Factors that Affect Taxonomic versus Thematic Preferences in Children and Adults: The Role of Manipulability

by

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Abstract

Items can be grouped together by taxonomic kinds (e.g., apples are fruit) or by thematic relations (e.g., apples grow on trees). This study assessed the impact of stimulus manipulability on taxonomic versus thematic preferences using a forced-choice match-to-sample task. Manipulability was measured in two different ways: (1) whether or not participants were allowed to physically manipulate stimulus items, and (2) whether items were presented as objects (more manipulable) or pictures (less manipulable). I predicted that greater manipulability would heighten thematic preferences. This prediction received mixed support. Adults, but not children, made more thematic links in the manipulable task condition than in the nonmanipulable task condition. The presentation of stimuli as objects or pictures did not affect responses in adults or children. However, participants at both ages made more thematic choices when the thematic relationship involved a direct, functional interaction than when it did not. Overall, these findings suggest that the encouragement of real-world action can, in some contexts, lead to increased thematic classification.

Factors that Affect Taxonomic versus Thematic Preferences in Children and Adults

Categories are critical for understanding, organizing, and identifying things we encounter in the world. Children learn different types of concepts at an early age, and treat these concepts in distinctive ways. A given object may be categorized taxonomically, as a member of a kind of thing (e.g., an apple is like an orange, in that both are fruit), or it may be categorized thematically, as interacting with or being part of the same scene or context as other items (e.g., an apple grows on a tree). Both taxonomic and thematic relationships are important to everyday functioning, and indeed both are available early in development. Most children are able to identify thematic and taxonomic categorizations by two years of age (Fenson, Vella, & Kennedy, 1989), to use them by preschool age (Blaye & Bonthoux, 2001; Scott, Greenfield, & Urbano, 1985), and to verbally justify both of them by first grade (Smiley & Brown, 1979).

Challenging the Notion of a Developmental Shift in Thematic and Taxonomic Strategies

The traditional view of taxonomic and thematic categorization is that there is a developmental trend that occurs throughout the lifetime. Smiley and Brown (1979) reported a U-shaped developmental trend in taxonomic and thematic choices: young and old individuals prefer thematic pairings, whereas adolescents and young adults prefer taxonomic pairings. These shifts were attributed to changes in preferences, not in knowledge organization, considering the excellent performance across age groups on verbal justification tasks of non-preferred matches in a match-to-sample task.

However, considerable evidence has raised doubts about the true nature of this shift. Waxman and Namy (1997) found that there is no persistent preference or developmental shift for young children for thematic or taxonomic relationships. Three- and four-year-old children were able to flexibly use both conceptual relations with no pervasive preference for either mode of

response. Some researchers have found that a preference toward thematic pairings exists in all age groups, and that it persists, not shifts, for children from three to fifteen years of age (Greenfield & Scott, 1986). Adults are also capable of representing thematic relations that are just as powerful as taxonomic relations (Lin & Murphy, 2001) and show a strong thematic preference when presented with stimuli that are equally susceptible to taxonomic or thematic sorting (Murphy, 2001), despite previous conclusions that adults exhibit taxonomic biases.

It is important to note that there are reports of persistent conceptual strategy preferences among individual subjects, despite their respective age groups. Individual biases of taxonomic or thematic strategies appear in adults (Lin & Murphy, 2001) and in children as young as three-years-old (Dunham & Dunham, 1995). Some children and adults show consistent taxonomic biases (selecting all taxonomic choices) and others show consistent thematic biases (selecting all thematic choices), whereas still others lie somewhere between the two extremes.

Several factors may affect the use of different conceptual groupings and account for the debate surrounding the development of conceptual relations. Young children are capable of using both taxonomic and thematic groupings when presented with minimally demanding tasks. When task demands increase, preschool children revert to a primarily thematic strategy, and make more taxonomic strategy errors (Scott et al., 1985). It is hypothesized that the ineffective use of the taxonomic system is due to intrusions of the favored thematic system.

Labeling can also influence performance. For example, Markman and Hutchinson (1984) showed that labeling pictures with an unfamiliar, novel word in a forced-choice task (i.e., “I’m going to show you a kind of dax. Then you’ll have to find another kind of dax. See this? It’s a kind of dax. Can you find another kind of dax?”; p. 9) leads children to make relatively more taxonomic choices, as compared to a no-word control condition (i.e., “See this? Can you find

another one that is the same kind of thing as this one?"; p. 9). Pictures labeled with their basic level name (i.e., "See this? It's a cow. Can you find another one that is the same kind of thing as this one?"; p. 10) also elicited more taxonomic choices. When children were not presented with novel or basic level labels, they chose thematic and taxonomic choices at chance. This shows that the label influenced their use of taxonomic over thematic responses.

Additionally, Waxman and Namy (1997) showed that the instructions of a task can recruit the use of one sorting strategy over the other. Variation in instructions on a match-to-sample task (e.g., choose the one that "goes best" vs. "goes with" vs. "another one") will induce either thematic or taxonomic choices. The "goes with" and "goes best with" prompts were more likely to elicit thematic choices, whereas the "find another one" prompt led to more taxonomic choices. Blanchet, Dunham, and Dunham (2001) also showed that three- and four-year-olds are sensitive to the kind of domain of a stimulus in their categorization choices. Children were more likely to choose thematic matches for an animate target item (e.g., a baby) than an artifact (e.g., a dress).

The factors that affect the use of different conceptual groupings indicate that children and adults are flexible in their use of conceptual strategies. Lin and Murphy (2001) conducted a series of experiments in order to examine the basis of adults' performance on taxonomic versus thematic target matching tasks with variations in instruction (i.e., wording) or type of stimuli (i.e., words versus pictures). They concluded that young adults are capable of performing thematic categorizations and exhibiting thematic biases, despite previous reports that they prefer taxonomic categorizations. Lin and Murphy (2001) also showed that thematic relations guide category-based inductive inferences, even though induction usually plays a more prominent role in taxonomic relations (e.g., "If robins have property *X*, do cardinals have property *X*?"; p. 22).

Murphy (2001) also suggests that previous observations of taxonomic preferences in adults may be due to inconsistencies within stimulus sets. Stimulus sets in past research have been designed with strong taxonomic relations, but without clear thematic links.

