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Learning in the Wild: Real-World Experiences Shape Children's Knowledge Organization

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Abstract

The organization of knowledge according to relations between concepts is critically involved in many cognitive processes, including memory and reasoning. However, the role of learning in shaping knowledge organization has received little direct investigation. Therefore, the present study investigated whether informal learning experiences can drive rapid, substantial changes in knowledge organization in children by measuring the effects of a week-long Zoo summer camp versus a control camp on the degree to which 4- to 9-year-old children's knowledge about animals was organized according to taxonomic relations. Although taxonomic organization did not differ at pre-test, only Zoo camp children showed increases in taxonomic organization at post-test. These findings provide novel evidence that informal, real-life learning experiences can drive rapid knowledge organization change.

Keywords: Cognitive Development; Semantic Knowledge; Semantic Development

Introduction

Knowledge is not merely a mentally stored body of information, but rather an interconnected network of concepts linked by meaningful relations (e.g., McClelland & Rogers, 2003). This organization of knowledge according to meaningful relations between concepts plays a critical role in many cognitive processes, including memory, reasoning, learning, and visual attention (Bjorklund & Jacobs, 1985; Bower, Clark, Lesgold, & Winzenz, 1969; Chi, Feltovich, & Glaser, 1981; Moores, Laiti, & Chelazzi, 2003; Pinkham, Kaefer, & Neuman, 2014). Therefore, a key facet of understanding cognition is understanding the development of knowledge organization.

Current conceptual development accounts suggest that learning experiences drive changes in knowledge organization, though the posited nature of such learning processes and the degree to which learning is emphasized in contrast with early (possibly innate) conceptual biases varies across accounts (e.g., Carey, 1985; Fisher, 2015; Gelman, 2003; Tenenbaum, Kemp, Griffiths, & Goodman, 2011). However, the role of learning in organizing knowledge can only be indirectly inferred from prior research, because no past studies have directly investigated learning experiences that may drive knowledge organization changes. This lack of direct evidence leaves open several key questions about learning-driven knowledge organization change. First, it is unknown whether such changes result from the protracted accumulation of learning experiences over long-term developmental time-scales (e.g., months and years), or whether they can result from experiences over relatively brief developmental time-scales (e.g., days or weeks). Second, the role of formal education versus day-to-day informal learning experiences in driving knowledge organization change remains poorly understood.

Indirect evidence for the contribution of learning experiences to knowledge organization comes from cognitive development, expertise, and learning science research. Within the cognitive development field, the emergence of knowledge organization has been a focus since the field's inception (Inhelder & Piaget, 1964). Specifically, numerous studies have attempted to characterize the developmental trajectory of knowledge organization by measuring the degree to which children of different ages possess knowledge of different types of relations between concepts. The relations that have received greatest interest to date include: Similarity based on shared perceptual features (e.g., shape or color); taxonomic relations based on membership in the same, stable category (e.g., mammal); and thematic relations based on co-occurrence in the environment (e.g., dog and bone) (Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006; Nguyen, 2007; Unger, Fisher, Nugent, Ventura, & MacLellan, 2016).

Evidence from some cognitive development studies has suggested that children apprehend and reason on the basis of multiple types of relations from an early age (e.g., Gelman & Coley, 1990; Nguyen, 2007). For example, Nguyen and colleagues used match-to-sample tasks to demonstrate that young children can match target items to both taxonomically and thematically related items versus unrelated items from age two (Nguyen, 2007; Nguyen & Murphy, 2003). These findings suggest apprehension of multiple relations from early childhood, and thus de-emphasize learning-driven changes in knowledge organization throughout development. However, this conclusion remains controversial. For instance, studies using the same paradigm demonstrated that young children could explain perceptual and thematic, but not taxonomic matches (Sell, 1992; Tversky, 1985). Similarly, Blaye et al. (2006) demonstrated that five-year-old children relied on thematic and perceptual relations to complete an ostensibly taxonomic organization task, whereas older children increasingly used true taxonomic knowledge. These findings suggest that (1) Young children can make decisions that are consistent with knowledge of a given relation without actually possessing such knowledge, and (2) Relations knowledge develops significantly beyond early childhood.

