.01
R^2 statistic (%)		0.06			0.10	
F statistic		5.25*			1.73	
Degrees of freedom for F statistic		1, 84			5, 80	

*p < .05.

Discussion

A primary goal of Study 3 was to further replicate work on the power of relational labels to facilitate children's ability to make deeper-level relational matches rather than relying on more superficial features such as in thematic or perceptual relations. Both participant and item analysis data confirmed a significant condition effect, replicating results demonstrating the beneficial use of relational labels versus no labels, in line with what was found in studies 1 and 2, as well as the original Gentner et al. work (2011).

The next focus of Study 3 was to investigate factors affecting individual differences in analogical reasoning for 4- and 5-year-olds. Specifically, the research explored individual differences in language, processing speed skills, SES and executive function to see whether they correlate with children's analogical learning ability in both a Relational Language and No Label condition.

In the no label condition, analyses showed significant differences in analogical reasoning between children from lower and higher SES backgrounds, as well as SES as a significant predictor of analogical ability over and above General Cognitive ability. In this condition, it may be that when the support structure of the label is lacking, the general processing demands of the task are increased such that children now must rely on their personal abilities to succeed. SES, EF, language and processing speed were positively correlated with relational ability in this condition, but results demonstrated SES is clearly influencing analogical reasoning above and beyond EF, language and processing speed.

Conversely, in the relational language condition there was no significant difference between children's analogical reasoning performance from lower and higher SES backgrounds. Results indicate they are performing at relatively the same level and may further support the notion that the presence of the relational language scaffolds analogical reasoning for children from either SES group. The label may act as a sufficient bridge, guiding children to think and match analogically. Put another way, the addition of relational language appears to scaffold children's relational reasoning independent of their individual SES background and general cognitive ability.

CHAPTER V

GENERAL CONCLUSION: ANALOGICAL REASONING ACROSS STUDIES

The developmental processes of noticing and connecting similarities across situations and transferring information from one context to another is at the core of analogical reasoning. Yet some facets of how this comparative process and subsequent abstract reasoning occur have not been studied in-depth. Therefore, the overarching purpose of this dissertation research was to investigate the extent to which the supplementation of relational language enhances children's analogical reasoning, and to investigate the influence of individual differences in regard to such facilitation. The aim of Study 1 was to replicate previously documented benefits of novel language for enhancing analogical reasoning using a between-group design in the real-world setting of a children's museum. In this research I also asked whether analogical reasoning of children of varying SES differs in analogical reasoning ability. The main objective of Study 2 was to investigate the potential value of a within-subjects design in measuring effects of relational language on analogical reasoning in the same museum setting, and to utilize this information to inform the design of Study 3. Finally, the goal of Study 3 was to explore individual differences of SES, executive function and language skills in analogical reasoning. Through a series of experiments, this paper replicated previously established findings that relational language facilitates analogical reasoning, extended this research in regard to investigation of individual difference variables related to analogical reasoning, and showed that individual differences such as SES influence analogical reasoning particularly when supportive relational language is absent. All three studies contributed to a comprehensive study of analogical reasoning in distinct but meaningful ways.

One of the primary dissertation goals was to attempt replication of the previously documented benefits of relational language for enhancing analogical reasoning. In all three studies, I hypothesized that children's analogical reasoning would benefit from relational language relative to when no relational labels were provided. This hypothesis was strongly supported: a clear benefit of the presence of relational language emerged in all three studies, either through participant or item analysis data. Results demonstrated that in both a museum and an in-lab setting, as well as in both a between-subjects and within-subjects design, children made more relational matches with the aid of novel relational labels. However, it is important to note that in Study 2, only one ordering of conditions replicated patterns of results observed in earlier research. Relational language benefitted children's analogical reasoning when they experienced the relational language first; when they experienced the no label condition first, they failed to subsequently show a benefit of relational language on analogical reasoning. This "carry-over" effect seems to suggest that children adopt a response set during the first condition they experience which carries over to the second condition they experience; moreover, the response set of selecting thematic and perceptual matches when the no label condition was experienced first could not be overcome by subsequent relational language. Among other things, these findings help to clarify that a between-subjects design is likely the best way to approach research on this topic in the future.

The second overarching goal addressed mainly in Study 3 was to explore potential contributors to individual differences in analogical reasoning performance. I expected to find relations among language, executive function, SES, processing speed and analogical learning in both conditions. However, I predicted stronger correlations in the relational language condition than in the no label condition because I hypothesized the addition of relational language would activate higher use of executive function and language skills. My prediction was not confirmed. Instead, the opposite pattern emerged: individual differences predicted relational reasoning only in the no label condition. In particular, SES was a predictor for relational ability in the no label condition, but not in the relational language condition. These unexpected findings from Study 3 may suggest that relational labeling is a powerful intervention and may especially scaffold relational reasoning in children from lower SES backgrounds.

In the relational language condition, it seems that children quite generally are receiving support from the label and succeeding in making analogical inferences. Perhaps children with higher cognitive skills and/or from higher SES backgrounds do not need as much support from the relational label and succeed on the task regardless of condition. Yet children with lower SES backgrounds and/or lower cognitive skills may need the label's structural boost and can take advantage of it in the relational language condition. When relational labels were unavailable, these children apparently did not have the scaffolding to succeed in finding relational matches in the task.

Past research has suggested that analogical reasoning is cognitively effortful and requires executive skills, such as inhibition and selective attention, to keep higher-order relations in mind while inhibiting attention to lower-order features (Richland, Morrison, & Holyoak, 2006). Specifically, during analogical learning, working memory may be utilized to keep relevant information active while simultaneously shifting attention between incoming stimuli and past knowledge. Inhibition may also be at work suppressing attention to superfluous information and the unrelated features of the novel stimuli. Concurrently, utilizing language as a tool may enhance the ability to retain attention to higher-order relations, thereby easing the executive demand. Additionally, children who spend more years in low-income environments display reduced performance on tasks assessing working memory, attentional set shifting, and inhibitory control, making poverty itself a predictor of executive function (Raver, Blair, Willoughby, 2013). Findings that emerged from Study 3 seem to bear out this general perspective on relations between SES and analogical reasoning. Yet, how exactly SES may influence executive skills when being deployed to aid analogical reasoning, and precisely when these cognitive skills are employed to work together during analogical reasoning require future investigation.

Limitations.

Despite the current studies' contributions toward a broader framework on analogical learning, the studies were potentially limited in several ways. Specifically, in Study 2, I found a carry-over effect in the higher number of relational choices in the no label condition when children experienced the relational language condition first. This carry-over effect seemed to be somewhat lessened with the addition of an intermediary task (HTKS) in Study 3 where it is was necessary to use a fixed order to assess individual differences, but we should be appropriately cautious in the way the results are interpreted.