The use of certain domains or stimulus items also can promote either taxonomic or thematic biases. Murphy (2001) presented participants with nine stimulus items across three domains (i.e., vehicles, professions, and locations) and three thematic categories (i.e., air, water, and auto travel), and 87% of participants created categories based on thematic relations. In contrast, when the location domain was replaced with an animal domain, 88% of the participants created categories based on taxonomic relations (Murphy, 2001). This suggests that the presence of a given domain will elicit either thematic or taxonomic preferences.

Children are also flexible in their choice of strategy. By three years of age, children are able to use both taxonomic and thematic principles efficiently when they are presented separately in target matching tasks (Blaye & Bonthoux, 2001), and by first grade they have the ability to justify both their preferred and non-preferred choices in target matching tasks (Smiley & Brown, 1979). Nguyen and Murphy (2003) found that three-year-olds are capable of cross-classifying food items using both taxonomic and script categories in forced-choice tasks. (Script categories include items that play the same role in an event schema; for example, oatmeal and pancakes are both breakfast foods.) They also found that four- and seven-year-olds can simultaneously represent a food as belonging to taxonomic and script categories. Furthermore, Nguyen (2007) showed that basic classification and cross-classification abilities for taxonomic and script categories are present by two years of age and continue to develop as the child ages.

In addition to behavioral data, recent studies have used neuroimaging methods to examine conceptual relations (Kalénine et al., 2009; Sachs, Weis, Krings, Huber, & Kircher,

2008) beyond the traditional match-to-sample and forced-choice tasks that dominate the body of research surrounding conceptual organization. Sachs and colleagues (2008) used fMRI to examine activation patterns in the brain as subjects completed a standard forced-choice task. They found that there was no significant difference in brain activation in areas activated during thematic or taxonomic categorization when they were presented as distinct tasks. This may be construed as evidence for the equal importance of the two strategies. But they also showed that selecting a taxonomic choice recruits an additional cortical network when participants were simultaneously presented with a thematic match and a taxonomic match. This effect was not seen when participants chose thematic matches over taxonomic matches. The researchers suggest that this may indicate that taxonomic categorizations require a deeper level of analysis and therefore more neural effort than thematic categorizations, even though they did not identify distinct regions for the two conceptual strategies.

On the other hand, a case study of patient LEW, a language-impaired aphasic, showed separate abilities in taxonomic versus thematic categorizations (Davidoff & Roberson, 2004). Patient LEW exhibited impaired performance in taxonomic classifications of color and shape sorting. In a match-to-sample forced-choice task, LEW showed a strong thematic preference, but when given labels for items in the task he exhibited a taxonomic preference. From these behavioral data, Davidoff and Roberson (2004) suggested that taxonomic and thematic groupings have separable mental representations.

Stimulus Medium and Manipulability

I have discussed how some factors, including task instructions and prior knowledge, can affect thematic or taxonomic responses. The present study aims to explore the possible effects of another factor, namely, item manipulability, on response choices. The prediction is that greater

manipulability will lead to more thematic choices. Manipulability was operationalized in two distinct ways: one way was direct, by varying whether or not participants were permitted to physically access and interact with the stimulus items; the other way was more indirect, by varying whether the items were objects (highly manipulable) or pictures (less manipulable). Previous research has focused on how issues such as the wording of task instructions can elicit taxonomic or thematic responses (Waxman & Namy, 1997), but the present study controls more subtle aspects of the tasks. While manipulability may not be as directive as differences in task instructions, it could play an important role in the recruitment of one conceptual strategy over the other. If children are sensitive to physical manipulability, this would suggest that conceptualizing an item in terms of thematic or taxonomic link is closely tied to one's actions and not just visual cues. This could provide us with a greater understanding of how children attend to and organize the world around them.

Stimulus Manipulability

The key factor I hypothesized might affect classification is the physical accessibility, or sensorimotor experience, of a given object. When people perceive an item, it is not just a visual experience, but also an overall sensory experience. Furthermore, that experience can also include the actions of the participant. Traditional theories of cognition presume that knowledge about the external world is stored in abstract, amodal semantic memory. These standard theories assume that the semantic memory system functions separately from the brain's systems for perceptual, motor, and introspective states (Barsalou, 2008).

However, a more recent view of cognition, called *grounded cognition*, does not focus on the separation between modal systems in the brain, but rather their interaction. This theory focuses on the simulation that occurs during a physical experience; experiences are stored in

memory as multimodal representations that can be accessed later when that same category is experienced again (Barsalou, 2008). Therefore the visual perspective of something, such as a picture or object, is actually an experience of perception, action, and introspection. In this sense, a visual experience (e.g., visual presentation of an object or picture) induces a sensorimotor experience as well. Barsalou (2008) proposes that, "As people perceive visual objects, simulations of potential actions become active in preparation for simulated action" (p. 624). Research has found that perceiving an object can trigger the brain's grasping network (Chao & Martin, 2001, as cited in Barsalou, 2008, p. 624), and activate simulations of gripping and operative actions for that object (Helbig et al., 2006, as cited in Barsalou, 2008, p. 624). These studies have shown that perception and action create an interactive experience.

The grounded cognition theory emphasizes that it is important to consider the physical experience one has when experiencing an object. Borghi, Bonfiglioli, Lugli, et al. (2007) showed that merely viewing objects automatically activates motor information about the manipulability and functional use of that object. Participants were asked to categorize pictures of objects that require being held with a power grip (e.g., the motor program used to grasp solid objects like glasses and jars) or precision grip (e.g., the specific motor program required to hold a needle or tweezers). Results showed that reaction times were faster for objects grasped with a simple power grip, as opposed to a more specific, complex precision grip.

The impact of manipulability and sensorimotor experience on the perception of objects suggests that these factors could also affect categorization of objects. Kalénine and Bonthoux (2008) showed that functional relations, which play an important role in thematic conceptual relations, are particularly relevant for physically manipulable object concepts. Kalénine and Bonthoux (2008) found that children and adults categorize thematic relationships faster for

manipulable objects (e.g., an orange) than nonmanipulable objects (e.g., a bus). Furthermore, children and adults categorize perceptual similarity relations, which play an important role in taxonomic conceptual relations, faster for nonmanipulable objects than manipulable objects. This suggests that object manipulability may play a crucial role in adults' and children's concept formation, including in taxonomic and thematic concepts.

