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Brief article

Dog is a dog is a dog: Infant rule learning is not specific to language

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Abstract

Human infants possess powerful learning mechanisms used for the acquisition of language. To what extent are these mechanisms domain specific? One well-known infant language learning mechanism is the ability to detect and generalize rule-like similarity patterns, such as ABA or ABB [Marcus, G. F., Vijayan, S., Rao, S. B., & Vishton, P. M. (1999). Rule learning by seven-month-old infants. *Science*, **283**, 77–80.]. The results of three experiments demonstrate that 7-month-old infants can detect and generalize these same patterns when the elements consist of pictures of animals (dogs and cats). These findings indicate that rule learning of this type is not specific to language acquisition.

Keywords: Infants; Learning; Rules; Statistics

1. Introduction

A central issue in cognitive neuroscience concerns how the brain is functionally organized. One view is that discrete systems exist in the human brain for solving

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specific problems facing the organism, such as learning language or processing faces. Alternatively, learning mechanisms may operate more generally, with similar processes underlying multiple functions. Domain-specificity has recently become the focus of debates regarding infant language acquisition. Consistent with the existence of general learning mechanisms, human infants are able to track sequential statistical information (e.g., the probability that *X* predicts *Y*) in linguistic material (e.g., Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996) as well as in non-linguistic material including musical tones (e.g., Saffran, Johnson, Aslin, & Newport, 1999) and visual shapes (e.g., Fiser & Aslin, 2002; Kirkham, Slemmer, & Johnson, 2002).

However, a different picture emerges when infants are confronted with simple grammatical rules.[1] In linguistic rule learning studies, infants are first presented with syllables (such as "*ga*" or "*ti*"), organized into triads that follow either the sequence ABA (e.g., "*ga ti ga*") or ABB (e.g., "*ga ti ti*"; Marcus et al., 1999). The infants are then tested using new syllables, which are arrayed in either the familiarized or novel patterns ("*wo fe wo*" versus "*wo fe fe*"). The question of interest is whether infants are able to generalize their knowledge about the rules governing the sound combinations, as evidenced by successful discrimination between the familiar and novel patterns when presented using new syllables. Infants readily acquire these rules when they are presented with linguistic stimuli. However, they fail to learn these rules when they are implemented using non-linguistic stimuli, including the same kinds of tones and shapes about which infants successfully learn in statistical learning tasks, suggesting that this rule-learning mechanism may be specific to language (Marcus, Johnson, & Fernandes, 2004).

An alternative view is that previous attempts to assess the domain-generality of infant rule learning have not adequately equated important features of linguistic and non-linguistic elements. There are many factors that influence the ease of representation of the input. One obvious factor is familiarity; elements similar to those that have been encountered previously are easier to represent and maintain in memory. It may also be easier to detect task-relevant similarities and differences given familiar elements, such as discovering that the A's and B's are different in any single ABA or ABB sequence. A second, related, factor is categorizability. In order to discover the patterns that obtain across a series of ABA or ABB sequences, learners must realize that each individual sequence is an example of a larger group of sequences. It is this linkage between the individual sequences that affords generalization at test. While it is apparently easy for infants to recognize that *wo-fe-wo* is an example of the same type of pattern as *ga-ti-ga*, this process may be more difficult when infants do not transparently group the training elements into a single category. Thus, for example, infants confronted with *triangle–square–triangle* and *rectangle–octagon–rectangle* may not treat both sequences as examples of the same pattern because they do not treat the elements as members of the same category. It may

[1] Our intent was to replicate the Marcus, Vijayan, Rao, and Vishton (1999) effects, and not to resolve ongoing debates about whether this sort of learning entails symbolic rules as opposed to similarity detection (e.g., Marcus, 1999; McClelland & Plaut, 1999). We have used the term "rule" throughout as notational shorthand.

be difficult for infants to discover this multilayered similarity structure (similarities and differences within an ABA/ABB string and similarities across multiple strings) when the stimuli are relatively novel, or when the stimuli are not ecologically meaningful; the computerized shapes and sounds used in prior non-linguistic rule-learning studies are likely to be unusual to infants along one or both of these dimensions. Statistical learning tasks that do not entail grouping across physically dissimilar strings, such as the Saffran et al. (1996) word segmentation task, likely require less representational flexibility, and are thus more robust to the exact structure of the input.