At least two different accounts arose from the contrast of individual differences results in Study 3 between the two conditions. First, the favored explanation was that relational language provided scaffolding for relational matches, and no such relational language was available to scaffold relational reasoning in the No Label condition. This would mean that SES and general cognitive ability had the opportunity to predict analogical reasoning only in No Label condition.

A second account for the contrast of individual differences results between the two conditions in Study 3 was the possibility of increasing fatigue resulting from the fixed order of conditions. That is, all children participated in the No Label condition after the Relational Language condition. Thus, the significant relationships between individual differences variables and relational matches in the No Label condition may have arisen as a result of fatigue effects being prominent during that later period of children's participation.

Another potential limitation to the research was the relatively high SES sample that was collected at the science museum and in-lab. Even though efforts were made to collect a wide-range of SES backgrounds (i.e., recruiting from Head Start schools, attending museum days that were free admission), children who participated were nevertheless in the top third of the SES spectrum. Therefore, they were not representative of a diverse socio-economic sample. Because the results are from a relatively higher-SES sample, they cannot be considered representative of the larger population and, specifically of, children from lower SES backgrounds. Nonetheless, even with this relatively high SES group it is noteworthy that SES was a strong predictor of relational matches.

In summary, these studies are limited to some extent, but they have generally replicated and extended previous findings. Notably, the replication in three different samples is valuable and contributes to the broader body of knowledge about the development of analogical reasoning (Maxwell, Lau, & Howard, 2015). In addition, the research highlights SES's influence on analogical reasoning. In future studies, research questions can address the limitations noted above to discriminate between the different accounts presented here.

Future Directions.

Future work will want to consider the limitations stated above and expand on the current findings. To address the possibility of a fatigue effect between conditions, video data from each session may be coded to identify any symptoms of fatigue observed in participants. Children typically completed the analogical learning paradigm and HTKS task within the first 8-10 minutes of each appointment and, anecdotally, did not generally demonstrate fatigue during those first ten minutes of the 45-minute assessment. However, further documentation to this effect via *post hoc* coding would be valuable.

Another line of future research involves deeper study of the effects of relational language particularly across more diverse SES populations. Since the power of supportive language was reaffirmed in these studies and appeared to alleviate SES differences in this sample, it would behoove translational and practical fields to further investigate what components of relational language best facilitated analogical reasoning. The beneficial component of the relational language could rely in the novel word itself or in the structure of the instructions used when conducting the paradigm. For example, the structure of the words "<u>The</u> house <u>is the</u> dax <u>for the</u> man" may be the bridge-building component that scaffolds children's thinking in making a relational match. Previous researchers have proposed that labels invite comparison and the act of comparing is the key to making cognitive connections (Gentner, 2005), but the novel labels alone or the relational labels in a simplified structure, such as “This is the man’s dax.” (while pointing to the house), may not support analogical learning as strongly as with the entire structure used in this paradigm. While empirical evidence demonstrated a benefit of using relational language, investigating these subcomponents could lead to more concrete evidence for using relational supports in intervention work in a wider setting.

Similarly, future research can target contextual differences between the relational language and no label conditions, and the associated cognitive strategies. For example, an interesting question concerns whether children’s long-term tendency to spontaneously engage analogical reasoning is benefitted more by frequently scaffolding analogical reasoning with supportive relational language, or by frequently encouraging analogical reasoning without the support of relational language. This is an important intervention question that awaits future investigation.

Broader Implications

The studies in this dissertation have focused on fine-grained aspects of analogical reasoning research, yet there are larger arenas in which this research is applicable. As explained in the literature review, analogical learning is a foundational skill necessary to draw inferences about new, every day experiences, to transfer learning across contexts, and to make abstractions for more complex thinking (Gentner, & Colhoun, 2010; Richland, Morrison & Holyoak, 2006). The comparative process of analogical reasoning is imperative for higher-order skills like conceptualization, prediction, and making connections. The process begins in infancy and progresses into adulthood, yet it is often overlooked as a foundational skill in educational settings. Schools often do not teach and test analogical concepts until high school language arts classes or in specialized courses on standardized test preparation like the GRE. Because these analogical processes begin early in development, explicit instruction on the use of such processes and scaffolding of relational language may be beneficial to implement in early education and primary school settings for concept development and other pre-literacy and cognitive skills. A focus on categorization, a primary step in analogical reasoning, is often found in early educational settings, but the connection to higher level thinking generally drops off over time.

Relatedly, educators habitually expect students to be able to access prior knowledge and carry year-to-year the concepts learned in school, but often educators do not teach children, even at a domain general-level, how to link prior knowledge to new experiences. The capacity to make sense of new learning, connect it to prior knowledge and then transfer it to new settings could be used as a framework in teaching children new vocabulary and relational concepts. As well, it could be useful in creating more complex language and thinking for second language learners, rather than just relying on labels and grammatical structures, as is the norm. By providing a framework for utilizing relational language and enhancing analogical reasoning, children's mental strategies may grow in cognitive complexity and ability.

In closing, the research conducted in the current studies contributed to a comprehensive study of analogical reasoning and provided more evidence that relational language facilitates analogical reasoning. These studies also provided the first evidence to date that individual differences in socio-economic status, and the underlying cognitive variables of language, executive function, and processing speed that it likely serves as a proxy for, are related to children's facility at analogical reasoning. In particular, these studies highlighted that relational language is an especially powerful aid to analogical reasoning for children who otherwise would be unlikely to engage in it by virtue of reduced SES circumstances that impact their general cognitive ability. This is the first of many steps towards establishing replicable evidence regarding how and why children's relational reasoning benefits from relational language, and possible interventions for children from broader SES backgrounds.

APPENDIX A

Analogical Learning record: *Circle the* ***choice*** *indicated by the child in the Test Phase row.*

			Choices:		
Exemplar 1	Man	House			
Exemplar 2	Bird	Nest			
<u>Test Phase</u> dax	Dog		Dog$_3$	Bone$_2$	Doghouse$_1$
Exemplar 1	Watermelon	Knife	Choices:		
Exemplar 2	Evergreen tree	Ax			
<u>Test Phase</u> blicket	Paper		Pencil$_2$	Scissors$_1$	Papers$_3$
Exemplar 1	Hand	Mitten	Choices:		
Exemplar 2	Head	Hat			
<u>Test Phase</u> modi	Foot		Shoe$_1$	Foot$_3$	Soccer ball$_2$
Exemplar 1	Train	Tracks	Choices:		
Exemplar 2	Boat	Water			
<u>Test Phase</u> troke	Car		Car$_3$	Road$_1$	Tire$_2$
Exemplar 1	Rabbit	Carrot	Choices:		
Exemplar 2	Robin	Worm			
<u>Test Phase</u> pontu	Horse		Saddle$_2$	Horse$_3$	Hay$_1$
Exemplar 1	Bee	Honey	Choices:		
Exemplar 2	Hen	Egg			
<u>Test Phase</u> harliss	Cow		Milk$_1$	Barn$_2$	Cow$_3$
Exemplar 1	Hair	Shampoo	Choices:		
Exemplar 2	Tooth	Toothpaste			
<u>Test Phase</u> queep	Hand		Hand$_3$	Ring$_2$	Soap$_1$
Exemplar 1	Coin	Coin purse	Choices:		
Exemplar 2	Shirt	Closet			
<u>Test Phase</u> shen	Crayon		Crayon box$_1$	Crayon$_3$	Papers$_2$
Exemplar 1	Woman	Baby	Choices:		
Exemplar 2	Cat	Kitten			
<u>Test Phase</u> koodle	Duck		Pond$_2$	Duckling$_1$	Duck$_3$

What words did the child say s/he did not know?