A handful of recent studies provide direct evidence that knowledge organization indeed evolves gradually across development (Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen, & Unger, 2014; Unger et al., 2016). These studies were designed to capture gradual knowledge organization changes by using a paradigm in which children make graded spatial judgments of the degree to which items are related (Goldstone, 1994). The results of these studies reveal that: (1) Overall, children increasingly differentiate related from unrelated items between ages four and seven, and (2) The influence of specific relations (i.e., thematic and taxonomic) on knowledge organization increases gradually across childhood. In contrast with the perspective suggesting early apprehension of different types of relations, it has been argued that this continuous evolution of knowledge organization implies a key role for learning experiences that transpire throughout childhood. However, these studies provide no direct insight into learning-driven knowledge organization change itself, including whether learning experiences must accumulate over months and years, and whether they must take place in formal education settings.

Further indirect evidence for the effects of learning on knowledge organization comes from expertise studies, which show that expertise in a specialized domain is associated not merely with knowledge of more concepts than novices possess, but the organization of concepts according to relations that are meaningful in the domain (e.g., Chi et al., 1981; Gobbo & Chi, 1986; Medin, Lynch, Coley, & Atran, 1997). However, this research does not illuminate whether knowledge organization changes can transpire without extensive learning experiences. Moreover, some researchers have argued that the effects of learning that produce expertize in the formalized knowledge domains studied to date are qualitatively different from the effects of learning in everyday domains (Gelman, 2003). Therefore, the role of everyday learning experiences on driving the acquisition of relations knowledge remains open for debate.

Finally, several learning science studies have measured the effects of brief learning experiences such as educational field trips on knowledge in everyday domains such as animals (e.g., DeWitt & Storksdieck, 2008; Farmer, Knapp, & Benton, 2007; Prokop, Tuncer, & Kvasničák, 2007). However, these studies almost exclusively measured children's knowledge of *individual concepts* (e.g., "Kangaroo rats have giant feet", Gottfried, 1980, p. 172). Accordingly, this research does not illuminate whether such informal and relatively brief learning experiences can *organize* children's knowledge according to meaningful relations.

Present Study

The present study aimed to bridge prior cognitive development, expertise, and learning sciences research by measuring the influence of real-world learning experiences on knowledge organization. To capture the effects of learning that appear in prior research to transpire over months or years (Fisher et al., 2015; Fisher et al., 2014; Unger et al., 2016), we measured the effects of a concentrated, immersive experience in a domain. Specifically, we measured the effects of a week-long, zoo-based summer camp versus a control, school-affiliated summer camp on 4- to 9-year old children's knowledge of biological taxonomic relations for a set of animals. We focused on the animal domain because it is familiar to children from an early age, and appears to undergo significant organizational changes with development (Unger et al., 2016). Therefore, this venue provides an ideal opportunity to investigate real-world experience-driven changes in knowledge organization.

Methods

Study Sites

Zoo Camp. Zoo camp consisted of lessons, interactions with animals, zoo tours, games, and crafts. Activities for each day were designed around a specific theme, such as "creatures of the night". Each year, the zoo camp organizers choose different themes for each age group. The themes for the age groups spanning our sample (4-5, 6-7, and 8-9 years of age) over the two summers during which testing took place are listed in Table 1. The majority of themes were not designed to teach biological taxonomic relations, with the exception of themes for children in the 8-9 age group in Year 2 and one instance of a "Reptiles" theme for children in the 4-5 age group in Year 2. These exceptions did not influence our results (see Results). To illustrate how themes shaped camp activities, the activities chosen for the "Extreme Families" theme were as follows. Children took part in two lessons: One about "Extreme Parents" that do or do not protect their offspring (e.g., chickens versus sharks), and another about benefits to animals that live in family groups (e.g., elephant). Children visited in person, completed crafts and played games related to a subset of animals described in lessons.

Control Camp. The Control Camp was a school-affiliated summer camp that did not provide immersive experiences

Table 1: Curriculum themes for each age group.