In an attempt to find non-linguistic stimuli that are more similar to syllables along these dimensions, the materials for Experiment 1 consisted of ABA and ABB sequences using images of dogs. Like speech, infants encounter dogs in their natural environments and generally find them quite interesting. In addition, even young infants treat pictures of dogs as members of the same category, despite considerable perceptual diversity across exemplars (e.g., Quinn, Eimas, & Rosencrantz, 1993). For these reasons, pictures of dogs and other animals are the most frequently employed stimuli in habituation-based studies of infant visual categorization. We designed our study to replicate Marcus et al. (1999) experiment, except that the material consisted of pictures of dogs of different breeds. Seven-month-old infants were first familiarized, via a habituation procedure, with either an ABA sequence or an ABB sequence of dogs (see Fig. 1). We then tested the infants using images of dogs not seen during habituation (see Fig. 2). The design was counterbalanced; the ABA test sequences were novel to the infants familiarized with the ABB sequences, and vice versa. We hypothesized that if infants learned the patterns inherent in the sequences of dog pictures presented during habituation, they should look longer at the novel pattern as compared to the familiar pattern.

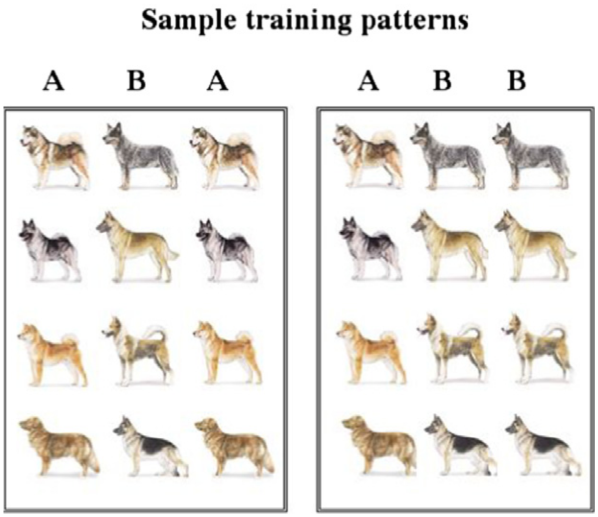

Fig. 1. Examples of training materials from the ABA and ABB conditions.

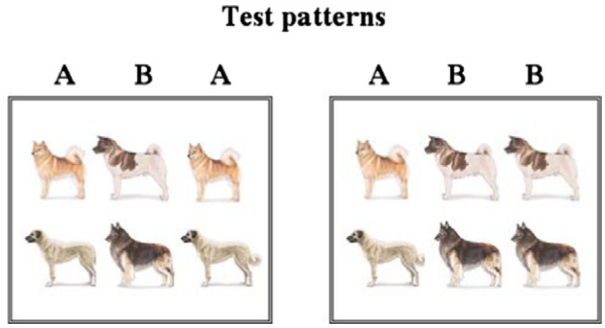

Fig. 2. The four test items. Each triad of dogs represents a single test event.

2. Experiment 1

2.1. Method

2.1.1. Participants

We tested 16 full-term infants with normal vision between 7 and 7.5 months of age ($M = 7.3$). Half of the infants were assigned to the ABA condition, and half were assigned to the ABB condition. An additional 4 infants were tested but not included in the analyses because of failure to habituate within the maximum of 25 trials (3 infants) and experimental error (1 infant).