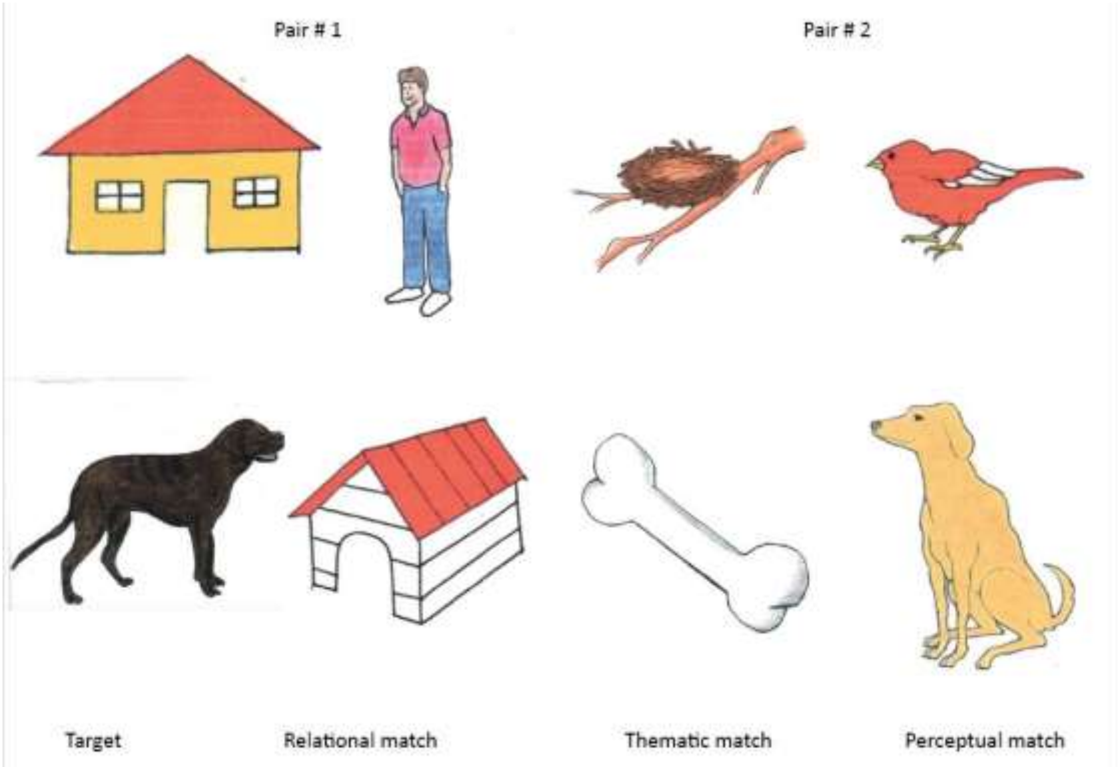
____

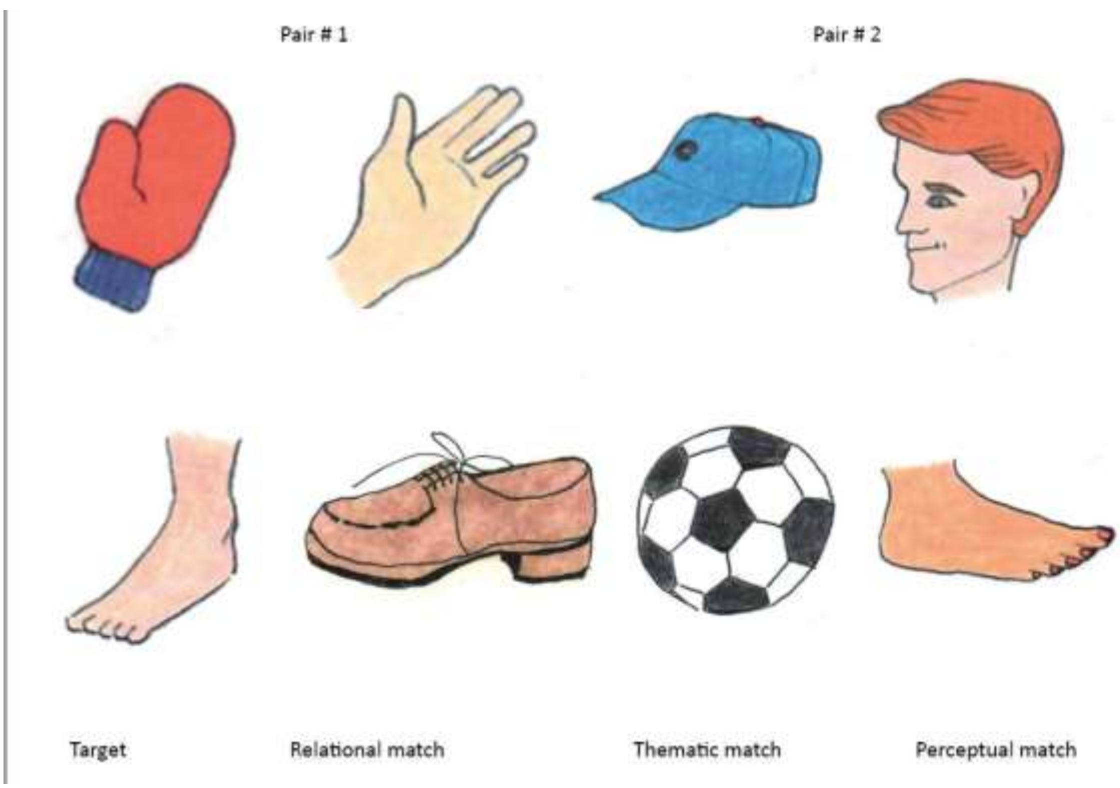
Scoring: Add up the number of times the child chose a word with the subscript:

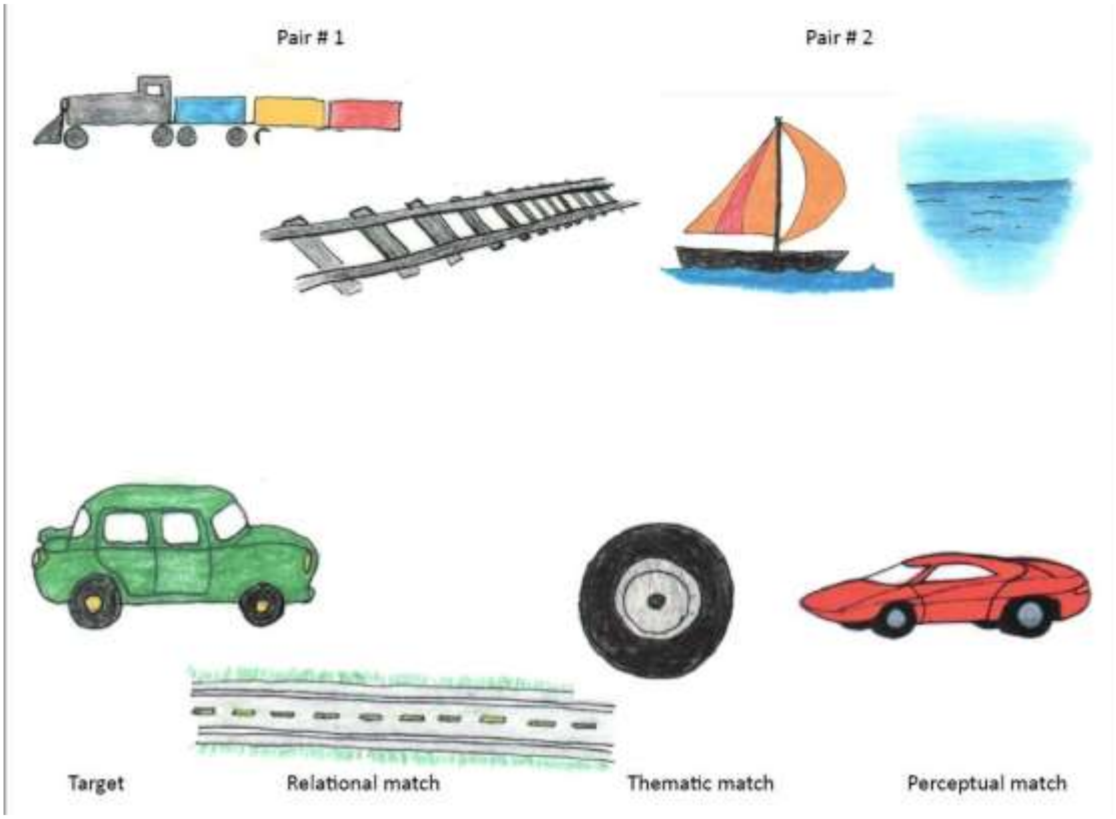
1 _______/ 9
2 _______/ 9
3 _______/ 9

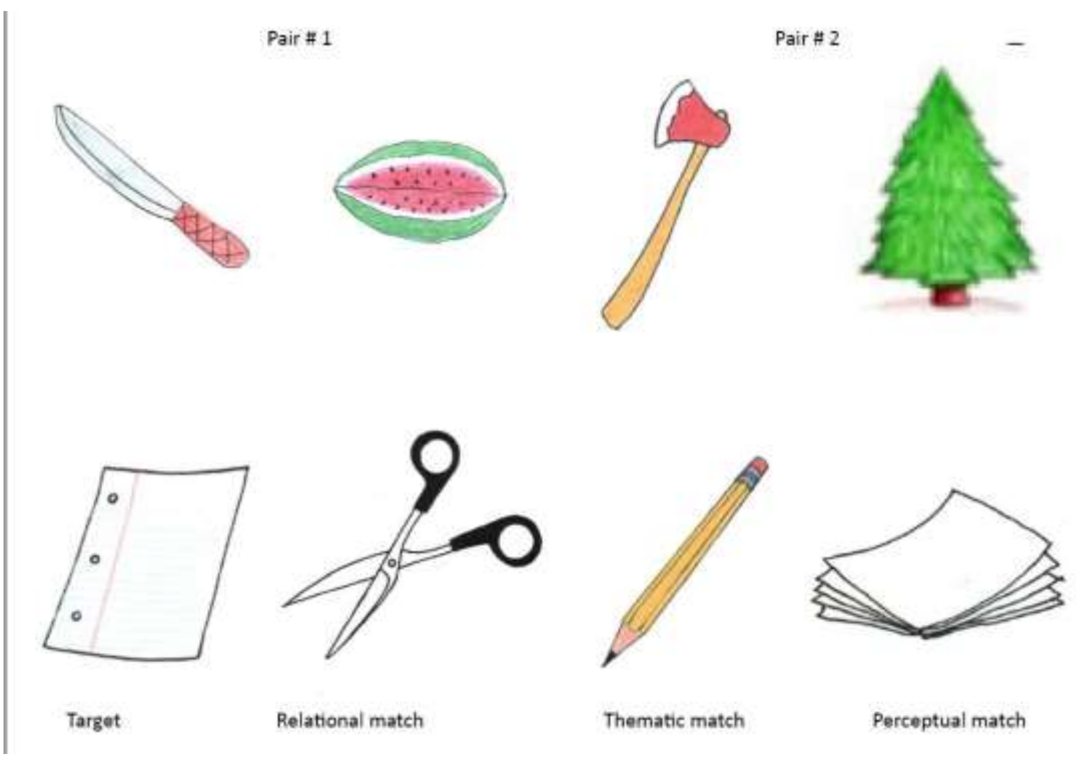
APPENDIX B

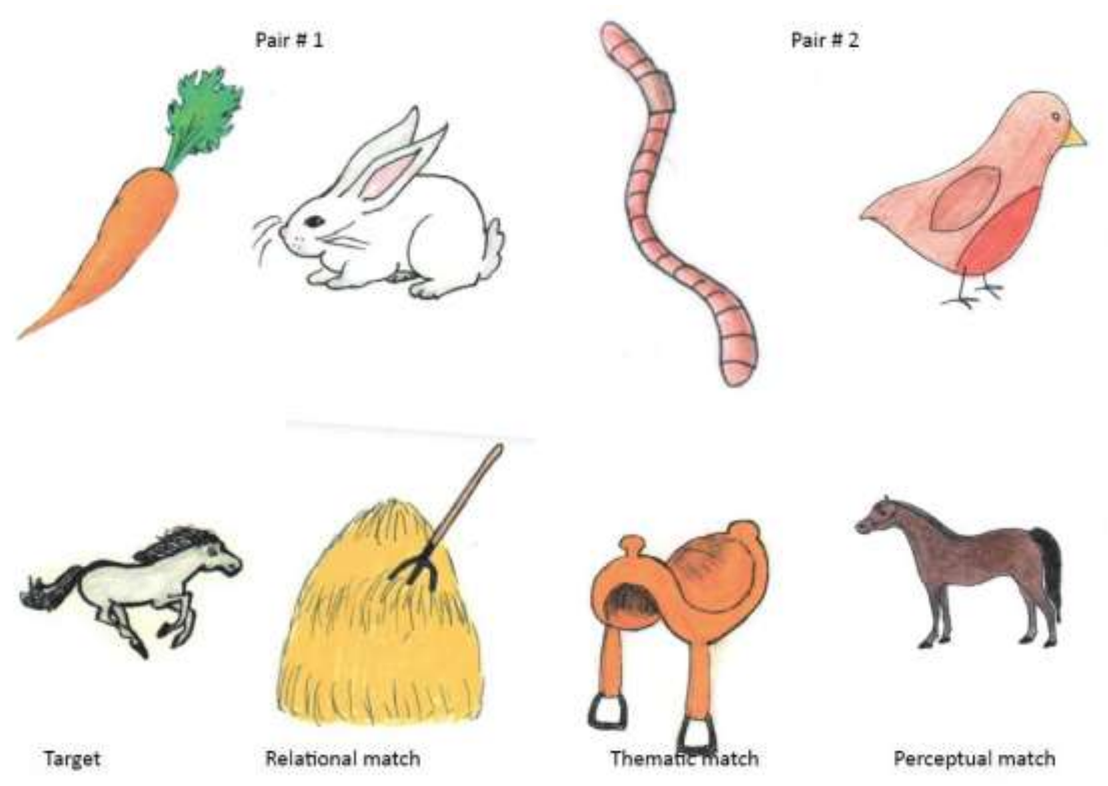
Stimuli sets

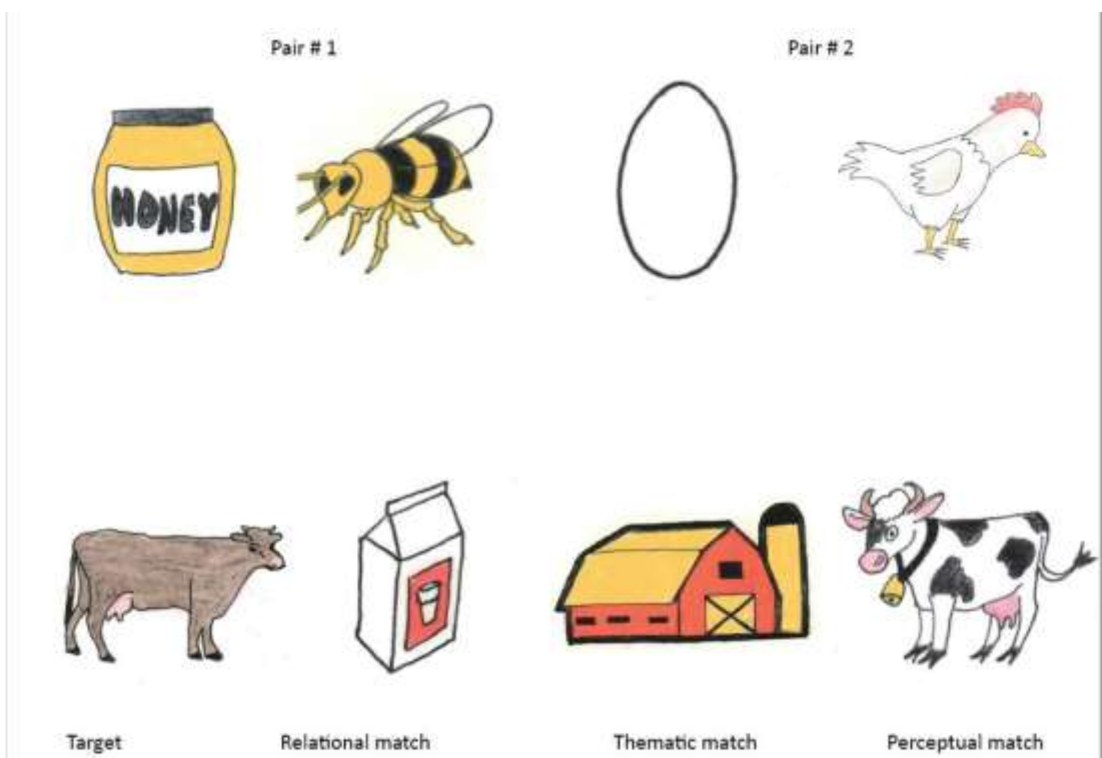


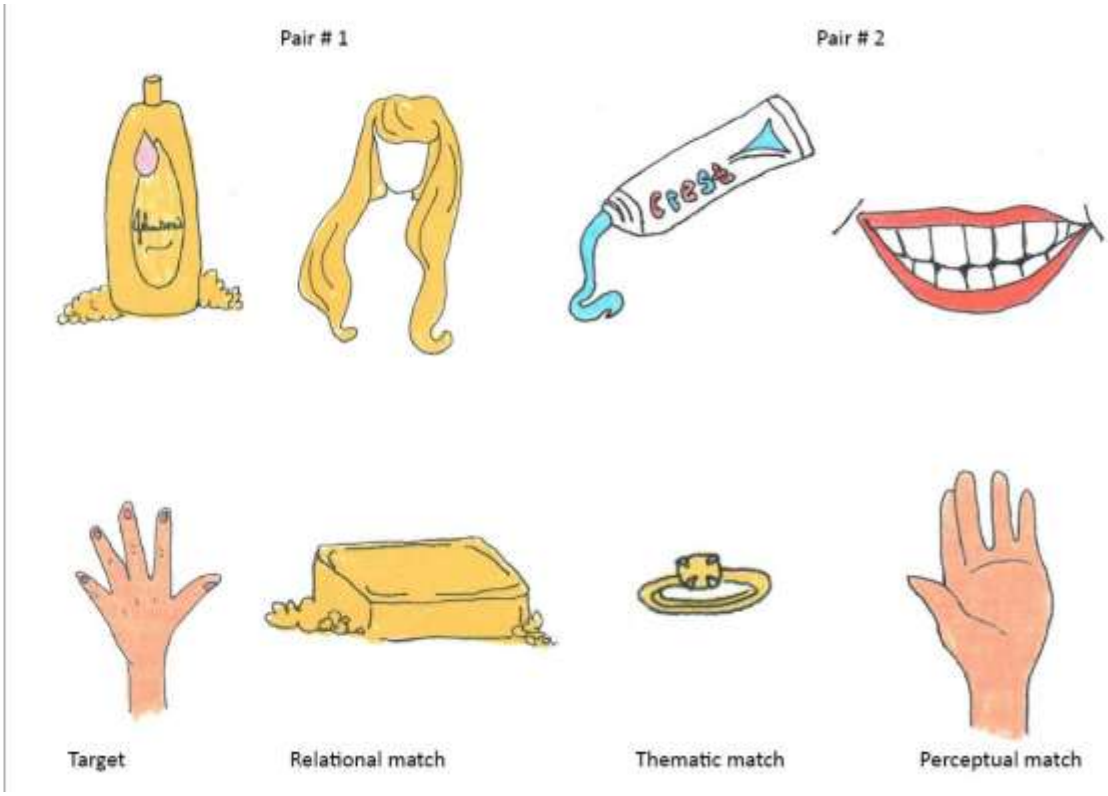



Pair # 1
Pair # 2
Target
Relational match
Thematic match
Perceptual match

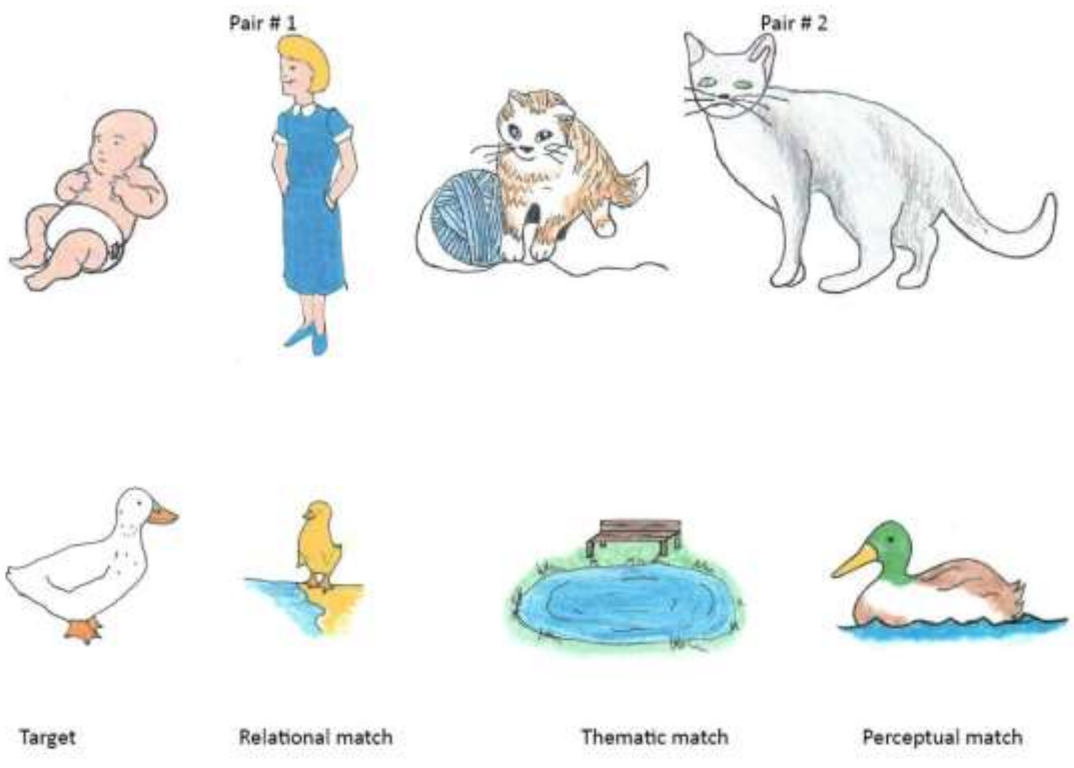

Pair # 1
Pair # 2
Target
Relational match
Thematic match
Perceptual match


Pair # 1
Pair # 2
Target
Relational match
Thematic match
Perceptual match


Pair # 1
Pair # 2
HONEY
Target
Relational match
Thematic match
Perceptual match


Pair # 1
Pair # 2
Crest
Target
Relational match
Thematic match
Perceptual match


Pair # 1
Pair # 2
Target
Relational match
Thematic match
Perceptual match


Pair # 1
Pair # 2
Target
Relational match
Thematic match
Perceptual match

APPENDIX C

MacArthur Sociodemographic Questionnaire

Sociodemographic Questionnaire

The MacArthur Network on SES and Health has developed a sociodemographic questionnaire which is currently being used in a number of network sponsored projects. The instrument begins with subjective social status questions developed by the network; (see MacArthur Subjective Social Status Scale in the Psychosocial Notebook). The remaining questions assess educational attainment, occupational status, income and assets. Ideally, all questions would be used; if a subset must be selected, items 1, 2, 3, 4, 6b and 6c, 7 and 9 are recommended.

Question 1.

Think of this ladder as representing where people stand in their communities.

