Rapid, Experience-Related Changes in the Organization of Children's Semantic Knowledge

Layla Unger¹

Anna V. Fisher²

¹Department of Psychology, Ohio State University, Columbus OH

²Department of Psychology, Carnegie Mellon University, Pittsburgh PA

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Abstract

The organization of knowledge according to relations between concepts is crucially important for many cognitive processes, and its emergence during childhood is a key focus of cognitive development research. Prior evidence about the role of learning and experience in the development of knowledge organization primarily comes from studies investigating differences between pre-existing, naturally-occurring groups (such as children from rural vs. urban settings, or children who own a pet vs. children who don't), and a handful of studies on the effects of researcher-developed educational interventions. However, we know little about whether knowledge organization can be relatively rapidly molded by shorter-term real-world learning experiences (e.g., on a time-scale of days vs. years or months). The present study investigated whether naturalistic learning experiences can drive rapid, measurable changes in knowledge organization in children by investigating the effects of a week-long Zoo summer camp (compared to a control school-based camp) on the degree to which 4- to 9-year-old children's knowledge about animals was organized according to taxonomic relations. Although there were no differences in taxonomic organization between the Zoo and the school-based camp at pre-test, only children who participated in the Zoo camp showed increases in taxonomic organization at post-test. Moreover, analyses of changes in taxonomic organization in Zoo camp children suggested that these changes were primarily driven by improvements in the degree to which children differentiated between taxonomic categories. These findings provide novel evidence that naturalistic experiences can drive rapid changes in knowledge organization.

Keywords: Cognitive Development; Semantic Knowledge; Semantic Development; Knowledge Organization; Concept Learning

Our knowledge about the world is often characterized not as an encyclopedia, with independent entries for information about separate topics, but rather as an interconnected network organized according to relational links between concepts (Cree & Armstrong, 2012; Jones, Willits, Dennis, & Jones, 2015; McClelland & Rogers, 2003). Organization is a key facet of semantic knowledge, because it plays a pervasive role in many cognitive processes, including knowledge retrieval (Bower, Clark, Lesgold, & Winzenz, 1969; Jimura, Hirose, Wada et al., 2016), reasoning (DiSessa, 1982; Heit, 2000), and the acquisition of new knowledge (Bein, Livneh, Reggev et al., 2015; Luiten, Ames, & Ackerson, 1980; Tse, Langston, Takeyama et al., 2007). Therefore, a key facet of understanding cognition is understanding how semantic knowledge organization emerges with learning and development.

A large body of prior research has investigated the emergence of semantic knowledge organization by evaluating differences in relational knowledge between pre-existing groups, such as children who have grown up in different communities (e.g., urban vs. rural settings) or children of different ages, (Bauer & Mandler, 1989; Coley, 2012; Fisher, 2011; Gobbo & Chi, 1986; Inagaki, 1990; Lucariello, Kyratzis, & Nelson, 1992; Nelson & Nelson, 1990; Smiley & Brown, 1979; Tversky, 1985; Unger, Fisher, Nugent, Ventura, & MacLellan, 2016; Walsh, Richardson, & Faulkner, 1993; Waxman & Namy, 1997). Evidence of group differences from these studies suggests that long-term exposure to different learning experiences acquired by different groups of children is associated with different patterns of knowledge organization development. Implied by these findings is the possibility that change in knowledge organization is prompted by individual learning experiences, and that differences in the accumulation of these learning experiences leads to differences in knowledge organization between groups of children

(Fisher, Godwin, & Matlen, 2015; Waxman & Medin, 2007). However, few studies have investigated the role of learning experiences in knowledge organization *directly* by moving beyond evaluating differences between pre-existing groups of individuals, and studying changes in knowledge organization prompted by a specific learning experience over relatively brief time scales (Alexander, Johnson, Leibham, & DeBauge, 2005; DeMarie-Dreblow, 1991). In addition to being few in number, these studies have investigated the effects of interventions designed specifically by researchers to prompt knowledge organization change, and therefore are not directly informative about whether brief real-world experiences that children naturalistically acquire can drive rapid knowledge organization change.

In what follows, we first review evidence about the emergence of knowledge organization from research that has measured differences in knowledge organization between naturally occurring groups of children, then review evidence from the handful of studies that have investigated knowledge organization changes prompted by brief learning experiences. We then highlight the limitations of the extant studies in illuminating whether brief, naturalistic learning experiences can drive rapid changes in knowledge organization, and present a study designed to address this gap.

Comparisons of Knowledge Organization in Pre-Existing Groups

A large body of prior research has investigated the emergence of knowledge organization by comparing knowledge organization differences between pre-existing occurring groups of children, including children of different ages (Bauer & Mandler, 1989; Fisher, 2011; Lucariello et al., 1992; Nelson & Nelson, 1990; Smiley & Brown, 1979; Tversky, 1985; Unger et al., 2016; Walsh et al., 1993; Waxman & Namy, 1997), and children with different long-term

histories of learning experiences (Coley, 2012; Gobbo & Chi, 1986; Inagaki, 1990). Evidence from this research suggests that learning over time leads to changes in knowledge organization.

For example, many studies have investigated cross-sectional age differences in knowledge for and ability to reason on the basis of a variety of relations, including perceptual similarity, co-occurrence or interaction in the environment (e.g., schematic or thematic relations, such as *dog* and *bone*), and membership in the same stable taxonomic category (e.g., the membership of *ostrich* and *robin* in the category of “birds” regardless of their perceptual differences and lack of environmental co-occurrence). According to the results of some studies, the nature of the relations that organize knowledge changes with age (Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006; Lucariello et al., 1992; Unger et al., 2016), such that knowledge of relations that are more easily observable in the environment (e.g., perceptual similarity and environmental co-occurrence) is evident from an earlier age than knowledge of less readily observable relations (e.g., membership in the same taxonomic category). According to the results of other studies (Bauer & Mandler, 1989; Nguyen, 2007; Waxman & Namy, 1997), children readily learn both easily observable relations and less observable taxonomic relations from an early age (possibly with the aid of innate biases towards utilizing taxonomically-relevant information in the environment, such as labels for taxonomic categories). Beyond whether knowledge of less readily observable taxonomic relations emerges early or later in development, some limits on taxonomic relation knowledge may commonly persist into adulthood. Specifically, results from a number of studies (Trowbridge & Mintzes, 1985, 1988; Yen, Yao, & Chiu, 2004) suggest that substantial minorities of students from elementary school through college possess misconceptions about the taxonomic category membership of items that are more

perceptually similar to or co-occur more often with members of a different taxonomic category (e.g., grouping *whales* with *fish* rather than *mammals*, or *turtle* with *amphibians* rather than *reptiles*).