	Year 1	Year 2
4-5	Domestic Animals	Animal Locomotion
	Super Senses	Reptiles
	Tropical Treasures	Aquatic Animal Diets
	Savanna Survival	Savanna Animal Patterns
6-7	Animal Babies	Rainforest
	How Animals Learn	African Savanna
	Animal Families	Ocean
	Aquarium Animals	Islands
8-9	Extreme Families	Mammals
	Extreme Senses	Birds
	Extreme Architects	Reptiles
	Animal All-Stars	Amphibians

with animals. At camp, children engaged in outdoor play, dance, crafts, games, and cooking. Additionally, children went on a field trip each week (e.g., to a baseball game), but did not visit the Zoo during this study.

Participants

Participants were 4 to 9-year-old children enrolled in the Zoo or the Control Camp located in the same Northeastern US city. The initial sample included 33 Zoo Camp (19 females) and 32 Control Camp (17 females) children. Of this sample, data from six Zoo Camp children and one Control Camp child were not included in analyses of performance on one of the two outcome measures due to a camera malfunction (see the Scoring section below). Although random assignment to a camp was not possible, children enrolled in the two camps performed equivalently on measures of taxonomic knowledge at pre-test (see Results), and were approximately matched for age (Zoo Camp: M_{age}=6.89 years, SD=1.43; Control Camp: M_{age}=6.23 years, SD=1.21; $t(57)=1.9$, p=.06).

Design

The study was a quasi-experiment in which children recruited from Zoo and Control camps participated in both Pre- and Post-Test sessions at the beginning and end of a week of camp. To ensure sufficient number of participants in the Zoo camp condition, data in this condition were collected in the summer of 2015 (Year 1) and 2016 (Year 2), and collapsed across years for analysis.

Stimuli

The animal stimuli were selected from the zoo camp curricula, such that knowledge in a given age group was assessed for animals about which Zoo Camp children in that age group learned. Accordingly, we developed a separate stimulus set for each age group in each year. Each set consisted of 15 animals, with an equal number of items in each of three biological taxonomic categories: Mammals, birds, and reptiles. To represent the animal stimuli, we used line drawings chosen to minimize perceptual similarity between animals in the same taxonomic category (see examples in Figure 1A-B).

Materials and Procedures

Participants completed pre- and post-test sessions on Monday and Friday morning of the same week that took place during a "before care" period prior to the start of camp activities. In both Years 1 and 2, these sessions included a Spatial Arrangement Method (SpAM) task (Goldstone, 1994), and in Year 2, children additionally completed a Match-to-Sample task (Figure 1). These tasks have complementary advantages: The match-to-sample task provides a straightforward assessment of taxonomic reasoning that is well-established in developmental research (e.g., Fisher, 2011; Smiley & Brown, 1979; Waxman & Namy, 1997), whereas SpAM yields a more graded measure of taxonomic relations knowledge and the degree to which it changes with training. A recent

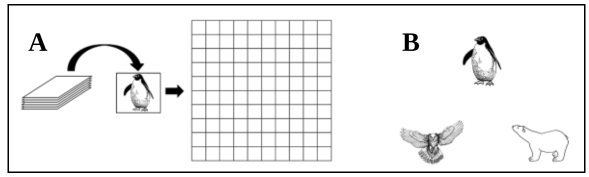

Figure 1: Schematic depiction of the SpAM task (A) and the match-to-sample task (B).

longitudinal study (Fisher et al., 2014) provided evidence that the two measures converge on the same underlying construct.

SpAM Task. Participants were seated at a game board consisting of a 10x10 grid, and were told that they were going to play a game in which their job was to help a fictional character, Zibbo, organize his favorite animals on the board (Figure 1-A). The experimenter then showed participants a stimulus sheet that depicted all 15 animal stimuli selected for the child's age group, named each animal, and removed the sheet from view. Next, the experimenter told the participant that they would organize the animals using cards that each depicted an animal on the game board, such that "animals that are the *same kind* of animal go close together, and *different kinds* of animals go farther apart". The experimenter placed one of the 15 animal cards on a central game board square, then named and presented each of the remaining cards for the participant one-by-one. Cards were presented in a pre-determined, pseudo-random order in which no more than two animals from the same taxonomic group appeared consecutively. Participants were allowed to move cards that they had placed earlier in the task. Finally, the experimenter photographed the board to record the locations of the cards.

