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Sensitivity to Purely Taxonomic Associations among Young Children

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Abstract

The goal of the present study was to examine an aspect of semantic development. Previous research investigated whether different *types* of relations between entities influence the degree to which children perceive them as similar.  The purpose of the present study was to compliment this research by investigating whether the *number* of relations between entities influences their perceived similarity.  The results showed that preschool-aged children perceive entities related along both single and multiple dimensions as more similar than unrelated entities, and entities related along multiple dimensions as more similar than those related along a single dimension.  Therefore, by four years of age children are sensitive to the number of relations linking entities.

Introduction

To function in the world, one must develop knowledge, a foundation of information with which one can formulate thoughts, actions, and behaviors.  Semantic knowledge, an understanding of concepts and their meanings, is a fundamental aspect of cognitive development.  As children grow and develop, their ability to observe and understand objects and events increases, their experiences in the world helping to establish a foundation of knowledge (e.g., Fisher, Godwin, Matlen, & Unger, in press; Tversky, 1985).

It has been suggested that as children develop, they go from using perceptual features as a means of understanding similarities between stimuli to making inferences based upon previous knowledge, expediting the process of observation and understanding as semantic knowledge grows (Tversky, 1985).  Knowledge of concepts ultimately allows people to go from simply observing the world around them to making inferences based on prior experience and knowledge, increasing mental efficiency and efficacy.

As children observe and learn about the world around them, they build associations among concepts. A large body of previous research has investigated children's sensitivity to different *types* of associations between concepts.  Taxonomic and thematic associations have been identified as two of the fundamental forms of relation. Taxonomic relations pair together members of similar kind with shared properties, like "dog" and "lion" both being mammals (e.g., Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006).  Thematic relations, on the other hand, group together stimuli based on whether entities appear together or are associated with the same environment (e.g. "turkey" and "cow" are animals that are both commonly found on farms) (e.g., Tversky, 1985; Blaye et

al., 2006).  Though concepts that are thematically related may share few to no perceptual properties, they are united by having a complementary relation such as occupying the same space (Lucariello, Kyratzis, & Nelson, 1992).  As such, thematic associations are more rooted in *ad hoc* observation, while taxonomic associations rely more on acquired knowledge.

The primary focus in the field of investigating children's understating of relationships has been to determine whether the *types* of relationships to which children are sensitive changes with age.  A number of studies have demonstrated that children's preference for taxonomic relations over other types of relations increases with age (e.g., Blaye et al., 2006; Lin & Murphy, 2001; Nguyen, 2007; Tversky, 1985).  For example, Tversky (1985) conducted a study with children three, four, six, and eight years of age.  This study used a *match to sample* paradigm in which children were asked to judge which of two test items should be grouped with a target item, and then to justify their selection.  The test items included an option that was perceptually related to the target, and an option that was taxonomically related to the target.  For instance, children might be presented with "snake" as the target, and be asked to choose whether it goes with a "hose" (perceptual relationship choice) or a "lizard" (taxonomic relationship choice).  The results showed that children younger than six years of age, were at chance at choosing taxonomic or perceptual matches; however, starting at age six children showed a preference for taxonomic relations. Children's ability to justify their choices (both perceptual and taxonomic) also increased markedly between three and eight years of age.  Therefore, it appears that preferences for linking entities according to taxonomic relationships increase with age.  This increased preference for taxonomic relationships is accompanied by

increasingly rich representations of taxonomic relations, as revealed by the more detailed and appropriate justifications for taxonomic choices that children provided with increasing age.

However, most studies in the literature have used forced choice tasks to assess children's lack of preference for taxonomic versus thematic relations.  Although these prior studies shed light on children's sensitivity to different types of relationships, entities in the real world are often linked by multiple relationships simultaneously.  For instance, lions and tigers are both taxonomically and thematically related to each other.  However, research to date has not investigated children's sensitivity to the number of relationships between entities.  Moreover, the match to sample paradigm used in most prior studies is inappropriate for investigating this question.  Specifically, this task only allows participants to indicate whether a given test item is or is not related to the target.  To determine children's sensitivity to the number of relationships between entities, participants must be able to provide judgments of relatedness on a graded scale. The purpose of the present study is to investigate the influence of number of relationships between entities on children's judgments of similarity between entities, using a paradigm that affords a graded measurement of perceived similarity.