2.1.2. Procedure

Familiarization and test materials were designed to be analogous to the materials used by Marcus et al. (1999). Infants were familiarized with triads of color photographs (2.5″ by 2.75″), presented on a 12″ monitor; pictures were taken from the breed standards of the American Kennel Club, as shown on the AKC website. Eight different pictures were used to create the familiarization patterns. Four pictures were assigned to the A group (*Alaskan Malamute, Norwegian Elkhound, Shiba Inu, Nova Scotia Duck Tolling Retriever*), and four to the B group (*Australian Cattle Dog, Belgian Malinois, Canaan Dog, German Shepherd Dog*). The A and B pictures were combined exhaustively to generate 16 different ABA and 16 different ABB triads. Each triad always included a repetition of one picture, with a third picture that was different. Thus, a sample ABA sequence was *Malamute–Cattle Dog–Malamute*, and a sample ABB sequence was *Malamute–Cattle Dog–Cattle Dog*. Previous research with adults suggests that visual pattern learning is affected by the use of sequential stimulus presentation as opposed to simultaneous stimulus presentation (e.g., Saffran, 2002). Moreover, visual categorization in infancy is enhanced by simultaneous stimulus presentation (Oakes & Ribar, 2005). We thus included both sequential and simultaneous structure in the presentations of the dog triads; the sequential structure allowed us to mimic auditory linguistic presentation while the simultaneous structure increased the likelihood of successful visual categorization. The first picture was displayed alone for .33 s, towards the left edge of the screen. The second picture was then added, to the right of the first picture; this two-dog display was presented for .33 s. After the third picture was added, to the right of the second picture, the full triad was displayed for .83 s. Each sequence was displayed for a total of 1.5 s. A blank screen (.5 s) separated the triad presentations on each trial. Sample familiarization triads are shown in Fig. 1.

Infants were familiarized using a standard infant-controlled habituation procedure (Habit 10.1; Cohen, Atkinson, & Chaput, 2004), while seated on a parent's lap. Parents wore glasses fitted with black paper, and could not see the display. An experimenter outside the booth monitored the infant's behavior by pressing keys on the experimental computer. Each trial lasted for as long as the infant looked at a computer monitor mounted in front of the infant, approximately 18″ from the infant's head. When a trial ended, the monitor displayed an attention-getting video until the infant re-oriented to the monitor. A new trial would then begin. Each trial consisted of triads of dogs, presented in random order, conforming to either the ABA or ABB pattern. The familiarization phase ended when the infant either met the habituation criterion (the average looking time for the last 3 trials was half the duration of the average looking time for the first 3 trials), or reached the maximum of 25 habituation trials. Note that the use of an infant-controlled habituation procedure is different from the fixed familiarization period used by Marcus et al. (1999) in their linguistic study.

All infants then received the same set of 4 test trials (shown in Fig. 2), in random order, repeated 2 times, for a total of 8 test trials. Each test trial consisted of repetitions of triads made up of 4 novel dog species (*Finnish Spitz, Akita, Anatolian Shepherd, Belgian Tervuren*). A blank screen separated each triad for .5 s. Half of the test trials followed the pattern seen during familiarization, and half followed a novel pattern (ABB for infants in the ABA condition, ABA for infants in the ABB condition).

2.2. Results

We first compared the results from the ABA and ABB conditions. As there were no significant differences between the two conditions [$t(14) = .97$, n.s.], results from the ABA and ABB conditions were combined in the following analysis. Infants looked significantly longer at the novel pattern (7.51 s, SE = .86) than the familiar pattern (5.21 s, SE = .54): $t(15) = 3.25$, $p < .01$ (see Fig. 3). Thirteen of the 16 infants showed this direction of preference. These results indicate that infants learned the dog patterns presented during familiarization and transferred this knowledge to include the new dog exemplars presented during testing.

Given infants' success in discriminating ABA patterns from ABB patterns when implemented with visual elements, we were interested in determining whether other related pattern contrasts are also distinctive for infants. In particular, infants may have attended to the presence or absence of an immediately reduplicated dog pair in Experiment 1 (for discussion, see Marcus et al., 1999). We thus decided to test the contrast between ABB and AAB in Experiment 2. This contrast retains the subtle distinction from Experiment 1 – a single element difference between familiar and novel items – but provides the opportunity to assess whether infants notice a

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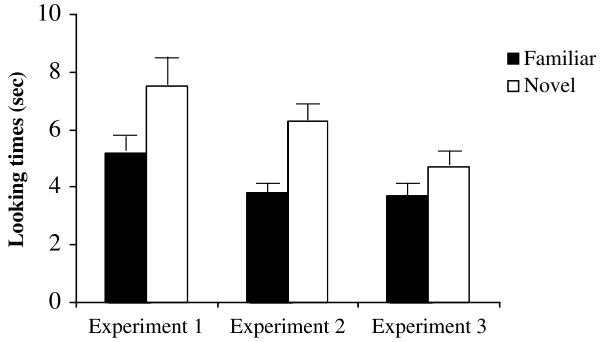

Fig. 3. Looking times (SE) to familiar and novel test sequences in Experiment 1 (ABA vs. ABB), Experiment 2 (AAB vs. ABB), and Experiment 3 (ABA vs. ABB).

different kind of distinction (here, the position of the reduplicated pair of elements in a sequence).