Although the results of these cross-sectional studies suggest that organization of knowledge changes with age, these studies do not shed light on how such changes may come about in the course of development and learning. This indirect nature of research on the role of learning experiences in the development of knowledge organization also characterizes research that has investigated whether the organization of knowledge in a given domain, such as knowledge about animals, varies across children with different background experiences in that domain. For example, comparisons between children who were experts versus novices in the domain of dinosaurs (Gobbo & Chi, 1986) have yielded correlational evidence that expertise is associated with the organization of knowledge in a domain according to more stable, meaningful relations, such as the organization of knowledge about dinosaurs based on taxonomic category membership rather than visual features. Similarly, comparisons of children raised in rural versus urban settings (Coley, 2012) have provided complementary evidence that the former group of children has more experiences with animals and shows a more sophisticated pattern of reasoning about animals based on meaningful relations at a younger age (e.g., reasoning about insides based on biological taxonomic relatedness, and reasoning about diseases based on ecological interaction). Finally, similar differences in reasoning about animals have been documented between children who have experience raising a pet versus those who do not (Inagaki, 1990).

Taken together, findings from these studies suggest that long-term exposure to different learning experiences that is acquired by different groups of children is often associated with

different patterns of knowledge organization. Implied by these findings is the possibility that change in knowledge organization is prompted by individual learning experiences, and that differences in the accumulation of these learning experiences leads to differences in knowledge organization between groups of children. Specifically, findings from the studies described above may reflect the cumulative effect of changes in knowledge organization prompted by many learning experiences in a domain, such as the effects on the organization of knowledge about animals from interactions with a pet or farm animals (Waxman & Medin, 2007) over a time-scale that may range from weeks to years. Yet, this research has not *directly* probed or manipulated experiences that presumably drive changes in semantic organization. Therefore, the timescale of changes in knowledge organization remains unknown – it is unclear whether experiences must accumulate over months or years in order to produce detectable changes in knowledge organization, or whether changes in knowledge organization can be more rapidly prompted by learning experiences over shorter timescales, such as weeks or days. As reviewed in the following section, only a handful of prior studies have investigated these questions using researcher-designed educational interventions.

Effects of Brief Learning Experiences

A small number of prior studies have investigated whether brief educational interventions can drive changes in knowledge organization. For example, in DeMarie-Dreblow's (1991) studies, 8-11 year old children (Study 1) and undergraduate students (Study 2) completed a series of knowledge and memory assessments before and/or after watching five short researcher-developed educational videotapes that provided information about the characteristics of several individual birds, and their membership in one of five bird categories (e.g., birds of prey). Of

particular interest here is the finding that the ability to group birds into categories was improved following the educational intervention in both children and adults. Similarly, in Alexander and colleagues' (2005) study, kindergarten children completed a series of knowledge and reasoning assessments over the course of a three-week researcher-developed curriculum, in which children completed activities designed to teach them about several dinosaur species and their membership in one of five dinosaur "families" (e.g., sauropods). As in the study conducted by DeMarie-Dreblow, children in this study showed improvements in their ability to organize the dinosaur species into their corresponding families over the course of participation in the curriculum.

Taken together, the results of these studies provide evidence that even relatively brief learning experiences can drive changes in the organization of knowledge in a domain. However, these results come from studies in which children were explicitly taught the same organization of items into categories that was assessed, using interventions designed by researchers for this purpose. Therefore, beyond expanding upon this small body of prior research, it is important to investigate whether *naturalistic* learning experiences can prompt changes in knowledge organization, and do so over relatively brief timescales. However, prior studies that investigated the effects of naturalistic learning experiences such as a field trip to a museum or zoo (Bexell, Jarrett, & Ping, 2013; Farmer, Knapp, & Benton, 2007; Gottfried, 1980; Prokop, Tuncer, & Kvasničák, 2007; Randler, Baumgärtner, Eisele, & Kienzle, 2007; Randler, Kummer, & Wilhelm, 2012; Stronck, 1983) largely focused on evaluating learning of specific facts (e.g., "Kangaroo rats have giant feet", (p. 172, Gottfried, 1980) rather than changes in the way that knowledge is organized according to *relations among different concepts*.

The distinction between learning of isolated facts on the one hand, and relations among concepts on the other hand, is a critical one. Specifically, individual units of information can be acquired piecemeal (e.g., through rote memorization) without changing overall knowledge organization, or the many cognitive processes that are affected by knowledge organization (such as retrieval of knowledge from memory and reasoning) (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010; Bein et al., 2015; Jimura et al., 2016; Tse et al., 2007). However, the extent to which brief, naturalistic learning experiences can promote changes in knowledge organization has remained largely unexplored in the literature.