The Semantic Space Task, created in the Cognitive Development Lab at Carnegie Mellon University, removes the forced-choice component from methodology (Fisher, Godwin, Matlen, and Unger (in press) and makes it possible to collect graded judgments of semantic similarity.  The Semantic Space task is presented to participants as a game called the Help Zibbo Game, in order to assess how children organize semantic knowledge about entities based on relationships between them.  Researchers presented

each participant with two neutral-colored blocks, each representing a member of an animal dyad.  The experimenter would place one square on the game board, to serve as a target animal, the block introduced as an animal (e.g., a crocodile).  The experimenter then handed the second block to the child while posing the question: "If the crocodile goes here, where do you think the alligator should go?"  Each participant was instructed to put animals of the same kind close together on a 9 x 9 square grid game board.  The experimenter removed the two blocks from the game board after each trial and used the blocks to represent a different dyad of animals on the next trial. Participants' responses were scored as the distance between the two blocks.

The goal of the Fisher et al. (in press) study was to examine whether children distinguish between highly semantically similar dyads and dissimilar dyads.  Therefore, in that study participants were presented with dyads of animals that were related both thematically and taxonomically (e.g., *lamb-sheep*).  The goal of the present study is to examine whether preschool-age children are sensitive to the number of relations linking different concepts.  Therefore, in the present study participants were presented with dyads of animals that either were related only taxonomically or both taxonomically and thematically.

**Overview of the Present Study**

The present study utilized the Semantic Space Task, using dyads of animals that were chosen to specifically test for sensitivity to purely taxonomic relationships versus multiple relationships that included both taxonomic and thematic associations.  The Semantic Space Task has been previously validated to show that it is a valid measure of semantic knowledge in young children, and that preschoolers understand the rules of the

game despite their relatively weak performance on the task (D'Emilia, Unger, & Fisher, 2013). As such, the Semantic Space Task is a valid measurement tool for assessing semantic knowledge, and was used here to assess children's sensitivity to different kinds of relations.

In the task, participants were told that Zibbo the zookeeper needed help organizing his zoo, and he wanted to put animals of the same kind close together (Fisher et al., in press). The experimenter placed the first block on the board, using it to represent an animal (e.g. "*if the duck goes here…*"), then the researcher asked participants where on the board they thought the second animal should be placed. The three categories of dyads used were multiple relations pairs (e.g. *duck-goose*), single taxonomic relation pairs (e.g. *duck-parrot*), and unrelated control trial pairs (e.g. *duck-squirrel*)

The purpose of the three distinct dyads was to examine children's sensitivity to different kinds of relations. The multiple similarities pairs were related along multiple dimensions: their taxonomic relatedness (e.g., "duck" and "goose" are both birds) and their thematic relatedness (e.g., both are found to reside on rivers, lakes, and on farms). As such, they relate to each other along more dimensions than the single taxonomic association pairs, which are only related along a single taxonomic dimension (e.g., "duck" and "parrot" are both birds, but are not associated with the same environment). The unrelated control trial pairs were designed to compare children's judgments of similarity between entities related along single and multiple dimensions to entities that bear no relationships with each other.

Three potential patterns of similarity judgment were of particular interest in this study. First, relatedness along a single dimension may be insufficient for children to judge

entities as more similar than unrelated entities.  In this case, we would predict differences

in similarity judgments between multiple relationships and unrelated dyads only. Second,

children may differentiate between related and unrelated dyads, but fail to differentiate

between related dyads that are linked according to multiple versus single relationships.

In this case, we would predict that children judge both multiple and single relationship

dyads as more similar than unrelated dyads, but fail to differentiate between multiple and

single relationship dyads.  Finally, children may be sensitive to both the presence and

number of relationships.  According to this possibility, children should judge multiple

relationship dyads as more similar than single relationship dyads, and single relationship

dyads as more similar than unrelated dyads.

**Method**

*Participants*

Twenty-nine participants (mean age = 4.71 years, *SD* = 0.55, 15 boys and 14 girls)

were recruited through the Children's School at Carnegie Mellon University in

Pittsburgh, Pa.  The students ranged from Pre-School to Kindergarten, ranging from ages

three to five.  The sample contained 14 Pre-School students (mean age = 4.23 years, *SD* =

0.33, 5 boys and 9 girls) and 15 Kindergarten students (mean age = 5.16 years, *SD* =

0.23, 10 boys and 5 girls).