People define community in different ways; please define it in whatever way is most meaningful to you. At the **top** of the ladder are the people who have the highest standing in their community. At the **bottom** are the people who have the lowest standing in their community.

Where would you place yourself on this ladder?

Please place a large **"X"** on the rung where you think you stand at this time in your life, relative to other people in your community.

Question 2.

9/18/2017

Think of this ladder as representing where people stand in the United States.

At the **top** of the ladder are the people who are the best off – those who have the most money, the most education and the most respected jobs. At the **bottom** are the people who are the worst off – who have the least money, least education, and the least respected jobs or no job. The higher up you are on this ladder, the closer you are to the people at the very top; the lower you are, the closer you are to the people at the very bottom.

Where would you place yourself on this ladder?

Please place a large "X" on the rung where you think you stand at this time in your life, relative to other people in the United States.

Question 3. What is the highest grade (or year) of regular school you have completed? (Check one.)

Elementary School	High School	College	Graduate School
01____	09____	13_____	17_____
02____	10____	14_____	18_____
03____	11____	15_____	19_____
04____	12____	16_____	20+____
05____			
06____			
07____			
08____			

Question 4. What is the highest degree you earned?

_____High school diploma or equivalency (GED)
_____Associate degree (junior college)
_____Bachelor's degree
_____Master's degree
_____Doctorate
_____Professional (MD, JD, DDS, etc.)
_____Other specify
_____None of the above (less than high school)

Question 5. Which of the following best describes your current main daily activities and/or responsibilities?

_____Working full time
_____Working part-time
_____Unemployed or laid off
_____Looking for work
_____Keeping house or raising children full-time
_____Retired

Question 6. With regard to your current or most recent job activity:

a. In what kind of business or industry do (did) you work?

____

(For example: hospital, newpaper publishing, mail order house, auto engine manufacturing, breakfast cereal manufacturing.)

b. What kind of work do (did) you do? (Job Title)

____

(For example: registered nurse, personnel manager, supervisior of order department, gasoline engine assembler, grinder operator.)

c. How much did you earn, before taxes and other deductions, during the past 12 months?
_____Less than $5,000
_____$5,000 through $11,999
_____$12,000 through $15,999
_____$16,000 through $24,999
_____$25,000 through $34,999
_____$35,000 through $49,999
_____$50,000 through $74,999
_____$75,000 through $99,999
_____$100,000 and greater
_____Don't know
_____No response

Question 7. How many people are currently living in your household, including yourself?

_____Number of people
_____Of these people, how many are children?
_____Of these people, how many are adults?
_____Of the adults, how many bring income into the household?