3. Experiment 2

3.1. Method

3.1.1. Participants

We tested 16 full-term infants with normal vision between 7 and 7.5 months of age ($M = 7.2$). Half of the infants were assigned to the AAB condition, and half were assigned to the ABB condition. An additional 4 infants were tested but not included in the analyses because of failure to habituate within the maximum of 25 trials (2 infants), parent stopping the experiment (1 infant) and experimental error (1 infant).

3.1.2. Procedure

The procedure was identical to Experiment 1, except that the dog triads used during training and test were organized into AAB and ABB patterns.

3.2. Results

We first compared the results from the AAB and ABB conditions. As there were no significant differences between the two conditions [$t(14) = .17$, n.s.], results from the AAB and ABB conditions were combined in the following analysis. As in Experiment 1, the infants looked significantly longer at the novel pattern (6.27 s, SE = .68) than the familiar pattern (3.79 s, SE = .26): $t(15) = 4.8$, $p < .001$ (see Fig. 3). Fourteen of the 16 infants showed this direction of preference. As observed in the ABA/ABB contrast in Experiment 1, infants successfully distinguished between the ABB and AAB sequences presented in Experiment 2.

Given infants' success in discriminating novel sequence types when exemplified as pictures of dogs, we were interested to see whether infants would perform similarly given other types of visual sequences. In our third experiment, we thus developed a new set of stimulus materials known to be categorizable by infants (e.g., Quinn et al., 1993) – pictures of cats – and ran a conceptual replication of Experiment 1 (ABA vs. ABB).

4. Experiment 3

4.1. Method

4.1.1. Participants

We tested 12 full-term infants with normal vision between 7 and 7.5 months of age ($M = 7.25$). Half of the infants were assigned to the ABA condition, and half were assigned to the ABB condition. One additional infant was tested but not included in the analyses due to parental interference.

4.1.2. Procedure

The procedure was identical to Experiment 1, except that the pictures were of cats (see Fig. 4). Infants were familiarized with triads of color photographs (2.48″ by 2.75″), presented on a 12″ monitor; pictures were scanned from Simon and Schuster's Guide to Cats and digitally edited. Eight different pictures were used to create the familiarization patterns. Four pictures were assigned to the A group (*Snowshoe, Russian Blue, Havana Brown, Somali*), and four to the B group (*American Wirehair, Chartreux, Ragdoll, Abyssinian*). The test cats were *Burmese* & *Tonkinese* (A) and *Singapura* & *Korat* (B).

4.2. Results

We first compared the results from the ABA and ABB conditions. As there were no significant differences between the two conditions [$t(10) = .79$, n.s.], results from the ABA and ABB conditions were combined in the following analysis. As in Experiments 1 and 2, the infants looked significantly longer at the novel pattern (4.72 s, SE = .43) than the familiar pattern (3.69 s, SE = .29): $t(11) = 4.2$, $p = .001$ (see Fig. 3). Eleven of the 12 infants showed this direction of preference.

5. General discussion

Infants' detection of simple rules – which elements in a sequence are the same and which are different – is not limited to linguistic stimuli. When presented with sequences of dog pictures, infants in Experiment 1 were able to learn the ABA and ABB patterns, as evidenced by their recognition and generalization of these familiar patterns when implemented with novel dog exemplars. Infants in Experiment 2 performed similarly given AAB and ABB patterns of dogs, as did infants in Experiment 3 given ABA and ABB patterns of cats. While this ability needs to