*Design*

The independent variable in this study was the type of dyad, of which there were four,

and the dependent variable was the distance score, the number of squares between the

initial target animal block and the second block placed by the participant. The experiment

used a mixed design, with dyad type as a within-subject variable and grade level as the

between-subject variable.  This experiment used 24 animal pairs, divided into four types

of dyads (see Table 1).  There were three critical types of trials: multiple similarities pairs

(e.g. *duck-goose*), single taxonomic association pairs (e.g. *duck-parrot*), and unrelated

control trial pairs (e.g. *duck-squirrel*).  These three types of trials utilized the same six

target animals.  Additionally, there were six non-critical filler trials utilizing animals with

no similarity (e.g. *zebra-caterpillar*).  The non-critical trials did not use the same target

animals as the critical trials and their distance scores were not coded and analyzed. The

24 animal dyads were randomly organized into a sequence of trials, creating Order 1.

That sequence was then reversed to create Order 2, creating two possible sequences of

dyad trials.  Participants were randomly assigned to one sequence or the other before

experiments occurred.

*Materials*

The materials for this experiment consisted of two neutral-colored blocks, one used to

represent the target animal, and the other given to the child and representing a second

animal.  The Semantic Space Task was conducted using a game board with a 9 x 9 grid of

white squares with the "zookeeper's house" located in the middle square on the board

(see Figure 1).

*Procedure*

Participants were tested in a testing room adjacent to their classroom.  After

introducing the Help Zibbo game to participants, children were told that Zibbo the

Zookeeper was trying to organize his zoo, and he wanted to put animals of similar kind

close together on the square grid game board (Fisher et al., in press).  For each of the 24

trials, the experimenter placed a block in a pre-determined spot on the board, telling

children that that the block represented an animal (i.e. *shark*, *duck*, etc.).  For the 18

critical trials, the target animals were randomized to one of eight potential squares around

the center of the board, as any of these locations would provide participants with a similar

number of potential squares to use.  For the non-critical trials, the target animals were

randomly assigned to the remaining squares, in order to communicate to the children that

it was possible to utilize the entirety of the grid in this task.  Participants were instructed

that they could only place animals on the white squares, excluding the squares with

numbers, colors, or the zookeeper's house located in the center of the board, so the

squares surrounding the center would have an equal number of squares around them,

essentially making the 8 squares around the center into new centers.

After placing the target animal on the board, the experimenter then gave the other

block to the child, telling them: "if the shark goes here, where do you think the dolphin

should go?"  After the child placed the second block somewhere on the board, the

experimenter recorded where the child placed the second block on a response sheet. The

experimenter then cleared off the board, before re-introducing the blocks as two different

animals.

*Scoring*

Distance scores were calculated according to the same method as used by Fisher et al.

(in press), namely the variant of the city block distance metric.  Coders counted the

number of squares occupied by the two blocks (e.g. two squares if they were placed on

different squares, one square if the blocks were on top of each other) and added to that

the number of squares between them.  After coding the raw distance scores for each

participant, scores were grouped together by dyad type, excluding the non-critical filler

trials.  Participant's distance scores were then averaged across all six dyads of each type

(i.e., multiple similarities dyads, taxonomically similar dyads, and unrelated dyads).

## Results

In the multiple similarities condition, Kindergarteners averaged a score of 4.73 ($SD =$

2.12), while Pre-Kindergarteners averaged a score of 4.83 ($SD = 2.23$).  In the single

taxonomic similarity condition, Kindergarteners averaged a score of 6.21 ($SD = 1.60$),

while Pre-Kindergarteners averaged a score of 5.62 ($SD = 1.45$).  In the unrelated

condition, Kindergarteners averaged a score of 7.41 ($SD = 1.73$), while Pre-

Kindergarteners averaged a score of 6.04 ($SD = 1.51$) (see Figure 2).

Distance scores were submitted to a mixed ANOVA, with grade level (pre-school vs.

kindergarten) as the between-subjects variable and dyad type (i.e., multiple similarities,

taxonomic similarity, or unrelated) as the within-subject variable.  The test of within-

subjects effects showed a significant main effect for dyad type, $F (2, 27) = 15.78$, $p <$

0.05.  There was no main effect found for grade level, $F (1, 27) = 1.35$, $p = 0.26$, meaning

that preschoolers and kindergarteners performed comparably in this study.  No significant

interaction between grade level and distance scores was found, $F (2, 27) = 2.26$, $p = 0.13$.