In an fMRI study conducted with a match-to-sample task, Kalénine et al. (2009) found that taxonomic and thematic conceptual strategies activate different cortical pathways. There was no competition between conceptual strategies in this study because each triad consisted of a target item, an unrelated match, and either a taxonomic or thematic match. When participants chose a taxonomic match, they showed activation in areas involved in early occipital processing that are commonly recruited during perceptual tasks. In contrast, when participants chose a thematic match, they showed activation in areas related to function and manipulation knowledge in the visuomotor system. In addition to differential activation observed in the imaging results, reaction time data also showed differences between the two conceptual strategies. Taxonomic relations were identified faster for natural objects (e.g., vegetables), and thematic relations were identified faster for artifacts (e.g., a car), specifically manipulable artifacts (e.g., kitchen utensils). Kalénine et al. (2009) concluded that their findings show distinct neural roles for domain, manipulability, and thematic and taxonomic strategies in concept formation.

Stimulus Medium

By "medium", I refer to whether an item is presented as a picture or as a toy object. As previously stated, the grounded cognition perspective proposes that experiences are based on interactions of our perceptual and motor systems. Given this perspective, the grounded cognition theory predicts that objects and pictures should be treated differently because they are

manipulated differently. Objects are more physically accessible and can be more directly manipulated than pictures and therefore can be linked more directly to motor actions and the motor system. Prior work does in fact suggest that pictures and objects are treated differently.

One way that pictures are treated differently from objects is that pictures elicit more talk about abstract category representations whereas objects elicit more talk about individuals (Gelman, Chesnick, &Waxman, 2005). Mothers and children produce more category-relevant utterances, for example generic noun phrases ("I like jelly beans."; "What do froggies say?", Gelman et al., 2005, p. 1143), during interactions with pictures than during interactions with objects. In contrast, they produced a higher proportion of utterances referring to individuals ("Bye Mr. Frog."; "Does this doggie have a name, too?"; Gelman et al., 2005, p. 1143) when they interacted with objects than when they interacted with pictures. The effect of objects versus pictures persists when mother-child dyads were presented with simple versus complex stimulus sets of items and pictures (Gelman, Waxman, & Kleinberg, 2008).

Furthermore, pictures also differ from objects in that they encourage adults and children to form different kinds of conceptual relations (Ware, Gelman, & Kleinberg, 2009). Ware et al. (2009) presented mother-child dyads with multiple pictures or objects all at once in order to promote discussion of relations among the items. Ware et al. found that for both mothers and children, objects promoted a greater number of thematic relations (e.g., "I think the elephant should eat the hot dog", p. 35) and slot-filler relations (e.g., "Oh the fish is gonna eat the ice cream? Now the elephant is?", p. 35). In contrast, for both mothers and children, pictures promoted a greater number of taxonomic relations ("Mommy you can play with the animals", Ware et al., 2009, p. 35) and shared-property relations (e.g., "And this [airplane] is green. That [fish] has green.", Ware et al., 2009, p. 35).

Ware et al. (2009) showed that these differences affect children's conceptual relations in a free-play task, but it is not currently known whether these differences would also affect how children classify items in a more constrained, forced-choice task. Since pictures motivate taxonomic conceptual relations, I predict that they will be more likely to elicit taxonomic choices in a forced-choice task. In contrast, I predict that the more individualized object representations will elicit more thematic choices in a forced-choice task.

Present Study

The present study is designed to examine the effects of stimulus manipulability on categorization choices at two points in development (preschool and college age). In contrast to reviewed research, the present study is unique in that stimulus manipulability is controlled in two different ways: first, each item is presented as either manipulable or nonmanipulable, depending on task condition. Second, each item is presented as either an object (more manipulable) or a picture (less manipulable). It was our goal to separate the manipulable properties of the real-world referent in order to give the items their own manipulability status.

I hypothesize that children and adults will categorize more thematically when the task is more closely grounded in real-world actions. Specifically, I predict that objects and the manipulable task will be more likely to promote thematic categorization, whereas pictures and the nonmanipulable task will be more likely to promote taxonomic categorization. Overall, this study will provide greater insight into how children and adults understand categories and organize their world.

Study 1

Study 1 considers how the factors of manipulability and stimulus medium affect adults' categorization of everyday items. Adults were presented with a target item and asked to make a

choice between thematic and taxonomic matches. This study allowed me to see if adults choose to use one type of categorization over the other and what factors affect their performance.

Method

Participants. Thirty-six undergraduates from a Midwestern university took part in the study. All of the participants were at least 18 years old. Thirteen of the participants were males and twenty-three were females. Participants received course credit for their participation.

Materials. Materials included 48 toy objects and 48 realistic color images of the same items; see Table 1. All objects were selected to be familiar to preschool children (for use in Study 2). Photographs of the toy objects were converted to color drawing-like images using an online software program. These pictures were designed to be as similar as possible to the toy objects in shape, color, and object details; see Figure 1. The items were divided into two sets (Set A or Set B), each of which included target items of two animals, two artifacts, and two foods. One set was presented as objects and one set was presented as pictures for any given participant. Across participants, half experienced Set A as objects and half experienced Set B as objects. Therefore each stimulus item was equally likely to be seen as an object or as a picture across participants.

Adult ratings. I obtained adult ratings for each of the 12 sets of items in order to pre-test the stimulus items used in this study. Twelve undergraduate students participated for course credit. The ratings were obtained for target items and their three possible matches for a total of 36 pairs of items (an additional 47 pairs of items were included on the ratings task for possible use in future studies). The pairs were rated using four different tasks: similarity (does item "A" look like item "B"), likelihood of the pair being found together (would you expect to see item "A" in the presence of item "B"), likelihood of the pair functioning together (does item "A"

physically function with item "B"), and classification (does item "A" belong in the same category as item "B"). Ratings were conducted on a scale of 1 (lowest rating) to 7 (highest rating). Averages can be seen in Table 2.

Procedure. Participants were tested in an on-campus laboratory. They were informed that they would see pictures and objects of everyday items. A forced-choice match-to-sample task developed by Dunham and Dunham (1995) was used to assess participants' taxonomic versus thematic preferences. Participants were asked to match a target item (e.g., a carrot) with a taxonomic (e.g., green pepper), thematic (e.g., rabbit), or irrelevant choice (e.g., shoe); see Figure 2. Set A and Set B choices were presented in one of two previously set orders. Each participant was presented with a set of picture stimuli and a set of object stimuli. Assignment of sets to picture or object conditions and order of picture and object presentations (pictures first, objects first) was counterbalanced. Participants were also randomly assigned to either the manipulable or nonmanipulable task condition. The experimenter wrote down participants' choices as they responded.