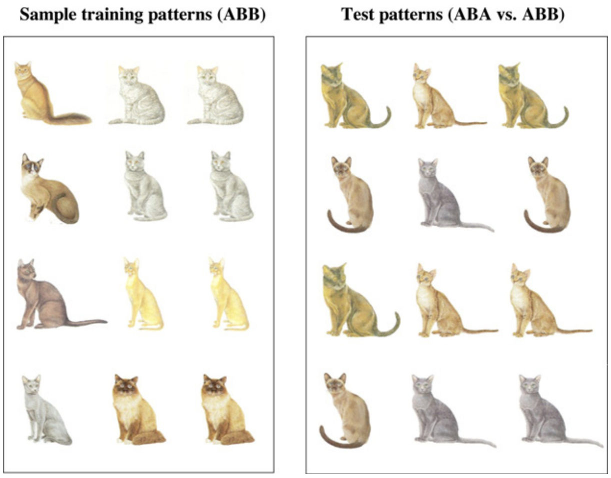

Fig. 4. Experiment 3 materials.

be explored with other patterns, including those more complex than the triads studied by Marcus et al. (1999), the results of these experiments demonstrate that infants can similarly detect and generalize at least some linguistic and non-linguistic rules. These findings are consistent with previous studies showing that cotton-top tamarin monkeys can learn these same sequences when they are implemented as linguistic material (Hauser, Weiss, & Marcus, 2002), suggesting that the learning mechanism in question is unlikely to have evolved solely to subserve language learning.

If rule learning is not limited to language, then why do infants have difficulty acquiring similarly organized patterns created from different non-linguistic materials (Marcus et al., 2004)? In particular, what might make sequences of syllables or animal pictures arrayed in ABA, ABB and AAB sequences easier to learn and discriminate than sequences of musical tones, musical timbres, animal sounds, or geometric shapes? As discussed in the introduction, one possible explanation is that these differences arise because the rule-learning task is about more than just sequence learning. Infants must first detect the same/difference relationships within each triad. Critically, they must also link the familiarization triads together in order to recognize that the same pattern is being repeated across triads that contain different exemplars. This is the difference between learning a pattern of tokens (e.g., *Malamute – Cattle Dog – Malamute*) versus a pattern of types (e.g., Element_{A} – Element_{B} – Element_{A}). In this case, infants must recode the sequences *Malamute – Cattle Dog – Malamute* and *Shiba Inu – Caanan Dog – Shiba Inu* as examples of Element_{A} – Element_{B} – Element_{A} (or possibly Dog_{A} – Dog_{B} – Dog_{A}).

While infants can easily represent syllables and visual representations of dogs and cats, as demonstrated in many prior studies of infant categorization, the same may not be true for the non-linguistic stimuli used by Marcus et al. (2004). For example, infants might have treated each element as its own distinct category (e.g., the category of red circles, the category of cow sounds, the category of piano sounds), without abstracting across the elements to create a more inclusive category (e.g., shapes,

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animal sounds, musical timbres).[2] This might disrupt the infants' ability to detect the patterns linking the familiarization triads together, leading each triad to appear unique to infants rather than an exemplar of a more general pattern. While the factors that affect representation and categorization in infancy are not fully understood, variables such as familiarity with, and interest in, a given stimulus domain can impact categorization (for review, see Rakison & Oakes, 2003). The use of dog/cat pictures and spoken syllables may facilitate this multifaceted process relative to stimuli such as novel looming shapes and computerized sounds. Indeed, preliminary analyses suggest that infants in Experiment 1 whose parents rated them as being highly interested in dogs performed best on the ABA/ABB pattern-learning task.[3] On this view, task performance should be facilitated by materials that infants can readily represent and/or categorize, such as animal pictures, speaker gender (e.g., Miller, 1983), vehicles (e.g., Mandler & McDonough, 1993), and faces (e.g., Cohen & Strauss, 1979). Importantly, infant categorization is heavily influenced by the presence of correlations among stimulus features (e.g., Younger & Cohen, 1983), a key factor that may distinguish naturally occurring materials from some of the more artificial stimuli used in prior studies of non-linguistic rule learning.