Planned comparisons indicated that children placed multiple similarities dyads closer

together than unrelated dyads, as shown by a paired-samples t-test, $t(28) = -4.50$, $p <$

.005.  This finding replicates the findings reported by Fisher et al. (in press).

Additionally, children placed taxonomically similar dyads closer together than unrelated

dyads, as shown by a paired-samples t-test, $t(28) = 3.08$, $p = .005$.  This is a novel

finding, suggesting that children have sensitivity to purely taxonomic associations when

no others are present.  Finally, children placed multiple similarities pairs significantly

closer than taxonomically similar pairs, as shown by a paired-samples t-test $t(28) = 3.37$, $p = .002$, suggesting that semantic similarity is higher for items that are related on multiple dimensions.

## Discussion

The results of this study show that preschool and kindergarten-age children are sensitive to the number of relations between animal concepts.  Specifically, children placed entities that were related along multiple (i.e., taxonomic and thematic dimensions) closer together on the game board than entities related along a single taxonomic dimension, and they placed entities related along a single and multiple dimensions closer together than unrelated entities.  No difference between grade levels emerged in the results, suggesting that semantic representations of animal concepts are fairly similar in preschool and kindergarten-age children.

Most prior studies used of forced choice tasks, in which test items matched the target item on one dimension (e.g., taxonomic versus perceptual or thematic relation) (e.g., Blaye et al., 2006; Nguyen, 2007; Tversky, 1985).  These studies inform us about the *types* of relations that children prefer at different points in development.  In contrast, the present study used the Semantic Space task to collect graded judgments of semantic similarity to examine whether the *number* of relations linking entities effects the similarity of representations of animal concepts.  Therefore, this study makes a novel contribution to our understanding of semantic development in preschool and kindergarten-age children.

Limitations of the present study manifest in the sample.  The students from the Children's School have experience taking part in numerous studies, and as a result their

performance may not be generalizable to the population as a whole.  Their previous experience could make them more comfortable in a testing environment, allaying any potential confusion or uneasiness that could manifest in children who have less experience taking part in a study.  The students likely also fall within a similar education level and socioeconomic status, possibly distinguishing them from the population at large.  The studied sample, 15 kindergarten students and 14 preschoolers, was also relatively small, allowing for the possibility that the observed results do not accurately reflect the developmental trends that may exist within the larger population.  Future studies should aim to use a larger sample of children from a wider range of schools, as a way of gathering a more generalizable, representative sample.

The present results expand our understanding of semantic knowledge as it develops in young children.  Children become more nuanced in their thinking as they grow, developing the ability to utilize multiple associations simultaneously in assessing relations between stimuli, ultimately making inferences based off their experience with such stimuli.  Studies on the developmental course of taxonomic and thematic associations have produced mixed results.  Specifically, some studies showed that are sensitive to both types of relations from an early age (e.g., Nguyen, 2007), whereas other studies showed a gradual development of preference for taxonomic associations as children develop (e.g. Tversky, 1985).  The present results show that nascent sensitivity to taxonomic relations exists in preschool-age children, although children's ability to encode and represent purely taxonomic relations likely increases with development (e.g., Fisher et al., in press).

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*Table 1*: Animal names used in Critical Trials.

| Target | Single Taxonomic Similarity | Multiple Similarities | Unrelated |
|---|---|---|---|
| Duck | Parrot | Goose | Squirrel |
| Chicken | Penguin | Turkey | Lion |
| Shark | Goldfish | Dolphin | Butterfly |
| Cow | Elephant | Horse | Flamingo |
| Rhino | Sheep | Hippo | Octopus |
| Moose | Pig | Deer | Ant |

*Figure 1:* Schematic depiction of the Semantic Space game board. Squares highlighted in red indicate the location of the critical trials; squares highlighted in yellow mark the location of the filler trials.  Note that in the experiment proper the locations of the critical and filler trials were not marked and all squares on the board were white.

*Figure 2*: Average distance scores by dyad type and grade level.  Error bars represent the standard errors of the mean.