Manipulable task condition. Participants in the manipulable condition were given the target item and were told to place it with their choice. For each *picture* set, the choices were presented in a row on a laminated card, approximately 4.5x11in. For each *object* set, the choices were also presented in a row, placed one by one on the table in front of the participant. After a brief pause that allowed participants to consider the choices, the experimenter physically handed the target item (either a laminated cut-out, for the picture condition, or an object, for the object condition) to the participant and said, "Look at this. Can you put this with another one?" This ensured tactile, sensorimotor interactions occurred in the manipulable condition. None of the items were labeled. This procedure was repeated with all 12 sets in the manipulable condition.

Nonmanipulable task condition. Participants in the nonmanipulable condition were asked to point on the table in front of their choice to prevent them from touching the objects. Picture and object choices were presented on the table in front of the participant. For each picture set, target and choice pictures were presented on an 8.5x11 laminated card, with the choices in a row below the target picture. For each object set, the target object was placed on a small, clear raised container behind the object choices, out of the reach of participants. Thus, all four objects (target plus three choices) were visible at once, with the target object separated from the choice objects. This set-up also prevented participants from physically interacting with the objects. For both pictures and objects, the experimenter pointed to the target item and said, "Look at this. Can you find another one?" None of the items were labeled. This procedure was repeated with all 12 sets in the nonmanipulable condition.

Results and Discussion

Overall, adults showed a taxonomic bias. They selected more taxonomic choices (M = 3.94, SE = 0.27) than thematic choices (M = 2.06, SE = 0.27). Thirty-nine percent (14 out of 36) of the adults selected taxonomic choices in 12 out of 12 sets. No adult participant selected thematic choices in all of the sets.

Each participant received four scores, corresponding to the total number of taxonomic choices and total number of thematic choices, separately for pictures and for objects. Scores could range from 0 to 6 (i.e., a participant who selected thematic choices in all 12 sets would receive a thematic score of 6 for pictures and a thematic score of 6 for objects). The presented analyses will only consider the thematic scores. The different responses (thematic, taxonomic, irrelevant) cannot be analyzed within a single analysis, because the scores are not independent of one another. Furthermore, considering that none of the adult participants chose the irrelevant

items, the taxonomic and thematic scores are complete inverses of one another. Therefore it would be redundant to analyze both the taxonomic and thematic scores.

I conducted a mixed ANOVA on the total number of thematic choices, with task condition (manipulable, nonmanipulable) and medium block order (pictures first, objects first) as between-subjects variables, and item type (picture, object) as the within-subject variable. As predicted, the main effect of task condition was statistically significant, $F(1, 32) = 16.15$, $p < .001$, $\eta^2 = .34$. Adults selected more thematic choices ($M = 3.19$, $SE = 0.40$) in the manipulable task condition than in the nonmanipulable task condition ($M = 0.92$, $SE = 0.40$). These results therefore provide support for the hypothesis that manipulability as task condition influences adults' choices.

The presentation of items as objects versus items as pictures did not show a significant effect ($M = 1.92$, $SE = 0.27$; $M = 2.19$, $SE = 0.35$, respectively). Additionally, the presentation of pictures first ($M = 2.44$, $SE = 0.40$) or objects first ($M = 1.67$, $SE = 0.40$) block orders did not show a significant effect on participants' choices.

These results suggest that, for adults, manipulability strongly affects adults' decisions about taxonomic vs. thematic conceptual relations, whereas the medium of objects versus pictures does not. Even though Ware et al. (2009) found that objects elicited more thematic conversations than pictures in an open-ended play context, this effect did not extend to the present forced-choice categorization task. In Ware et al.'s procedure, participants were not forced to choose between a thematic and taxonomic link as they do in the present study; rather, they were able to openly interpret the task and create their own interactions between the items. Furthermore, participants in the Ware et al. task were more likely to participate in pretend-play with the objects than with the pictures. Because adults in the present study did not engage in

pretend-play with the objects or the pictures, it is possible that the differences between objects and pictures in the present study did not foster the same kind of interaction as the task in the Ware et al. (2009) study.

Study 2

Study 2 makes use of the same design as Study 1 in order to examine the developmental progression of thematic and taxonomic preferences. The purpose of Study 2 was to examine the effects of manipulability in preschool children's choices as compared to those of adults. As in Study 1, I predicted that young children presented with objects and those in the manipulable task condition would be more likely to make thematic choices, as compared to young children presented with pictures and those in the nonmanipulable task condition.

Method

Participants. Thirty-five four-year-old children ranging from 4 years 0 months to 4 years 11 months ($M = 4.45$) participated in the study. Twelve of the children were boys and twenty-three were girls. Participants were recruited from a Midwestern university town and were primarily Caucasian native English speakers.

Materials. Materials used in Study 2 were identical to those used in Study 1; see Table 1.

Procedure. Participants were tested in an on-campus laboratory or in quiet rooms in their respective preschools. The parents of all participants gave informed consent for their children to participate. The procedure was identical to that of Study 1, using the same forced-choice match-to-sample task. The presentation of sets as pictures or objects and order of picture and object presentations (pictures first, objects first) was counterbalanced. Participants were

randomly assigned to the manipulable or nonmanipulable task condition. The experimenter wrote down participants' choices as they responded.

Manipulable task condition. The protocol for the manipulable task condition was identical to that of Study 1. Children in the manipulable condition were free to touch items when choosing a match. This allowed them to act out physical interactions between the target item and their matched choice. For example, many children put the dog into the doghouse or placed the pizza on the plate, as did some adults.

Nonmanipulable task condition. The protocol for the nonmanipulable task condition was identical to that of Study 2, except that children in the nonmanipulable condition were instructed at the beginning of the session not to touch the items that the researcher presented. They were asked to point on the table in front of their choice to prevent them from touching the objects. The experimenter said to children in the nonmanipulable condition, "When you tell me your choice please show me by pointing on the table in front of your choice. We're just going to look at these right now, not touch them."