Question 8. Is the home where you live:

_____Owned or being bought by you (or someone in the household)?
_____Rented for money?
_____Occupied without payment of money or rent?
_____Other (specify)________________________________

[Some might try to get a "market value" estimate of the value of owned homes and an estimate of how much principal was outstanding on the mortgage.]

Question 9. Which of these categories best describes your total combined family income for the past 12 months?
This should include income (before taxes) from all sources, wages, rent from properties, social security, disability and/or veteran's benefits, unemployment benefits, workman's compensation, help from relatives (including child payments and alimony), and so on.

_____Less than $5,000
_____$5,000 through $11,999
_____$12,000 through $15,999
_____$16,000 through $24,999
_____$25,000 through $34,999
_____$35,000 through $49,999
_____$50,000 through $74,999
_____$75,000 through $99,999
_____$100,000 and greater
_____Don't know
_____No response

Question 10. If you lost all your current source(s) of household income (your paycheck, public assistance, or other forms of income), how long could you

continue to live at your current address and standard of living?

______ Less than 1 month
______ 1 to 2 months
______ 3 to 6 months
______ 7 to 12 months
______ More than 1 year

Question 11. Suppose you needed money quickly, and you cashed in all of your (and your spouse's) checking and savings accounts, and any stocks and bonds. If you added up what you would get, about how much would this amount to?

______Less than $500
______$500 to $4,999
______$5,000 to $9,999
______$10,000 to $19,999
______$20,000 to $49,999
______$50,000 to $99,999
______$100,000 to $199,999
______$200,000 to $499,999
______$500,000 and greater
______Don't know
______No response

If you now subtracted out any debt that you have (credit card debt, unpaid loans including car loans, home mortgage), about how much would you have left?

______Less than $500
______$500 to $4,999
______$5,000 to $9,999
______$10,000 to $19,999
______$20,000 to $49,999
______$50,000 to $99,999
______$100,000 to $199,999
______$200,000 to $499,999
______$500,000 and greater
______Don't know
______No response

APPENDIX D

Study vocabulary checklist

Please mark off all of the words that your child knows.

☐ man	☐ head	☐ horse	☐ soap
☐ house	☐ hat	☐ saddle	☐ coin
☐ bird	☐ foot	☐ hay	☐ coin purse
☐ nest	☐ shoe	☐ bee	☐ shirt
☐ dog	☐ soccer ball	☐ honey	☐ closet
☐ bone	☐ train	☐ hen	☐ crayon
☐ doghouse	☐ tracks	☐ egg	☐ paper
☐ watermelon	☐ boat	☐ cow	☐ crayon box
☐ knife	☐ water	☐ barn	☐ woman
☐ tree	☐ car	☐ milk	☐ baby
☐ ax	☐ tire	☐ hair	☐ cat
☐ paper	☐ road	☐ tooth	☐ kitten
☐ pencil	☐ rabbit	☐ hand	☐ duck
☐ scissors	☐ carrot	☐ shampoo	☐ pond
☐ hand	☐ robin	☐ toothpaste	☐ duckling
☐ mitten	☐ worm	☐ ring	

APPENDIX E

Item randomization in within-subjects design

Set A	Set B
4, 2, 1, 3	1, 2, 4, 3
4, 3, 1, 2	4, 2, 3, 1
1, 2, 4, 3	3, 1, 4, 2
2, 1, 3, 4	4, 2, 1, 3
1, 4, 2, 3	1, 4, 3, 2
1, 3, 2, 4	2, 1, 3, 4
3, 1, 2, 4	3, 2, 1, 4
2, 4, 3, 1	3, 2, 4, 1
3, 4, 2, 1	1, 2, 3, 4
1, 4, 3, 2	3, 4, 1, 2
3, 2, 4, 1	2, 4, 3, 1
3, 2, 1, 4	2, 4, 1, 3
3, 4, 1, 2	2, 3, 1, 4
4, 1, 2, 3	3, 1, 2, 4
4, 2, 3, 1	1, 3, 4, 2
2, 3, 1, 4	1, 4, 2, 3
4, 1, 3, 2	2, 3, 4, 1
1, 2, 3, 4	4, 3, 2, 1
2, 3, 4, 1	2, 1, 4, 3
4, 3, 2, 1	1, 3, 2, 4
2, 4, 1, 3	4, 1, 3, 2
3, 1, 4, 2	3, 4, 2, 1
2, 1, 4, 3	4, 3, 1, 2
1, 3, 4, 2	4, 1, 2, 3

APPENDIX F

Stimuli response totals for study 1: Museum between-subjects design totaled midstream data collection.

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9
Relational choices	8	8	11	11	2	9	5	11	10
Thematic choices	4	3	0	1	8	3	7	1	2
Perceptual choices	1	2	2	1	3	1	1	1	1

APPENDIX G

Behavioral Rating Inventory of Executive Function (BRIEF) *Preschool*

Child's Name ________ Gender ______ Age ______ Birth Date __/__/__

Your Name ________ Today's Date __/__/__

Relationship to Child: ☐ Mother ☐ Father ☐ Teacher* ☐ Other* ________

How well do you know the child? ☐ Not Well ☐ Moderately Well ☐ Very Well *Have known the child for____ ☐ months ☐ years.

During the past 6 months, how often has each of the following behaviors been a *problem*?

	Never	Sometimes	Often
1. Overreacts to small problems	N	S	O
2. When given two things to do, remembers only the first or last	N	S	O
3. Is unaware of how his/her behavior affects or bothers others	N	S	O
4. When instructed to clean up, puts things away in a disorganized, random way	N	S	O
5. Becomes upset with new situations	N	S	O
6. Has explosive, angry outbursts	N	S	O
7. Has trouble carrying out the actions needed to complete tasks (such as trying one puzzle piece at a time, cleaning up to earn a reward)	N	S	O
8. Does not stop laughing at funny things or events when others stop	N	S	O
9. Needs to be told to begin a task even when willing to do it	N	S	O
10. Has trouble adjusting to new people (such as babysitter, teacher, friend, or day care worker)	N	S	O
11. Becomes upset too easily	N	S	O
12. Has trouble concentrating on games, puzzles, or play activities	N	S	O
13. Has to be more closely supervised than similar playmates	N	S	O
14. When sent to get something, forgets what he/she is supposed to get	N	S	O
15. Is upset by a change in plans or routine (for example, order of daily activities, adding last minute errands to schedule, change in driving route to store)	N	S	O
16. Has outbursts for little reason	N	S	O
17. Repeats the same mistakes over and over even after help is given	N	S	O
18. Acts wilder or sillier than others in groups (such as birthday parties, play group)	N	S	O
19. Cannot find clothes, shoes, toys, or books even when he/she has been given specific instructions	N	S	O
20. Takes a long time to feel comfortable in new places or situations (such as visiting distant relatives or new friends)	N	S	O
21. Mood changes frequently	N	S	O
22. Makes silly mistakes on things he/she can do	N	S	O
23. Is fidgety, restless, or squirmy	N	S	O
24. Has trouble following established routines for sleeping, eating, or play activities	N	S	O
25. Is bothered by loud noises, bright lights, or certain smells	N	S	O
26. Small events trigger big reactions	N	S	O
27. Has trouble with activities or tasks that have more than one step	N	S	O
28. Is impulsive	N	S	O
29. Has trouble thinking of a different way to solve a problem or complete an activity when stuck	N	S	O
30. Is disturbed by changes in the environment (such as new furniture, things in room moved around, or new clothes)	N	S	O

During the past 6 months, how often has each of the following behaviors been a *problem*?