Present Study

The aim of the present study was to investigate whether measurable, rapid changes in the organization of knowledge about animals transpires given the acquisition of naturalistic learning experiences in this domain over a short timescale of days. To accomplish this aim, we compared changes in the organization of knowledge about animals that transpired in 4- to 9-year old children over the course of a week of summer camp that did or did not include learning experiences with animals.¹ Specifically, in this quasi-experimental study, we measured the effects of a week-long, zoo-based summer camp versus a control, school-affiliated summer camp on the degree to which children's knowledge about a set of animals was organized according to taxonomic relations. Critically, as we describe below, taxonomic organization was equivalent in the two groups of children at the beginning of the week of summer camp, such that rapid effects of learning

¹ According to a 2015 survey conducted by the American Camp Association (<https://www.acacamps.org/press-room/aca-facts-trends>), there are approximately 14,000 summer camps in the US, many of which (approximately 12%) provide nature/environment education programs like the one studied here.

experiences on knowledge organization could manifest as a greater increase in taxonomic organization at the end of the week for children who attended the zoo versus the control summer camp.

Overall, the present study extends prior research in the following ways. First, in contrast to prior studies, we directly investigated whether naturalistic learning experiences in a domain prompt relatively rapid changes in knowledge organization. Second, our approach allowed us to more thoroughly describe the learning experiences of interest than was possible in prior studies involving pre-existing group differences. However, it should be noted that we did not aim to evaluate whether educational programming at the zoo has unique pedagogical features that are particularly effective for fostering learning about animals; therefore, similar to prior studies, we did not specifically investigate which pedagogical components of the zoo camp learning experiences may have played a causal role in prompting changes in knowledge organization.

Methods

Participants

Participants were 4- to 9-year-old children who were enrolled in the Zoo or the Control Camp located in the same Northeastern US city. The initial sample included 34 Zoo Camp (20 females) and 32 Control Camp (17 females) children. Of this sample, data from six Zoo Camp children were lost due to experimenter error (see the Results section below). Additionally, data from one of the two outcome measures from one child in the Control Camp were also lost due to an experimenter error (data from the other outcome measure were included in the analyses).

Overall, the final sample consisted of 28 children in the Zoo camp and 32 children in the Control Camp.

Critically, 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 the Results section below). The two camp samples were approximately matched for age (Zoo Camp: $M_{\text{age}}=6.89$ years, $SD=1.43$; Control Camp: $M_{\text{age}}=6.29$ years, $SD=1.21$; Welch's $t(51.28)=1.73$, $p=.098$) and number of children in each of three age groups spanning the total age range (i.e., 4-5, 6-7, and 8-9; see below for further details) ($p=.15$, Fisher's exact test). In the Zoo camp group, 78% ($n=22$) of participants were Caucasian; 7.14% ($n=2$) were of more than one race/ethnicity, 3.5% ($n=1$) were African American, 3.5% ($n=1$) were Asian/Pacific Islander, 3.5% ($n=1$) reported "Other", and 3.5% ($n=1$) did not respond. In the Control camp, 69% ($n=22$) of the participants were Caucasian, 19% ($n=6$) were Asian or Pacific Islander, 6% ($n=2$) were Black, and 6% ($n=2$) did not provide the race and ethnicity information.

Study Sites

Both the Zoo and Control summer camps were paid admission programs. Both camps provided an option of full-day (i.e., 9 am – 4 pm) attendance or half day (i.e., 9 am – noon) attendance. The sample included children who attended full-day as well as children who attended half-day, although we do not have information about the scheduled attendance for each participant. Anecdotally, younger children were more likely to attend half-day and older children were more likely to attend full-day. The costs of both programs are comparable to each other. Specifically, at

present², the cost of a week-long camp at the Zoo is \$215 for half-day attendance and \$315 for full-day attendance (with a discount of \$30 and \$50, respectively, available to Zoo members). At the Control camp, at present, the cost of a week-long camp is \$150 for half-day attendance and \$300 for full-day attendance.

Both summer programs were located in the same city, within four miles of each other in family-friendly neighborhoods, with similar rates of families with children (25.4% in the neighborhood where the Control camp was located, and 22.0% in the neighborhood where the Zoo camp was located). Overall, the neighborhood where the Control camp was located was less racially diverse and more affluent than the neighborhood where the Zoo camp was located. Specifically, according to data from the US Census Bureau (<https://statisticalatlas.com/United-States/Overview>), the racial and ethnic make-up of the neighborhoods is as follows: 74.8% White, 5.6% Black, 4% Hispanic, and 12% Asian (for the neighborhood where the Control camp was located); and 66.6% White, 22.6% Black, 2.4% Hispanic, and 5.9% Asian (for the neighborhood where the Zoo camp was located). According to the same source, the median household income is as follows: \$87.5K in the neighborhood where the Control camp was located, and \$56.2K in the neighborhood where the Zoo camp was located.

Zoo Camp. Broadly, zoo camp consisted of lessons, interactions with preserved and live animals, tours of the zoo, games, and craft sessions for children of all ages. Each day, activities were designed to help children learn about a specific theme, such as “creatures of the night”. Each year, the zoo camp organizers arrange a different set of themes into curricula for different age

² The price information was retrieved online on April 10, 2018. We did not collect price information during the years when we collected data (2015-2017).

groups that span the age range of children who attend the camp. The age groups spanning our sample were 4-5, 6-7, and 8-9 years of age. The themes taught in the curricula for these age groups over the two summers³ during which we conducted this study are listed in Table 1. It is worth noting that the majority of themes were not oriented towards explicitly teaching children biological taxonomic relations, with the exception of the themes for children in the 8 to 9 age group in Year 2 and one instance of a “Reptiles” theme for children in the 4 to 5 age group in Year 2.

Table 1

<i>Curriculum themes at the Zoo camp for each age group during the study.</i>		
	Year 1	Year 2
4-5 group	Domestic Animals	Animal Locomotion
	Super Senses	Reptiles
	Tropical Treasures	Aquatic Animal Diets
	Savanna Survival	Savanna Animal Patterns
6-7 group	Animal Babies	Rainforest
	How Animals Learn	African Savanna
	Animal Families	Ocean
	Aquarium Animals	Islands
8-9 group	Extreme Families	Mammals
	Extreme Senses	Birds
	Extreme Animal Architects	Reptiles
	Animal All-Stars	Amphibians

Note. Because our pre- and post-test sessions took place on Monday and Friday mornings, respectively, Friday themes are not included here.