Results and Discussion

Like the adults, children showed an overall taxonomic bias, selecting more taxonomic pairs ($M = 3.77$, $SE = 0.27$) than thematic pairs ($M = 2.00$, $SE = 0.28$). However, most children (89%) selected at least one thematic and at least one taxonomic choice. Only 4% of children's total responses were irrelevant choices, indicating that they understood the task and were not making random selections. Three children (9%) selected the taxonomic choice in all twelve out of twelve sets and one child (3%) selected the thematic choice in all twelve sets.

Statistical analyses were conducted in the same manner as Study 1. Each participant received four scores, corresponding to the total number of taxonomic choices and total number

of thematic choices, separately for pictures and for objects. Scores could range from 0 to 6 (i.e., a participant that selected thematic choices in all 12 sets would receive a thematic score of 6 for pictures and a thematic score of 6 for objects). The presented analyses will only consider the thematic scores. The different responses (thematic, taxonomic, irrelevant) cannot be analyzed within a single analysis, because the scores are not independent of one another. Furthermore, the overwhelming majority (96%) of children's choices were thematic or taxonomic (only 4% were irrelevant), so that thematic and taxonomic choices were virtually inverses of one another.

I conducted the same mixed ANOVA as I did with adults, with the number of thematic responses as the dependent variable. Task condition (manipulable, nonmanipulable) and medium block order (pictures first, objects first) were the between-subjects variables, and item type (picture, object) was the within-subject variable. Children in the manipulable condition selected equivalent numbers of thematic choices as those in the nonmanipulable condition (M = 2.09, SE = 0.37; M = 1.92, SE = 0.38, respectively). Therefore, in contrast to the adults, manipulability as a task condition was not statistically significant for children. I also found no significant effects for medium (objects: M = 2.11, SE = 0.29; pictures, M = 1.90, SE = 0.30) or medium block order (pictures first: M = 1.78, SE = 0.37, objects first: M = 2.23, SE = 0.38).

Children did not show any significant response to the factors included in this study. Whereas prior work showed that children responded differently to pictures versus objects in their open-ended conversations with their parents (Ware et al., 2009), they did not appear to respond to variations in task manipulability or stimulus medium in the present study. Ware et al. (2009) showed that pictures and objects induce different kinds of conceptual relations in mother-child discussion in a free play setting. In contrast, the present study presents a structure that is different in many crucial ways. First, this study separates adults and children to examine the

developmental aspect and to remove the potential scaffolding of mothers interacting with their children. This allows us to see how children think about conceptual relations without parental influence. Also, this study does not present multiple thematic and taxonomic matches all at once as the Ware et al. study did, but asks participants to make a judgment between a single taxonomic or thematic choice in each set. Children in this study were forced to make a choice between recognizable, conventional thematic and taxonomic links on every trial. In contrast, the Ware et al. study did not present stimuli with conventional links. Rather mothers and children created thematic relations (e.g., making the frog lick the ice cream), which may have allowed children to be more flexible in their choices. Additionally, mothers and children in the Ware et al. study were able to choose which items they manipulated and how. Therefore even though the stimulus items were lacking in conventional links, the emphasis in the Ware et al. study was on functional links that participants created (e.g., making the horse play the piano). In contrast, the present study focused on conventional interactions and was lacking in functional interactions. Participants had only one thematic choice in each set and this item was not always functionally compatible with the target item. Taking these comparisons into consideration, it is clear that the different types of conceptual links, closed structure, and context effects of this study may explain why I did not observe the effect of pictures versus objects that was observed in the Ware et al. study.

Combined adult and child results. I also conducted a mixed ANOVA analysis with both child and adult scores combined to examine the developmental patterns. I used task condition (manipulable, nonmanipulable), medium block order (pictures first, objects first), and age (adult, child) as the between-subjects variables, and item type (picture, object) as the within-subject variable. Once again, only thematic analyses will be presented.

Overall, children and adults were more likely to select thematic choices in the manipulable task condition ($M = 2.64$, $SE = 0.27$) than the nonmanipulable task condition ($M = 1.42$, $SE = 0.27$). The main effect of condition proved to be significant in the combined data analyses, $F(1,63) = 10.02$, $p < .005$, $\eta^2 = .14$.

The combined data also showed a significant two-way interaction between age and task condition, $F(1,63) = 7.42$, $p < .01$, $\eta^2 = .11$. Adults in the manipulable task condition selected more thematic choices (M = 3.19, SE = 0.38) than adults in the nonmanipulable task condition (M = 0.92, SE = 0.38), $p < .001$, Bonferroni's. In contrast, children in the manipulable task condition did not select more thematic choices (M = 2.09, SE = 0.39) than children in the nonmanipulable task condition (M = 1.92, SE = 0.40). Another interesting effect of this interaction is that adults in the manipulable task condition selected significantly more thematic choices than children in the manipulable task condition, $p < .05$, Bonferroni's. Conversely, adults in the nonmanipulable task condition tended to be less thematic than children in the nonmanipulable task condition, although this difference did not reach significance, $p = .074$, Bonferroni's. This finding suggests that adults are more sensitive to the context of the task presentation than children. Furthermore, this result demonstrates that there is not a fixed developmental trend in taxonomic vs. thematic responding, since the developmental patterns go in opposite directions, depending on the task.

All other main effects and interactions were not significant.

These results indicate that a developmental shift occurs in regards to the manipulability of items. Adults were sensitive to the distinction between task conditions (manipulable vs. nonmanipulable), but children were not. This suggests that at four years of age, children may not experience the interaction between action and perceptual systems in the same way adults do.

Borghi, Bonfiglioli, Lugli, et al. (2007) found that the visual experience one has activates motor information about the manipulability and functional use of that object. But that study was conducted only on adult participants and consequently cannot be generalized to children. Therefore it is not known if children's visual experiences activate the same motor and functional information as adults' visual experiences. The present study suggests that it may not.