		Never	Sometimes	Often
31.	Angry or tearful outbursts are intense but end suddenly	N	S	O
32.	Needs help from adult to stay on task	N	S	O
33.	Does not notice when his/her behavior causes negative reactions	N	S	O
34.	Leaves messes that others have to clean up even after instruction	N	S	O
35.	Has trouble changing activities	N	S	O
36.	Reacts more strongly to situations than other children	N	S	O
37.	Forgets what he/she is doing in the middle of an activity	N	S	O
38.	Does not realize that certain actions bother others	N	S	O
39.	Gets caught up in the small details of a task or situation and misses the main idea	N	S	O
40.	Has trouble "joining in" at unfamiliar social events (such as birthday parties, picnics, holiday gatherings)	N	S	O
41.	Is easily overwhelmed or overstimulated by typical daily activities	N	S	O
42.	Has trouble finishing tasks (such as games, puzzles, pretend play activities)	N	S	O
43.	Gets out of control more than playmates	N	S	O
44.	Cannot find things in room or play area even when given specific instructions	N	S	O
45.	Resists change of routine, foods, places, etc.	N	S	O
46.	After having a problem, will stay disappointed for a long time	N	S	O
47.	Cannot stay on the same topic when talking	N	S	O
48.	Talks or plays too loudly	N	S	O
49.	Does not complete tasks even after given directions	N	S	O
50.	Acts overwhelmed or overstimulated in crowded, busy situations (such as lots of noise, activity, or people)	N	S	O
51.	Has trouble getting started on activities or tasks even after instructed	N	S	O
52.	Acts too wild or out of control	N	S	O
53.	Does not try as hard as his/her ability on activities	N	S	O
54.	Has trouble putting the brakes on his/her actions even after being asked	N	S	O
55.	Unable to finish describing an event, person, or story	N	S	O
56.	Completes tasks or activities too quickly	N	S	O
57.	Is unaware when he/she does well and not well	N	S	O
58.	Gets easily sidetracked during activities	N	S	O
59.	Has trouble remembering something, even after a brief period of time	N	S	O
60.	Becomes too silly	N	S	O
61.	Has a short attention span	N	S	O
62.	Plays carelessly or recklessly in situations where he/she could be hurt (such as playground, swimming pool)	N	S	O
63.	Is unaware when he/she performs a task right or wrong	N	S	O

APPENDIX H

Children's Social Understanding Scale (short form)

Staff use: Subj. No. ______

Children's Social Understanding Scale (Short Form)

Today's Date ____________________ **Sex of Child** M F (Please circle one)

Child's Date of Birth _______________ **Age of Child** ______Yrs/ ______Mo.s
Month Day Year (Years) (Months)

Your Relationship to Child **Number of Siblings** ______

Mother _____ **Father** _____ **Ages of Siblings** ____________

Other: (please indicate relationship)

____

Instructions: Please read carefully before beginning:

On the following pages you will see statements that describe children's everyday behaviors and thinking. We would like you to tell us how well each statement describes your child's behavior and/or thinking. There are no "correct" answers. The skills and behaviors described in the statements develop gradually, and children differ widely in their behavior and ways of thinking. It is these differences we hope to learn about.

Please read each statement and decide whether it's a "True" or "Untrue" description of your child's thinking and behavior. Use the following scale to indicate how well a statement describes your child:

Circle #	If the statement is:
1	Definitely Untrue
2	Somewhat Untrue
3	Somewhat True
4	Definitely True

Please do your best to respond to all of the items. However, if you cannot answer an item because you have no idea whether your child thinks or behaves in that way, then circle "Don't Know" (DK).

Please be sure to respond by circling a number or "Don't Know" for every item.

Thank you for helping us learn more about children's development!

	My Child…	Definitely Untrue	Somewhat Untrue	Somewhat True	Definitely True	Don't Know
1	Talks about differences in what people like or want (e.g., "You like coffee but I like juice").	1	2	3	4	DK
2	Uses words that express uncertainty (e.g., "We might go to the park"; "Maybe my shoes are outside").	1	2	3	4	DK
3	Realizes that experts are more knowledgeable than others in their specialty (e.g., understands that doctors know more than others about treating illness).	1	2	3	4	DK
4	Has trouble figuring out whether you are being serious or just joking.	1	2	3	4	DK
5	Is good at playing "hide and seek" (e.g., is hard to find, does not make give-away noises).	1	2	3	4	DK
6	Talks about how her/his beliefs have changed over time (e.g., "I used to think that drinking from a cup is hard, now I think it's easy").	1	2	3	4	DK
7	Talks about people's mistaken beliefs (e.g., "He thought it was a dog but it was really a cat"; "I thought mommy was coming but it was really daddy").	1	2	3	4	DK
8	Understands that hurting others on purpose is worse than hurting others accidentally.	1	2	3	4	DK
9	When given an undesirable gift, pretends to like it so as not to hurt the other person's feelings.	1	2	3	4	DK
10	When talking on the phone, behaves as if the listener can actually see her/him (e.g., assumes that the listener knows what s/he is wearing).	1	2	3	4	DK
11	Understands that different people can have different feelings about the same thing (e.g., one child likes a dog but another child is scared of it).	1	2	3	4	DK
12	Takes into account what others want (e.g., takes turns, shares toys, compromises with other children regarding which game to play).	1	2	3	4	DK

	My Child…	Definitely Untrue	Somewhat Untrue	Somewhat True	Definitely True	Don't Know
13	Talks about the difference between the way things look and how they really are (e.g., "It looks like a snake but it's really a lizard").	1	2	3	4	DK
14	Talks about conflicting emotions (e.g., "I am happy to go on vacation, but I am sad about leaving friends behind").	1	2	3	4	DK
15	Is good at directing people's attention (e.g., points at things to get others to look at them).	1	2	3	4	DK
16	Talks about the difference between intentions and outcomes (e.g., "He tried to open the door but it was locked").	1	2	3	4	DK
17	Understands that telling lies can mislead other people.	1	2	3	4	DK
18	Talks about the difference between what people want and what they actually get (e.g., "She wanted a puppy but she got a kitten").	1	2	3	4	DK

Please check that you have answered all questions!

THANK YOU!!!

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