To provide a representative example of how these themes shaped the activities in which children took part, the activities incorporated into the “Extreme Families” theme were as follows. Children took part in two lessons: 1) A lesson about “Extreme Parents” that engage in behaviors to protect their offspring (e.g., octopus, chicken, penguin), with contrasting examples of animals

³ One additional child in the 4-5 age group was tested in 2017. The themes for this age group in this year were the same as those used in 2015.

that do not (e.g., sharks), and 2) A lesson about the benefits to animals that live in family groups (e.g., skink and elephant). During the lessons, counselors showed children live specimens of some of the animals discussed (e.g., a live skink), and other animal-related specimens relevant to the lessons (e.g., shark egg cases). Following each lesson, children visited a subset of the animals described at the zoo, while a counsellor highlighted the relevance of the animal to the lesson (e.g., when visiting a penguin, a counsellor described how a penguin parent cares for its chick). Children additionally completed crafts projects (e.g., made a shark tooth necklace) and played games (e.g., octopus tag) that were related to some of the animals about which they had learned, but were not designed to convey further pedagogical information about the topic of the lessons. Finally, the activities for the 4-5 and 6-7 age groups often included a counsellor reading aloud a picture book relevant to the day's theme.

Activities on all days of zoo camp followed this format of presenting lessons on a topic with specimens, visiting animals in the zoo mentioned in the lessons while providing further information relevant to the topic, and engaging in crafts projects/games that are thematically related to animals mentioned in the lessons but that do not provide further pedagogical content. However, the amount of information presented in lessons, and the ratio of time spent on lessons versus animal visits and craft projects/games, increased over the 4-5, 6-7, and 7-8 age groups.

Control Camp. The Control Camp was a summer program offered through a private non-denominational Pre-K through Grade 8 school (although summer camp participants did not have to be students at the school). Importantly, the Control camp did not provide immersive experiences with animals, but offered a variety of other recreational and learning opportunities. At the Control camp, children engaged in outdoor play, water play, storytime, dance, crafts, games, and cooking.

Additionally, children went on a field trip each week (e.g., to a library or a baseball game), but did not visit the Zoo during the summer when testing took place.

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 across multiple summers 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 (see Supplemental Materials). 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, and full set in Appendix A).

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 all years, 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 (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 longitudinal study (Fisher, Godwin, Matlen, & Unger, 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. Therefore, children were made aware of the full set of animals they would judge prior to beginning of the task. 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. At the conclusion of the task, the experimenter

photographed the board to record the locations of the cards. Due to experimenter error⁴, data from this task were lost for six participants at the Zoo camp and one participant at the Control camp.

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 (see Supplemental Materials). Triads were designed to eliminate non-taxonomic cues to Taxonomic Matches, such as visual similarity, shared habitat, or shared mode of locomotion. 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.

⁴ On the digital camera that was used, the button for taking photos, when gently rather than firmly pressed, would not record a photo, but would refocus in a way that gave some experimenters the impression that a photo had been taken.

Figure 1. Schematic depiction of the SpAM task (stimulus sheet, cards, and game board) (Panel A) and the match-to-sample task (Panel B).

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 all years ($N=28$ following exclusion of six children's data due to experimenter error) 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 lost due to experimenter error).

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 were taken as a measure of the degree to which participants judged 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.

Due to the fact that the set of items was composed of 5 animals from 3 taxonomic categories (Mammal, Bird, and Reptile), the pair distances for a given participant at Pre- or Post-Test consisted of 30 distances between pairs of animals that were both from the same taxonomic category (i.e., 10 distances for each of the 3 taxonomic categories), and 75 distances between pairs of animals from different taxonomic categories. To capture the degree to which participants placed pairs of animals from the same taxonomic category closer together than pairs of animals from different taxonomic categories, we used these distance data to calculate a Taxonomic Score for each pair of animals from the same taxonomic category. To calculate a Taxonomic Score for a

given same taxonomic category pair (e.g., Duck-Owl) for a given participant in a given session, we took the distance between this pair for this participant in this session, and subtracted it from the mean distance between *all* pairs of animals from different categories (e.g., Alligator-Sheep) measured for the same participant in the same session. Because each set of animals contained 30 same taxonomic category pairs, this calculation yielded 30 Taxonomic Scores for each participant in each session. Taxonomic Scores greater than zero indicate that members of the same taxonomic category were judged to be more closely related than members of different categories, such that larger Taxonomic Scores reflected stronger judgments that taxonomically related versus unrelated animals were of the “same kind”. Taxonomic Scores equal to zero indicate that members of the same taxonomic category were judged as no more strongly related than members of different categories, and Taxonomic Scores below zero indicate that participants judged members of different categories as more strongly related than members of the same taxonomic category.

Match-to-Sample Task. For this task, we calculated an Accuracy measure for each participant in which we scored their responses for each of the six triads as either 1 (chose the Taxonomic Match) or 0 (chose the Distractor).

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 Taxonomic Scores on the SpAM task at Pre-Test was -6.92 to 6.31 (chance=0), and the range of mean Accuracy scores on the Match-to-Sample task was .17 to .83 (chance=.5). To conduct this comparison, we calculated each participant’s mean SpAM Taxonomic Score and mean Match-to-Sample Accuracy at Pre-Test, and assessed differences between the two camps using Welch’s t-tests. The results of

comparisons for both measures yielded no significant differences between camps (Taxonomic Score: $M_{zoo}=0.76$, $SD_{zoo}=1.30$, $M_{control}=0.60$, $SD_{control}=1.20$, $t(55.23)=.49$, $p=.62$; Accuracy: $M_{zoo}=0.54$, $SD_{zoo}=0.18$, $M_{control}=0.58$, $SD_{control}=0.17$, $t(28.86)=.68$, $p=.50$).