However, prior research has shown that children are sensitive to the experience of manipulability in a different way. Children and adults were faster at categorizing manipulable object relations than nonmanipulable object relations in a study that measured reaction times (Kalénine & Bonthoux, 2008). Kalénine and Bonthoux (2008) concluded that this shows that children can distinguish between concepts of manipulable and nonmanipulable items early on in their development. It would seem that children should be able apply this distinction to their understanding of conceptual relations, but this effect was not observed in the present study. However, the Kalénine and Bonthoux study that showed children's sensitivity to manipulability was structured much differently from the present study. Kalénine and Bonthoux used black and white line drawings as stimuli and presented the triads on a computer monitor. In contrast, the present study used more complex, colorful stimuli and allowed participants to interact with the items in the manipulable task condition. Furthermore, the children in the Kalénine and Bonthoux study were five and seven years of age, which is older than the four-year-olds in the present study. Additionally, manipulability in the Kalénine and Bonthoux study was a within-subject variable defined using the properties of the real-world referents of the drawings, not as a between-subjects task condition. These differences could explain why children were sensitive to the manipulability effects in that study, but not in the present one.

Supplementary analyses: Thematic strength analysis. The pre-testing conducted on the stimulus items showed interesting differences among thematic pairs. There was a fairly wide range of scores on the "function together" ratings, suggesting that some of the thematic pairs were more functionally interactive than others (e.g., a dog physically and spatially fits inside of a doghouse, whereas a cake and a present can both be found at birthday parties, but they do not function together). It is also interesting that pairs that "function together" are more manipulable than pairs that do not (non-interactive pairs). I speculated that the degree to which items functionally interact might affect participants' rate of thematic choices. Therefore I decided to investigate differences within the thematic pairings according to the adult ratings and apply them to the combined dataset. Thematic pairs that received adult ratings of greater than 6.5 out of 7 on the "found together" and "function together" rating tasks were considered to be functionally interactive thematic pairings (i.e., basketball/hoop; carrot/rabbit; horse/saddle; dog/doghouse; screwdriver/handyman). Pairs that received adult ratings lower than 6 out of 7 on the same tasks were considered to be non-interactive (i.e., cake/present; car/stop sign; cow/glass of milk). Each participant received two scores, corresponding to the percentage of trials on which they provided thematic choices for the functionally interactive items and the non-interactive items, respectively. These scores were combined for pictures and objects, as there were too few items to analyze by this factor. Scores could range from 0% to 100% for both the functionally interactive pairs and the non-interactive pairs.

I conducted a mixed ANOVA on the percentage of thematic choices, with thematic strength (functionally interactive, non-interactive) as the within-subjects variable, and age (adult, child) and condition (manipulable, nonmanipulable) as between-subjects variables. For this analysis I only report effects and interactions involving thematic strength, as the other factors

were already analyzed earlier. Overall, participants were more likely to choose thematically on the functionally interactive sets (M = .42, SE = .04) than on the non-interactive sets (M = .24, SE = .04), as seen by the main effect of thematic strength, $F(1, 67) = 25.29$, $p < .001$, $\eta^2 = .27$. This effect held for both adults and children examined separately, ps < .01. This suggests that functionally interactive pairs present stronger thematic links than non-interactive thematic pairs.

No other main effects or interactions involving thematic strength were significant. However, when participants considered functionally interactive items, there is some indication that they may show a bigger condition effect (manipulable versus nonmanipulable) than when they considered non-interactive items. For both functionally interactive and non-interactive items, participants selected the thematic match more often in the manipulable task condition than the nonmanipulable task condition, p's < .05. However, the effect was somewhat larger for the functionally interactive pairs, p = .001, than non-interactive pairs, p < .05. This suggests that the effect of condition may be greater for certain items than others. Functionally interactive items may give a more sensitive measure of the manipulability effect because they are in fact more physically manipulable in the real world than non-interactive items.

These results suggest that different types of thematic relationships are more likely to elicit thematic responses than others. Thematic relationships can be spatial, causal, temporal, and/or functional. For both children and adults, perceived strength of thematic relationships increases if the pair shares a functional interaction (e.g., a handyman physically manipulates a screwdriver as part of his job) or close-knit spatial property (e.g., a basketball hoop is made to specifically fit a basketball). Additionally, functional and spatial relations relate directly to physical manipulability status. Prior research has tended not to differentiate among these types of relationships, and thus may have contributed to inconsistent patterns in the literature.

General Discussion

The present study assessed the impact of manipulability on participants' taxonomic versus thematic preferences, using a match-to-sample forced-choice task. Manipulability was operationalized in two distinct manners: first, by varying the ability of participants to physically access and interact with items, and second, by varying whether the stimuli were objects (highly manipulable) or pictures (less manipulable). I predicted that the sensorimotor and physical experience of items (in both manipulability and medium) would affect the recruitment of one conceptual strategy over the other. Specifically, I predicted that thematic choices would be higher when there is greater opportunity for participants to physically interact with the item, either because they are encouraged to manipulate the items, or because the items are presented as three-dimensional objects. Such a finding would be consistent with a "grounded cognition" framework. This study was unique in that both factors were systematically controlled by condition, keeping item content constant, rather than by using wholly different sets of stimuli. Additionally, I examined developmental trends by studying both preschool children and adults.

Adults

In the current experiment, stimulus manipulability affected adults' responses. The manipulable task condition encouraged adults to categorize items on the basis of thematic relations, more often than with the nonmanipulable task. Moreover, thematic relationships that entail functional interactions (e.g., basketball and hoop) led to more thematic choices than thematic relationships that are non-interactive (e.g., cake and present). Furthermore, I found that effects of manipulability may be larger for sets that include a functionally interactive thematic relation than for sets that do not. Surprisingly, however, I found that the presentation of stimuli as either objects or pictures did not influence conceptual organization for adults in this study.

These findings suggest that manipulability and physical access to items play important roles in how adults make decisions about conceptual relations. Denying adults tactile access to items causes them to revert to taxonomic choices, which has in the past been assumed to be the dominant conceptual strategy of young college adults. My findings instead suggest that taxonomic relations are most salient in contexts that restrict participants from considering real-world motor actions.

This finding is consistent with prior research, which has shown that object manipulability facilitates performance on manipulability-relevant tasks that involve pre-activation of the motor system (e.g., whether or not objects could be put inside a backpack), but that it interferes with performance on manipulability non-relevant tasks (whether the object was an artifact or a natural kind) (Borghi, Bonfiglioli, Ricciardelli, Rubichi, & Nicoletti, 2007). Nonmanipulable objects were categorized faster than manipulable objects in the manipulability non-relevant task. Borghi, Bonfiglioli, Ricciardelli et al. (2007) propose that manipulable objects activate functional information about how they can be used and motor information about how they can be manipulated. This extra information activated by manipulable objects interferes with the categorization response and results in a slower reaction time. However, the interference effect disappeared in the manipulability-relevant task; instead, the relevance of motor information in Borghi, Bonfiglioli, Ricciardelli et al. facilitated faster responses to manipulable natural objects. These results suggest that when manipulability information is not relevant to the task at hand, its activation can interfere with the motor program (i.e., pressing a button) needed to accomplish the task; however when it is relevant to the task it facilitates the motor program needed to accomplish the task.