These considerations are consistent with recent results suggesting that while infants cannot learn rules based on tones or visual shapes, they are able to generalize linguistic rules learned based on syllables to include these non-linguistic elements (Fernandes, Marcus, & Little, 2005). Extending previously learned type-based patterns to include sequences of tones or shapes may be easier than learning type-based patterns based on sequences of tones or shapes. Critically, the transfer task does not require infants to generalize a pattern across sequences of elements, unlike the learning task. Once infants have acquired the type-based patterns of syllables, their representations are apparently sufficiently flexible that they can encompass novel elements drawn from other categories. Thus, stimulus familiarity and categorizability – more generally, ease of representation – likely influences pattern learning far more than subsequent pattern extension. These findings are consistent with prior results demonstrating that adult learners can transfer artificial grammar knowledge across modalities (e.g., Altmann, Dienes, & Goode, 1995).[4] Interestingly, it appears

[2] Infants could presumably categorize another class of stimuli used by Marcus et al. (2004), tones varying in pitch. However, infants likely encoded each tone triad as a distinct melody. Infants may have then failed to generalize across the familiarization melodies because they differed in intonation contour, relative pitches, or absolute pitches, all highly salient to infants (e.g., Trehub, Schellenberg, & Hill, 1997).

[3] To examine this possibility, we asked parents in Experiment 1 about their infants' interest in dogs: "Very interested" (8 infants); "Somewhat interested" (7 infants); "Not interested" (0 infants). Analyses revealed a significant interaction between task performance and the dog-interest measure [$F(1,13) = 5.72$, $p < .05$]: the reportedly very-interested infants showed a stronger learning effect than the somewhat-interested infants. Analyses of overall looking time and trials to habituation were not significant, suggesting that both groups of infants were equally engaged in the task. Interestingly, whether or not infants actually have a pet dog at home was not a significant predictor of task performance, nor did it correlate with infants' reported interest in dogs.

[4] Unlike the infants, adults can transfer from tones to syllables and vice versa, suggesting that experience affects our ability to learn non-linguistic elements.

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that at least for adults, the presence of repeating elements is critical for modality transfer (e.g., Tunney & Altmann, 1999); the role of repetitions for infant learners remains unknown.

These issues concerning generalization may also help to illuminate the differences between statistical learning tasks and rule-learning tasks. In the statistical learning tasks that focus on finding words in fluent speech (e.g., Saffran et al., 1996), the stimuli are designed such that the relevant patterns lie between individual syllables: e.g., that *go* predicts *la*, and *la* predicts *bu*, pointing to the word *golabu*. No generalization is required (beyond speaker normalization and other factors involved in word recognition).[5] These are token-level patterns awaiting discovery. However, in the rule-learning studies, the infants must do more than learn the token-level patterns. If they stopped at *Malamute – Cattle Dog – Malamute*, and did not discover Element_A – Element_B – Element_A, a learning outcome only available by comparing across individual triads, they would be unable to perform the test discrimination correctly. Following this logic, stimulus features that hamper categorizability and/or generalization should impair learning in the ABA/ABB/AAB task, but not the statistical word segmentation task. This may explain why the statistical segmentation task appears to be more domain-general than the rule-learning task. All infants must do to succeed at the statistical segmentation task is to perform computations over representations of individual elements. Thus, sequential statistical-style segmentation should occur over a broader class of stimuli than rule learning. Future studies are needed to clarify the relevant dimensions that influence which computations infants perform over which primitives. A recent study by Gerken (2006) provides intriguing suggestions in this regard, showing that the structure of the stimulus domain in question influences the grain of regularities tracked by infants in a linguistic rule-learning task. Similarly, the structure of tone sequences affects the perceptual dimensions of pitch tracked by infants in a non-linguistic statistical learning task (Saffran, Reeck, Niehbur, & Wilson, 2005).

More generally, pattern learning is facilitated when the perceptual information presented is well suited to the learning mechanism in question. On this view, whether the input is linguistic or non-linguistic matters less than how the input is represented in the minds of learners. It is clear that all learning does not occur in the same way: learning mechanisms are constrained by the nature of the information to be acquired (e.g., Saffran, 2003). Within a given domain, there are also limits on the particular units over which learning can occur (e.g., Bonatti, Peña, Nespor, & Mehler, 2005; Newport, Weiss, Wonnacott, & Aslin, 2004; Saffran & Griepentrog, 2001). However, it is premature to posit narrow domain-specific processes in learning when the structure of the input may not be equally accessible to encoding at the levels required for successful task performance. Only by disentangling the factors that might lead a particular behavior to appear domain-specific can we expect to understand the nature of human learning.

[5] Indeed, infants in word segmentation tasks appear not to generalize; for example, infants familiarized with fluent speech containing "cup" do not incorrectly recognize "tup" during testing (Jusczyk & Aslin, 1995).

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