Correspondence between Outcome Measures

Prior evidence indicates that children's responses on the Match-to-Sample task are related to performance on the SpAM task, suggesting that both paradigms capture aspects of relational knowledge (Fisher et al., 2014). To test whether this was the case in the present study, we calculated the overall mean of each participant's Taxonomic Score and Accuracy at each testing session⁵, and assessed whether these two measures were correlated. We found an overall significant positive correlation between mean Taxonomic Score and mean Accuracy ($r=.33$, $p=.002$; Figure 2). Moreover, this significant correlation occurred for both Pre- and Post-Test sessions for Zoo camp participants and for the Post-Test session for Control camp participants (all $ps < .01$) (but was not significant at Pre-Test for Control camp participants; $p=.12$). These results add to the small body of prior evidence that Match-to-Sample and SpAM paradigms measure aspects of the same underlying body of relational knowledge.

⁵ Note that this averaging procedure results in a range of Taxonomic Scores and Accuracies that is narrower than the full range of raw values.

Figure 2. Correspondence between each participant's overall SpAM Taxonomic Score and Match-to-Sample Accuracy.

Pre- to Post-Test Change in 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 Taxonomic 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 of these outcome measures, our primary analyses consisted of mixed effects regression models with fixed effects of Camp (Zoo versus Control) and Test Session (Pre-Test versus Post-Test)⁶, and random effects of participant and item. The mixed effects model was linear for the Taxonomic Score outcome measure, and logistic for the Accuracy outcome measure. Therefore, we report F-statistics for the results of analyses of Taxonomic Score, and χ^2 -statistics

⁶ Note: Age was not included in these analyses, because it may have been correlated with other factors, including the amount/type of information conveyed in Zoo camp lessons, and whether children attended camp on a full- or half-day basis. We therefore present exploratory analyses of Age in a separate, exploratory section.

for the results of analyses of Accuracy. These analyses were conducted in the R environment (R Development Core Team, 2008) using functions from the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) for mixed-model linear and logistic regression, and the car package (Fox & Weisberg, 2011) for calculating test statistics and significance values for main effects and interactions from mixed-model regression.

SpAM Taxonomic Score. The mixed effects model for Taxonomic Score revealed a main effect of Test Session ($F(1,3450)=10.34, p=.001$), which was qualified by an interaction with Camp ($F(1,3450)=14.41, p=.0001$). The interaction between Test Session and Camp indicates differences between Pre- and Post-Test performance that vary between the Zoo and Control camps. To investigate this interaction, separately for each camp, we generated mixed effects models with a fixed effect of Test Session, and random effects of participant and item. These models revealed a main effect of Test Session in the Zoo camp ($F(1,1622)=25.39, p<.0001$), such that Taxonomic Scores were greater at Post-Test than Pre-Test, but no effect of Test Session in the Control Camp ($F(1,1799)=.08, p=.78$) (see Figure 3 panel A).

Match-to-Sample Accuracy. The mixed effects model for Accuracy revealed no main effects, but as in the model for Taxonomic Score, Test Session significantly interacted with Camp ($\chi^2(1)=6.33, p=.012$). As we did to investigate the Test Session by Camp interaction for Taxonomic score, we generated mixed effects models for the Accuracy outcome measure separately for each camp comprised of a fixed effect of Test Session, and random effects of participant and item. These models also revealed a main effect of Test Session in the Zoo Camp ($\chi^2(1)= 7.43, p=.006$), such that Accuracies were greater at Post-Test than Pre-Test, but no effect of Test Session in the Control Camp ($\chi^2(1)= 0.18, p=.67$) (see Figure 3 panel B).

Figure 3. Pre- to Post-Test changes in SpAM Taxonomic Scores (panel A) and Match-to-Sample Accuracies (panel B) for participants in the Control and Zoo camps.

Taxonomic Improvement from Pre- to Post-Test in Zoo Camp: What Changed?

The preceding analyses indicate that the degree of taxonomic organization in the animal domain increased during a week of learning about animals Zoo camp, but not during a week of camp that did not involve learning experiences in this domain. To further investigate this effect, we investigated two facets of the change in taxonomic organization: 1) Whether changes consisted of treating animals from the same taxonomic category as more strongly related, treating animals from different taxonomic categories as less strongly related, or both, and 2) Whether changes varied across the three taxonomic categories investigated in this study (i.e., mammals, birds, and reptiles).

Same versus Different Taxonomic Category. It is not possible to disentangle Pre- to Post-Test increases in treating animals from the same taxonomic category as related from

decreases in treating animals from different taxonomic categories as related based on performance on the Match-to-Sample task, because this task yields only a single measure of whether or not participants chose the taxonomic match in each triad. However, these possibilities can be disentangled based on performance on the SpAM task. Specifically, it is possible to measure, for each participant in each testing session, the distances between all pairs of animals from the same taxonomic category, and all pairs of animals from different categories. Increases in treating animals from the same taxonomic category as related would manifest as shorter distances between same taxonomic category pairs at Post- versus Pre-Test, and decreases in treating animals from different taxonomic categories as related would manifest as longer distances between different taxonomic category pairs.

To investigate these possibilities, we took distances between all pairs for each Zoo camp participant at each testing session as our outcome measure, and predicted these distances using a linear mixed effects model in which Testing Session and Category Membership (Same Category versus Different Category) were fixed effects, and participant and item were random effects. This model revealed main effects of Testing Session ($F(1,202)=8.26, p=.004$) and Category Membership ($F(1,202)=247.13, p<.0001$) that were qualified by an interaction with each other ($F(1,202)=14.41, p=.0001$). To investigate the source of this interaction, we generated follow-on models separately for each Category Membership condition that included Testing Session as a fixed effect. From Pre- to Post-Test, these models revealed a significant increase in Different Category distances ($F(1,144)=20.04, p<.0001$), and no significant decrease in Same Category distances ($F(1,58)=2.68, p=.11$) (although there was a numeric trend in this direction; Figure 4).