The adult findings also provide support for the grounded cognition theory over traditional theories of perception that separate the perceptual and motor experiences. Our findings suggest that adults in this study utilized an interaction between their perceptual and motor systems when completing this task. The way that they perceived the stimuli was dependent on their sensorimotor interaction with the items. This finding goes against standard theories of cognition that propose that our experience of the external world is separated by our perceptual, motor, and introspective experiences (Barsalou, 2008). In contrast, these results suggest that when adults are actively categorizing and manipulating items, they are accessing an integration of neural systems beyond the visual system. This interaction is also evident from the neuroimaging studies that show activation in visual-motor areas during categorization forced-choice tasks (Kalénine et al., 2009).

Although the current results demonstrate that manipulability promotes thematic choices, it is not known if it does so by facilitating thematic relations or inhibiting taxonomic relations. This is a question to be considered for future research.

Children

Unlike adults, children's responses in the present study did not show an effect of stimulus manipulability (manipulable task condition versus nonmanipulable task condition). Stimulus medium (objects versus pictures) also did not affect children's conceptual relations. However, I cannot strongly conclude that manipulability has no effect on children. As discussed in Study 2, supplementary analyses of types of thematic relationships showed that children selected thematic choices more often when they were functionally interactive than when they were non-interactive. This finding provides some indirect support that item manipulability influences their categorization choices, in that functionally interactive pairs are defined by their real-world

physical actions and spatial relationships (i.e., manipulability), whereas non-interactive thematic pairs are not. It is much easier to imagine throwing a basketball into a hoop than manipulating a cake and a present together in some way. However, the fact that manipulability matters on this indirect measure, but not on the other two measures (task and medium) is puzzling, and a question to consider for future research. It is also puzzling that sensorimotor experiences and manipulability influenced children's categorization in prior research (Kalénine & Bonthoux, 2008), but not with the present methods.

Another interesting finding in this study is that children and adults showed different dominant response patterns, depending on the response context (manipulable versus nonmanipulable). Children made more taxonomic choices than adults in the manipulable task condition, whereas adults made more taxonomic choices than children in the nonmanipulable task condition. Conversely, adults made more thematic choices than children in the manipulable task condition, whereas children made more thematic choices than adults in the nonmanipulable task condition. These findings suggest that there is no overall preference for taxonomic or thematic choices in children or adults, but that the context of the task presentation will elicit choices one way or the other. Both the present findings and Ware et al. (2009) suggest that taxonomic and thematic conceptual relations are available to children and adults, and it is the context of presentation that recruits one strategy over the other.

Limitations and Suggestions for Future Research

One surprising result was that our hypotheses about item medium were not supported. In this study, pictures and objects did not contribute to the differential recruitment of taxonomic or thematic strategies. It may be that the use of toy objects rather than actual objects was a limitation here. Participants may have been more sensitive to the differences between pictures

and objects if I had included actual, real-life objects. Consider that the toy objects were often not actually functional (e.g., the toy screwdriver was too wide to fit into an actual screw), and the size of the items often precluded actual real-world manipulations (e.g., the toy basketball didn't actually fit through the toy hoop). Participants may have attended more closely to the thematic links among items if they had been presented with actual objects that have the appropriate properties and scale, as opposed to the toy items. In future research, it would be interesting to see if actual objects—or even toy objects that have the key functional elements (e.g., appropriate scale and parts to enable appropriate interactions)—would be categorized using different conceptual strategies than pictures of those objects.

Another result that was not initially anticipated (and thus not built into the study design) concerned the different types of thematic relationships, which turned out to be predictive of the frequency of thematic responses, for both children and adults. Consider the thematic pairing of a cow and a glass of milk. A cow provides us with milk. Therefore a cow and a glass of milk present a conventional thematic relationship (and indeed have been used as an item in previous studies). However, the relationship is not temporal, spatial, or functional. It is very rare that a cow would actually be found with a glass of milk. The thematic relationship is present, but it is an indirect causal relationship (i.e., the cow produces the milk, which is processed and then eventually poured into a glass; ultimately, then, the glass of milk is a distal effect of the cow). There are large temporal and spatial gaps between the elements in this thematic pair. Therefore this type of thematic relationship is unlikely to recruit thematic responses in the same manner as a cow and a cowbell, which directly interact with one another. A cowbell is worn by the cow, and therefore this relationship becomes spatial, interactional, possibly functional, and strengthened by actions that relate the items. Furthermore, in ratings collected to examine

thematic relationships, causal thematic pairs (e.g., a cow and a glass of milk; a bee and a jar of honey) showed extremely low ratings for similarity, functional, thematic, and taxonomic tasks. This suggests that something can be conventionally classified as thematic, but function differently from other thematic conceptual relations.

There is an abundance of mixed results in the wide range of literature on taxonomic concepts versus thematic concepts. It is possible that part of this variability stems from the differences in thematic relationship type. If one set of stimuli is more likely to elicit thematic choices than the other, one must carefully consider the implications of each taxonomic and thematic pair. Lin and Murphy (2001) used multiple experiments to show that when thematic relationships are meaningful and prominent, adults can show thematic preferences, despite the body of research that says adults exhibit a taxonomic preference. Smiley and Brown (1979) conducted a groundbreaking study that was one of the first to propose the developmental U-trend, in which college adults exhibit a taxonomic bias. However, when considering the examples they provide of their stimulus sets, 3 out of 10 are non-interacting (sheep/wool; bee/honey; cow/milk). If the researchers had used more salient thematic pairings, it is possible that adults may have shown more of a thematic bias. This is a limitation of the present study as well. If I had balanced functionally interactive and non-interactive thematic relationships evenly in my sets, it is possible that children would have been sensitive to manipulability effects. Future research should take the effect of different types of thematic pairings and their resulting thematic strength into consideration when preparing stimulus sets with thematic relationships.