Match-to-Sample Task. The animal stimuli for a given age group were arranged into six triads that each consisted of a Target, a Taxonomic Match that belonged to the same taxonomic category as the Target and a Lure that belonged to a different category (Figure 1-B). Of the six triads, two had mammal Targets, two had bird Targets, and two had reptile Targets. Triads were designed to eliminate non-taxonomic cues to Taxonomic Matches, such as visual similarity or shared habitat. For example, a triad might consist of a type of flightless bird such as penguin as the Target, a bird capable of flight such as *owl* as the Taxonomic Match, and a non-bird such as *polar bear* as the Lure.

For each triad, the experimenter asked participants to choose whether the Taxonomic Match or the Lure was "same kind of animal" as the Target. The experimenter pointed to and labeled the animals while providing these instructions (e.g., "Which one is the same kind of animal as the *penguin*, the *owl* or the *polar bear*?).

Results

Of the Zoo Camp sample, children in both Year 1 and Year 2 (N=27) completed the SpAM task, whereas only children in Year 2 (N=16) completed the Match-to-Sample task. All 32 children in the Control Camp sample were tested during Year

2, and completed both tasks (although one participant's SpAM data were excluded due to camera malfunction).

Scoring

SpAM Task. The photographs taken following each arrangement trial were scored by treating the 10x10 board as a coordinate plane, identifying the coordinates of each card, and calculating the Euclidean distance between the coordinates. The range of possible distances was 1 (adjacent cards) to 12.73 (cards on diagonally opposite corners of the board). These distances are taken as a measure of the degree to which participants judge a given pair of animals to be the "same kind of animal", where shorter distances indicate stronger judgments that the pair are of the same kind.

We used these distance data to calculate a Difference Score for each participant at both Pre- and Post-test that captured the degree to which participants placed taxonomically related animals closer together than unrelated animals by subtracting distances between pairs of animals from the same taxonomic category from distances between taxonomically unrelated pairs. Accordingly, larger Difference Scores reflected stronger judgments that taxonomically related versus unrelated animals were of the "same kind".

Match-to-Sample Task. We calculated an Accuracy score for each participant in which we calculated the proportion of times they chose the Taxonomic Match.

Pre-Test Performance

We first assessed whether participants in both camps performed comparably on the two measures of taxonomic relations knowledge at Pre-Test. Note that the range of Difference Scores on the SpAM task at Pre-Test was -.65 to 5.25 (chance=0), and of Accuracy scores on the Match-to-Sample task was .17 to .83 (chance=.5). The results of independent samples t-tests indicated that there was no significant difference at Pre-Test between the performance of participants in the two camps on either measure (SpAM: M_{zoo}=.80, $M_{control}$=.61, $t(56)$=.57, p=.57; Match-to-Sample: M_{zoo}=.54, $M_{control}$=.58, $t(46)$=.69, p=.49). Performance at Pre-Test on the SpAM task was above chance in both camps (both ts>2.86, both ps<.01), whereas performance on the Match-to-Sample task was above chance in the Control Camp only (Zoo: $t(15)$=.94, p=.362, Control: $t(31)$=2.61, p=.014).

Effects of Zoo versus Control Camp

These analyses measured the effects of Zoo Camp versus Control Camp on changes from Pre- to Post-Test in taxonomically organized knowledge: I.e., the degree to which participants' SpAM Difference Scores indicated that they made "same kind" judgments based on taxonomic relations, and the degree to which participants chose the Taxonomic Match on the Match-to-Sample Task.