These results therefore suggest that learning experiences at Zoo camp served to improve differentiation between taxonomic categories.

Figure 4. Pre- to Post-Test changes in SpAM task distances between pairs of animals from the same taxonomic category, versus pairs of animals from different taxonomic categories.

Mammals, Birds, and Reptiles. In these analyses, we tested whether the improvement in taxonomic organization from Pre- to Post-Test in Zoo camp participants varied across the three taxonomic categories investigated in this study. It was possible to conduct these analyses using data from both SpAM and Match-to-Sample tasks, because our primary outcome measures for both tasks (i.e., Taxonomic Score and Accuracy, respectively) included an equal number of observations in each taxonomic category.

We generated mixed effects models for each outcome measure for Zoo camp participants in which Testing Session and Taxonomic Category were fixed effects, and participant and item were random effects. As in our primary analyses of Pre- to Post-Test changes in the Zoo and

Control camps, these models revealed a significant main effect of Testing Session for both outcome measures (both $ps < .01$). This effect was not significantly qualified by an interaction with Taxonomic Category (although the interaction was marginally significant for SpAM task Taxonomic Scores; $p=.09$). This outcome suggests that the improvement from Pre- to Post-Test occurred across all three taxonomic categories included in this study (for additional exploratory analyses of patterns across individual items, see Appendix B).

Figure 5. A) Pre- to Post-Test changes for Zoo camp participants in SpAM task Taxonomic Score (left) and Match-to-Sample task Accuracy (right), plotted separately for each taxonomic category. B) Same Pre- to Post-Test scores plotted for Control camp participants.

The main effect of Taxonomic Category was not significant for the analysis of SpAM task Taxonomic Scores ($p=.14$), but was significant in the analysis of Match-to-Sample Accuracies ($p=.003$). As shown in Figure 5-A, the relative overall performances across the three taxonomic categories varied across the two measures, which may be associated with the somewhat different demands of these tasks (e.g., in the Match-to-Sample task, a target item is evaluated against only

one taxonomic match and one distractor, whereas in the SpAM task, each item is evaluated against all other items). In spite of such variability, overall, these analyses indicate that Zoo camp experience influenced taxonomic organization across the three taxonomic categories investigated in this study. In contrast, no such improvement was observed in Control camp participants on either measure of semantic organization for any of the taxonomic categories ($ps > .49$ for the effect of Testing Session for all categories; see Figure 5-B).

Variation in Taxonomic Improvement with Age and Prior Knowledge: Exploratory Analyses

It is possible that the degree to which the immersive experiences with animals acquired at zoo camp prompted changes in taxonomic organization varied with children's ages or extent of prior knowledge in the animal domain (e.g., older or more knowledgeable children learned more readily). A rigorous analysis of relationships between taxonomic organization improvement and age is not possible in the present study, because age varied with the content of the lessons children experienced at camp, and may have varied with the likelihood that children attended a full- versus half-day of camp. Similarly, although we can take Pre-Test performance as a measure of prior knowledge, prior knowledge may have varied with age (indeed, Age was significantly correlated with Pre-Test SpAM performance ($r=.24$, $p<.001$), though not with Pre-Test Match-to-Sample performance ($p=.53$)). Therefore, we instead present exploratory analyses of the relationship between improvement in taxonomic organization in zoo camp children and age and prior knowledge, with the caveat that these factors may have been confounded with the amount of time children spent at camp and the specific content that children experienced at camp.

To conduct these exploratory analyses, we calculated Learning Gain scores for both the Match-to-Sample and SpAM tasks by subtracting each zoo camp child's overall Pre-Test score from their overall Post-Test score. We then measured the correlation between children's Learning Gain scores and age: Age was marginally correlated with Learning Gain scores on both Match-to-Sample task ($r = .45, p = .06$) and SpAM task ($r = .35, p = .06$). In contrast, prior knowledge (as measured from Pre-Test performance) was not correlated with Learning Gain scores on either measure (both $ps > .14$). Therefore, the results of these exploratory analyses may be taken as suggestive that the degree of improvement in taxonomic organization prompted by zoo camp experiences may have been greater for older children than younger children. However, caution is warranted in interpreting these findings because the correlations between Learning Gain scores and age were only marginally significant in this sample, and may have been confounded with other factors discussed above.

Discussion

The purpose of the present study was to investigate whether the organization of knowledge in the animal domain is subject to rapid, learning-driven changes. To accomplish this goal, we assessed changes in the taxonomic organization of children's knowledge about sets of animals that transpired between the beginning and end of the end of a four-day period that either did or did not include learning experiences in the animal domain. Learning experiences in the animal domain consisted of attendance at a zoo summer camp (versus a non-zoo control camp).

Across two complementary measures, children who attended zoo camp showed significant increases in taxonomic organization from the beginning to the end of the camp week. In contrast, there was no detectable change in taxonomic organization over the same time period for children

who attended a summer camp that did not include learning experiences in the animal domain. Critically, this difference between children who attended the two camps transpired in spite of no significant differences in performance on the taxonomic organization measures at the beginning of the camp week. Additionally, the results of follow-up analyses on the change in taxonomic organization in children who attended zoo camp suggested that these changes were primarily associated with improvements in the degree to which children treated members of different taxonomic categories as different, rather than the degree to which they treated members of the same taxonomic category as related. These results indicate that naturalistic learning experiences in a domain can prompt rapid changes in semantic knowledge organization. Additionally, the results of exploratory analyses provided some suggestion that the degree to which these experience prompt changes may increase with age (although these effects reached only marginal significance and may have been confounded with other factors).

These findings are consistent with evidence from prior studies, which have shown that knowledge organization differs across pre-existing groups of children with different long-term learning experience histories, such as children who have grown up in different communities (Coley, 2012; Gobbo & Chi, 1986; Inagaki, 1990). Moreover, the present findings expand upon these prior studies by providing evidence that, given two groups of children from the same (urban) setting and with comparable initial performance on measures of knowledge organization, the accumulation of learning experiences over a brief period of time in one group of children prompted rapid changes in knowledge organization.