Functionally interactive thematic relationships are also more grounded in real-world actions than non-interactive relationships. Functionally interactive thematic pairs elicit motor information in addition to perceptual information, given the direct, physical interaction between

the two items (e.g., putting a baby into a crib), whereas non-interactive relationships do not. Therefore functionally interactive relationships can be considered more manipulable than non-interactive relationships, which could explain the differences seen in thematic strength among the different types of thematic relationships. The present study suggests that manipulability influences conceptual relations on many different levels (task condition, type of stimulus, stimulus conceptual relationships) and it would be beneficial to explore the wide-reaching extent of manipulability in future research.

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Table 1

Complete list of stimuli used in Study 1 and Study 2

Target Item	**Taxonomic Match**	**Thematic Match**	**Irrelevant Match**
Apple	*Grapes*	*Tree*	*Airplane*
Crib	*Couch*	*Baby in Pajamas*	*Crab*
Dog	*Moose*	*Dog House*	*Orange*
Screwdriver	*Saw*	*Handyman*	*Penguin*
Cake	*Donut*	*Present*	*Panda Bear*
Horse	*Elephant*	*Saddle*	*Bed*
Basketball	Football	Basketball hoop	Corn
Carrot	Green Pepper	Rabbit	Shoe
Chimpanzee	Cat	Banana	Baseball
Pizza	Hot dog	Plate	Tiger
Car	Boat	Stop sign	Ice Cream
Cow	Bear	Glass of Milk	Pear

Note. Items in italics appeared in Set A.

Table 2

Averages of Adult Ratings for Taxonomic, Thematic, and Irrelevant Matches on Four Different Rating Tasks (with Standard Deviations in Parentheses)

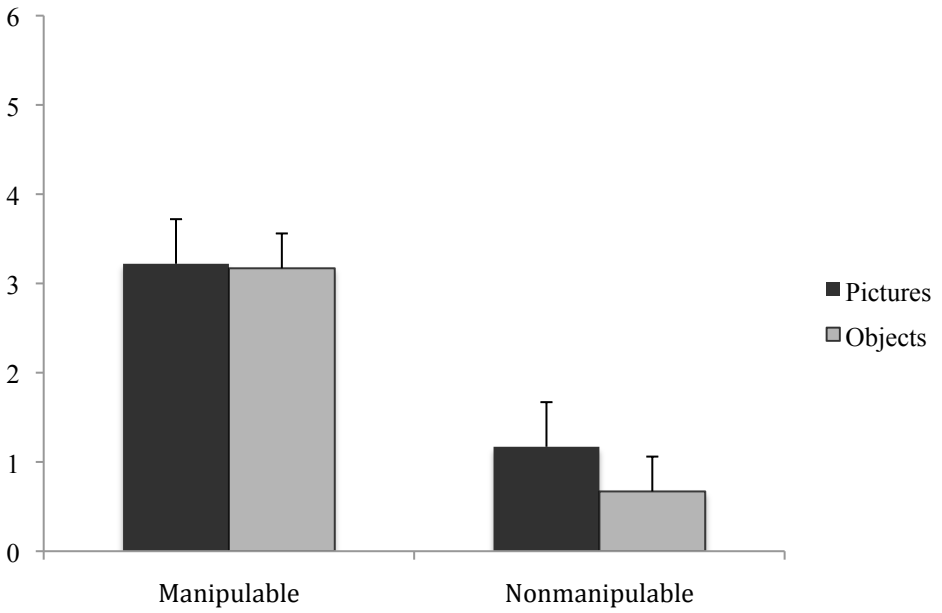
	Similarity	*Found Together*	*Function Together*	*Classification*
Taxonomic	3.34 (0.66)	3.83 (1.55)	2.56 (0.85)	6.13 (0.70)
Thematic	1.58 (0.36)	6.11 (1.05)	6.04 (1.15)	2.52 (0.65)
Irrelevant	1.21 (0.18)	1.47 (0.48)	1.36 (0.27)	1.17 (0.16)

Note. Maximum possible rating on each task = 7.

Figure 1. Sample object and picture versions of three target test items (cake, screwdriver, apple).

Figure 2. Sample target item with irrelevant, thematic, and taxonomic match (pizza with tiger, plate, and hot dog).

a)



b)

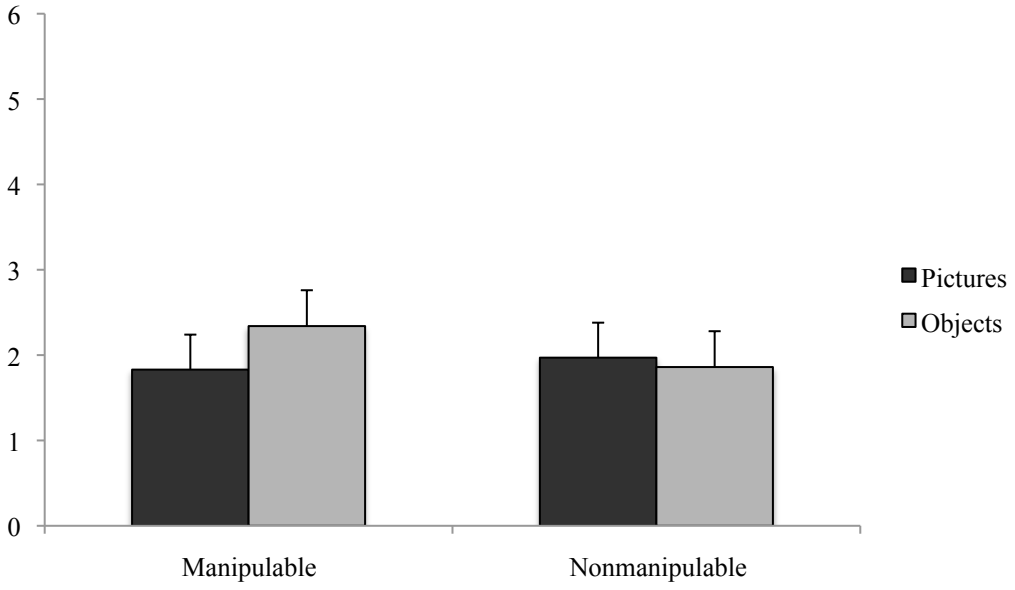


Figure 3. Mean number of thematic choices as a function of medium (pictures, objects) and task condition (manipulable, nonmanipulable), separately for (a) adults and (b) children.