For each measure, we assessed whether Zoo camp participants manifested greater improvements from Pre- to Post-Test than participants in the Control camp using two analyses. First, we used paired t-tests to compare Pre- versus Post-Test Difference and Accuracy Scores for participants in each camp separately, and found that whereas Zoo camp participants performed significantly better across both measures at Post- than Pre-test (SpAM: M_{pre}=.80, M_{post}=1.30, $t(26)$=3.01, p=.006, Cohen's d=.34; Match-to-Sample: M_{pre}=.54, M_{post}=.73, $t(15)$=3.74, p=.002, Cohen's d=1.02), Control camp participants' performance did not improve from pre- to post-test (SpAM: M_{pre}=.61, M_{post}=.59, $t(30)$=.19, p=.85, Match-to-Sample: M_{pre}=.58, M_{post}=.56, $t(31)$=.61, p=.55).

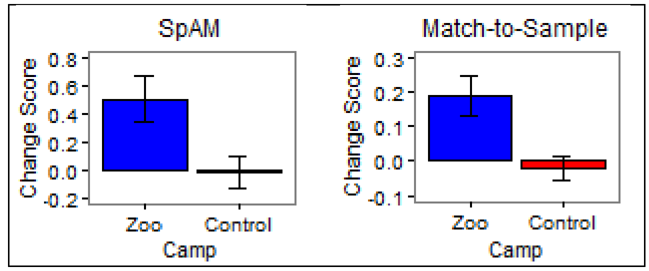

Figure 2. Change scores for Zoo and Control Camp participants in SpAM (left) and Match-to-Sample (right) tasks. Error bars represent standard errors of the mean.

Second, to compare performance of participants at both camps directly, we calculated a Change Score for each participant in which we subtracted Pre- from Post-Test scores (such that larger Change Scores indicated larger improvements). We then used independent samples t-tests to compare SpAM and Match-to-Sample Change Scores between the camps, and observed that across both measures, Change Scores for Zoo Camp participants were larger than those for Control Camp participants (SpAM: $t(56)$=2.61, p=.011, Cohen's d=.68, Match-to-Sample: $t(46)$=3.48, p=.001, Cohen's d=1.06; Figure 2).

Effects of Camp across Age Range

To test whether the effects of attending Zoo versus the Control camp varied with age, we measured the correlation between age and Change Score for each task in each camp. Age was not correlated with Change Score for either task in Control camp participants ($r_{match\text{-}to\text{-}sample}$=-.033, r_{SpAM}=-.002, ps>.86), whereas in Zoo camp participants, age was significantly correlated with Match-to-Sample task Change Score (r=.56, p=.024) and marginally correlated with SpAM task Change Score (r=.33, p=.09) (Figure 3). Moreover, these correlations were not merely due to older children having more taxonomic relations knowledge to start out with: In Zoo camp children, pre-test performance on the SpAM task was not correlated with Change Score (r=.11, p=.597) and pre-test performance on the Match-to-Sample task was marginally *negatively* correlated with Change Score (r=-.49, p=.052).

Influence of Taxonomic Themes

Finally, to test whether these results were driven by the handful of Zoo Camp themes designed to teach taxonomic relations, we re-ran all analyses excluding all data from