The results of the present study also expand upon prior research that has investigated the influence of brief learning experiences. First, these results both add to evidence from the small

number of prior studies that have shown knowledge organization change prompted by a brief intervention, and expand upon this evidence by demonstrating knowledge organization change following a real-world, naturalistic learning experience. Second, these results also expand upon evidence about the effects of similar real-world, naturalistic learning experiences, such as a field trip to a museum or zoo (Bexell et al., 2013; Farmer et al., 2007; Gottfried, 1980; Prokop et al., 2007; Randler et al., 2007; Randler et al., 2012; Stronck, 1983). Specifically, this body of research has provided evidence that such experiences can prompt the acquisition of knowledge for individual facts or principles. The present study further demonstrates that these learning experiences can go beyond fostering knowledge of isolated items of information by fostering changes in the way that knowledge in a domain is organized into an interconnected network of concepts.

Limitations

Although the absence of pre-test differences between the children in two camps on the assessments of taxonomic organization supports the conclusion that learning experiences in the animal domain acquired at Zoo camp prompted the observed improvements in taxonomic organization, a direct investigation of the *causal* influence of learning experiences on knowledge organization was not possible in the present study due to its quasi-experimental design. Such a direct investigation could be accomplished using a design in which participants are randomly assigned to conditions in which they either do or do not acquire learning experiences in a domain, or acquire learning experiences in one of two different domains.

The results of the present study also only provide a suggestion that the magnitude of the effects of learning experiences on knowledge organization may increase with age, but do not

rigorously test this possibility. A rigorous investigation of this influence was not possible, because age in the present study may have been confounded with both whether children attended a full- versus a half-day of camp, and for Zoo camp participants, with the amount/type of information conveyed during lessons. Developmental changes in the readiness with which knowledge organization is shaped by experience would represent an important avenue for future research. However, any such research would need to carefully disentangle effects of age from the effects of other factors that may vary with age, such as prior knowledge in a domain.

Open Questions

The present demonstration of rapid, experience-related change in knowledge organization highlights multiple key questions for future research. First, does the readiness with which knowledge organization changes given learning experiences vary over development? With age comes many changes that may improve a child's receptiveness to learning experiences. For example, development is accompanied by improvements in executive functions such as working memory and selective attention capacity (e.g., Fisher, Thiessen, Godwin, Kloos, & Dickerson, 2013; Fry & Hale, 2000), which may help children take in the information presented during a learning experience. Moreover, improvements in prior knowledge in a domain that may come with age (Unger et al., 2016) may improve the integration of new information into semantic memory (Kaefer, Neuman, & Pinkham, 2015; Shing & Brod, 2016). As described earlier in this section, the results of the present study provided some suggestion that the effects of learning experiences at Zoo camp on knowledge organization increased with age. However, a rigorous examination of this question remains open for future research.

Second, do changes to knowledge organization prompted by a given learning experience generalize to other concepts in the same domain? In the present study, we investigated changes in the organization of knowledge about animals that were part of the learning curricula that children at zoo camp experienced. It is possible that learning experiences at Zoo camp only fostered changes in relations between the animal concepts children encountered. Alternately, learning experiences at Zoo camp might have fostered changes that could generalize to other animal concepts, such as highlighting the salience of taxonomically-relevant features.

Third, the present results, like the results of prior research that has compared knowledge organization across groups of children with different long-term experience histories, do not illuminate what specific input and mechanisms drive knowledge organization change. Some possible candidates come from research on pedagogical approaches that help learners group together or differentiate between concepts, such as structural alignment, in which instruction highlights the underlying relations between features that different concepts do or do not share (Jee, Uttal, Gentner et al., 2013; Kurtz, Miao, & Gentner, 2001). Aside from explicit instruction, knowledge organization may also be shaped by sensitivities to regularities in the environment. Evidence for this possibility primarily comes from computational modeling research involving the creation of simulated semantic networks that form representations of concepts and their interrelations from input available in the environment, such as the features of entities (Kemp & Tenenbaum, 2008; McClelland & Rogers, 2003), or the visual or linguistic contexts in which entities or their labels occur (Frermann & Lapata, 2015; Huebner & Willits, 2018; Sadeghi, McClelland, & Hoffman, 2015). The success with which such models have captured human semantic behavior (Cree & Armstrong, 2012; Jones et al., 2015) suggests that they represent

viable hypotheses about the sources of input and mechanisms that contribute to semantic organization. Empirically testing these hypotheses by investigating whether and how the organization of children's semantic knowledge changes when exposed to these sources of input would be a fruitful path for future research.

Conclusion

This study reports the first investigation of changes in semantic knowledge organization as a result of a relatively brief naturalistic learning experience (i.e., a week-long summer camp at a local Zoo). We found that the taxonomic organization of children's knowledge about animals changed measurably over the course of a short, four-day period when it contained learning experiences in that domain acquired at a Zoo summer camp. In contrast, children who performed similarly on assessments of taxonomic organization at the beginning of this period, but who attended a Control camp and did not acquire learning experiences in the animal domain, showed no evidence of increased taxonomic organization by the end of the period. These results therefore provide novel evidence of rapid, learning-related changes in knowledge organization.

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Appendix A*Items used in SpAM and Match-to-Sample Tasks*

Table A1

Animal Stimuli used for 4-5 year olds in each year, selected from the animals that appeared in Zoo camp curricula for this age group.

Year 1			Year 2		
<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>	<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>
Giraffe	Duck	Alligator	Bat	Duck	Alligator
Gorilla	Ostrich	Gecko	Beaver	Ostrich	Pancake Tortoise
Elephant	Owl	Milk Snake	Hedgehog	Owl	Python
Sheep	Toucan	Python	Elephant	Penguin	Sea Turtle
Sloth	Vulture	Tortoise	Rabbit	Toucan	Skink

Table A2

Animal Stimuli used for 6-7 year olds in each year, selected from the animals that appeared in Zoo camp curricula for this age group.

Year 1			Year 2		
<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>	<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>
Bat	Duck	Alligator	Gorilla	Macaw	Boa
Kangaroo	Kestrel	Gecko	Fennec Fox	Ostrich	Pancake Tortoise
Orangutan	Macaw	Komodo Dragon	Sea Otter	Penguin	Python
Sea Otter	Owl	Python	Sloth	Toucan	Sea Turtle
Zebra	Penguin	Sea Turtle	Walrus	Vulture	Skink

Table A3

Animal Stimuli used for 8-9 year olds in each year, selected from the animals that appeared in Zoo camp curricula for this age group.

Year 1			Year 2		
<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>	<i>Mammals</i>	<i>Birds</i>	<i>Reptiles</i>
Bat	Chicken	Alligator	Bat	Kiwi	Alligator
Beaver	Kestrel	Horned Lizard	Fennec Fox	Macaw	Glass Lizard
Fennec Fox	Ostrich	Python	Polar Bear	Ostrich	Komodo Dragon
Elephant	Penguin	Sea Turtle	Sea Lion	Owl	Pancake Tortoise
Polar Bear	Swift	Skink	Sea Otter	Penguin	Skink

Table A4

Match-to-Sample trials used in each age group in Year 2.

	Target	Match	Distractor
4-5 Years	Hedgehog	Bat	Penguin
	Sea Turtle	Python	Beaver
	Rabbit	Elephant	Pancake Tortoise
	Owl	Ostrich	Hedgehog
	Alligator	Sea Turtle	Toucan
	Duck	Owl	Beaver
6-7 Years	Gorilla	Walrus	Vulture
	Sea Turtle	Boa	Macaw
	Ostrich	Toucan	Fennec Fox
	Pancake Tortoise	Python	Sloth
	Penguin	Macaw	Fennec Fox
	Sea Otter	Sloth	Skink
8-9 Years	Bat	Otter	Macaw
	Alligator	Glass Lizard	Ostrich
	Sea Lion	Bat	Komodo Dragon
	Penguin	Owl	Polar Bear
	Pancake Tortoise	Glass Lizard	Sea Lion
	Kiwi	Macaw	Fennec Fox

Appendix B

Variation in Taxonomic Improvement Across Items: Exploratory Analyses

An investigation of patterns of Taxonomic improvement in Zoo Camp children's knowledge of specific items is of interest for determining whether the overall improvement in taxonomic organization observed in these children was indicative of a general shift towards taxonomic organization, or the clarification of the taxonomic category membership of only a handful of items. However, item effects are difficult to investigate in this study because items varied across age groups and years (such that when an item was only used with children of a given age group, its effects may be confounded with age). Therefore, we present here an exploratory, qualitative analysis of patterns of taxonomic improvement across items.

To explore item effects in SpAM task data, for each item, we calculated the average improvement in Taxonomic Score from Pre- to Post-test across all pairs that included the item. Similarly, to explore item effects in Match-to-Sample task data, we calculated the average improvement in accuracy from Pre- to Post-test for each Target item. Graphs of these data can be found below. Inspection of these data reveals that, according to SpAM Taxonomic Scores, improvement occurred for the majority of items. Inspection of Match-to-Sample data reveals improved accuracies for only approximately half of the Target items (though it should be noted that this includes items from all three taxonomic categories used in the study). It is likely that inspection of the SpAM data reveals a more complete picture of improvements, because it is designed to provide a more sensitive, graded measure of taxonomic organization (in contrast with the Match-to-Sample task, in which participants are only presented with a binary decision on which they can be scored as correct or incorrect).

Figure C1. Average changes in SpAM Taxonomic Score (top) and Match-to-Sample Accuracy for each item, color-coded according to indicate consistency across tasks.

Several caveats should be taken with this analysis about why individual items may sometimes show different patterns of change in the Match-to-Sample versus SpAM tasks (as identified in the graphs above). First, whereas the SpAM task used the full set of items for a given age group in a given year, only a subset of items appeared as Targets in the Match-to-Sample task. This means that, in some cases, data for an item in the Match-to-Sample task come from only a subset of the participants who judged the same item in the SpAM task. For example, as shown in Appendix A, “Gorilla” was included in the full set of items judged in the SpAM task for both 4-5 year-old children in Year 1 and 6-7 year-old children in Year 2, but was only a Target in the Match-to-Sample task in the latter group. This means that the SpAM data for Gorilla include children from an additional, younger age group in comparison to the Match-to-Sample task data, and therefore may contribute to the fact that Gorilla appeared to improve more in the Match-to-Sample task than the SpAM task.

Second, most of the items that showed inconsistent patterns across the tasks (7 out of 8 items) are the ones that had relatively smaller improvements in the SpAM task, but no improvement in the Match-to-Sample task. As noted in above, this could be due in part to the fact that the Match-to-Sample task provides a binary, all-or-nothing measure, whereas the SpAM task is more graded and nuanced. Therefore, the SpAM task might be sensitive to smaller improvements in taxonomic knowledge that do not manifest in the Match-to-Sample task.

Finally, the Match-to-Sample and SpAM tasks place somewhat different contextual demands. For example, when Gorilla appeared in both tasks, it was judged only against Walrus (category match) and Vulture (distractor) in the Match-to-Sample task, whereas it was judged against all other mammals and non-mammals in the SpAM task. Learning in Zoo Camp might have affected knowledge about how an item used as a Target in the Match-to-Sample task is

related to its category match vs. its distractor relatively more or less than it affected knowledge about the overall relatedness between that item and a variety of same- versus different-category items.

These caveats notwithstanding, the results of this exploratory qualitative item analysis indicate that the overall improvement in taxonomic organization observed in this study was not driven by a few items, but instead occurred for a substantial subset of items that children were tested on.