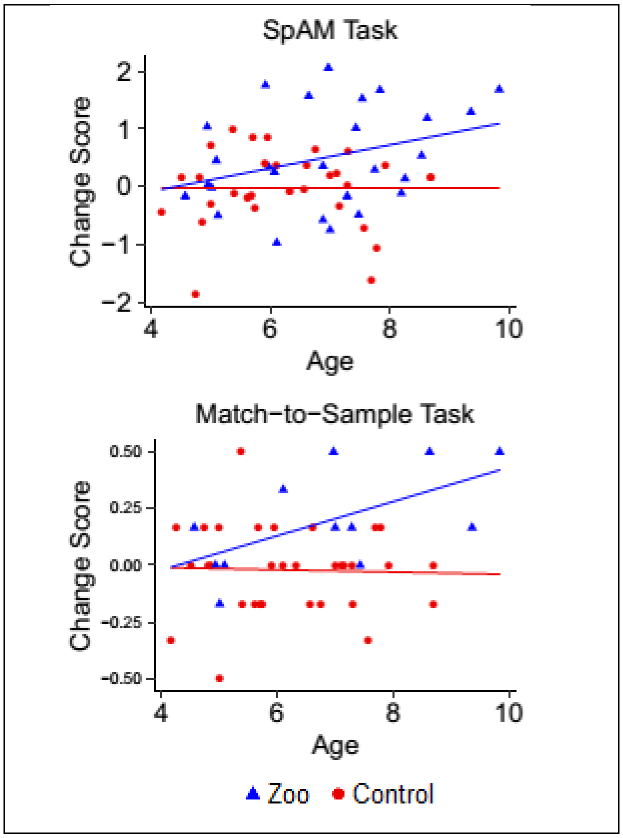

Figure 3: Correlations with age of Change Scores in SpAM and Match-to-Sample tasks for each camp shown with best-fit lines.

children in the 8-9 age group in Year 2 who experienced a week of taxonomically-oriented themes (*N*=2), and trials involving reptiles from children in the 4-5 age group in Year 2 who experienced a reptile-oriented theme (*N*=4). All results reported above remained unchanged: Significant outcomes remained for Pre- to post-test Zoo Camp comparisons, Zoo vs. Control Camp Change Score comparisons, and correlation between age and Match-to-Sample task Change Score in Zoo Camp (all $ps < .05$).

Discussion

This study aimed to capture learning-driven changes in knowledge organization in action by measuring the effects of concentrated, real-world learning experiences on the organization of children's knowledge about animals. Specifically, we measured the effects of a week-long Zoo-based summer camp on children's knowledge of biological taxonomic relations between animals. We observed that across two converging measures, taxonomic relations increasingly influenced knowledge organization in Zoo but not Control Camp children. These effects transpired despite equivalent Pre-Test performance, suggesting that the difference between camps at Post-Test cannot be attributed to greater prior taxonomic relations knowledge in Zoo Camp children. Moreover, the difference between camps remained even when data from Zoo Camp children who received explicit taxonomic instruction were removed from analyses. Finally, the results provided evidence that the degree to which Zoo Camp experiences improved taxonomic relations knowledge was associated with age, suggesting that older children learn relations more effectively than younger children (a possibility we discuss further below). Taken together, these findings provide the first direct evidence that learning experiences need not accumulate over lengthy periods of time or take place in formal education settings to shape knowledge organization. Instead, an immersive but relatively brief learning experience in an informal setting can promote significant knowledge organization changes.

Open Questions

The evidence for learning-driven knowledge organization change presented here highlights the importance of examining the mechanisms by which experience shapes knowledge organization. For example, although the present study was not designed to arbitrate between accounts of conceptual development that place different emphases on early conceptual biases versus domain-general processes and learning mechanisms, our findings are inconsistent with the perspectives emphasizing early conceptual biases towards perceiving entities as organized into taxonomic categories (e.g., Gelman, 2003; Keil, 2007; Wellman & Gelman, 1992). By the same token, these findings support a key role for learning throughout development in shaping the organization of semantic knowledge (e.g., Fisher et al., 2015; McClelland & Rogers, 2003; Tenenbaum et al., 2011). Research following on from the present study could further arbitrate between these accounts, particularly with respect to illuminating the nature of learning mechanisms posited to shape knowledge organization given environmental input.

Finally, our results provide some evidence that the magnitude of learning-driven knowledge organization changes increased with age. One characteristic of the learner that may improve with age is prior knowledge organization (Unger et al., 2016). Although taxonomic knowledge at pre-test for the specific animals tested in this study was not correlated with learning-driven improvements, it is possible that older children's knowledge of animals in general was better organized than younger children's knowledge. Consequently, it may have been easier for older versus younger children to integrate new information into existing knowledge structures. Future research that investigates the relationship between such learner characteristics and learning-driven knowledge organization changes could illuminate how learning from experience improves with age.

Conclusions

This study demonstrated that immersive learning experiences at a zoo summer camp produced changes in organization of children's knowledge about animals. These findings build upon research in several domains, including cognitive development, expertise, and the learning sciences by providing the first direct evidence for learning-driven changes in knowledge organization. Future research should further investigate the mechanisms by which learning drives the development of knowledge organization.

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