The Official Journal of the International Society on Infant Studies
Infancy

Infancy, **20**(5), 548–575, 2015

ISSN: 1525-0008 print / 1532-7078 online
DOI: 10.1111/infa.12092

WILEY Blackwell

One is Not Enough: Multiple Exemplars Facilitate Infants' Generalizations of Novel Properties

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Across three experiments, we examined 9- and 11-month-olds' mappings of novel sound properties to novel animal categories. Infants were familiarized with novel animal–novel sound pairings (e.g., Animal A [red]–Sound 1) and then tested on: (1) their acquisition of the original pairing and (2) their generalization of the sound property to a new member of a familiarized category (e.g., Animal A [blue]–Sound 1). When familiarized with a single exemplar of a category, 11-month-olds showed no evidence of acquiring or generalizing the animal–sound pairings. In contrast, 11-month-olds learnt the original animal–sound mappings and generalized the sound property to a novel member of that category when familiarized with multiple exemplars of a category. Finally, when familiarized with multiple exemplars, 9-month-old infants learnt the original animal–sound pairing, but did not extend the novel sound property. The results of these experiments provide evidence for developmental differences in the facilitative role of multiple exemplars in promoting the learning and generalization of information.

Categorization, or the process of grouping items together based on shared features, is an early emerging ability. It is now well documented that infants can form a wide range of categories (for a review see Rakison & Yermolayeva, 2010), with even newborns demonstrating fundamental categorization abilities (e.g., Slater, 1995). One critical aspect of categorization involves

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the ability to link object properties with categories, and more importantly to generalize those properties to new members of a familiar category. Here, we report on three experiments that examined 9- and 11-month-olds' ability to form categories consisting of novel animate objects, and to generalize properties to new members of those categories.

During their first year of life, infants form global- and basic-level categories for both novel and familiar objects (e.g., Eimas & Quinn, 1994; Mareschal & Quinn, 2001; Quinn, 2002; Quinn, Doran, Reiss, & Hoffman, 2009; Quinn & Eimas, 1996a,b; Quinn, Eimas, & Tarr, 2001). For example, newborns form global categories of novel geometrical shapes, differentiating open (e.g., crosses) from closed shapes (e.g., squares, circles) but failing to distinguish between specific shape categories (e.g., triangle versus square; Quinn, Slater, Brown, & Hayes, 2001). By 3–4 months of age, however, infants successfully form prototypic representations of basic shapes, such as triangles and squares (Bomba & Siqueland, 1983). Even more remarkable is the abundance of findings suggesting that, by 3 months of age, infants form different kinds of categorical representations of animate and inanimate objects. For example, infants form global categories of mammals that exclude nonmammalian animals (e.g., fish) and furniture, and also differentiate the category of furniture from that of vehicles and mammals (Behl-Chadha, 1996). Furthermore, 3- to 4-month-olds form categories of cats and dogs (French, Mareschal, Mermillod, & Quinn, 2004), using the general shape of the animal or the silhouette of the head as the basis for their categorical decisions (Quinn et al., 2009; Quinn, Eimas et al., 2001).

Given that infants can form different types of categories very early in infancy, research has sought to examine the factors that impact infants' categorical decisions, with a focus on cues that promote category formation as well as those that lead infants to privilege one type of category over another (for reviews see Madole & Oakes, 1999; Rakison & Oakes, 2003; Rakison & Yermolayeva, 2010; Westermann & Mareschal, 2014). One line of research has explored the conditions under which linguistic and nonlinguistic information promotes categorization, demonstrating that naming has a powerful facilitative effect on categorization for infants as young as 3 months of age (Booth & Waxman, 2002; Fulkerson & Haaf, 2003; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007; Waxman & Markow, 1995; Waxman & Braun, 2005). Other empirical work has demonstrated that infants possess a sophisticated understanding of the features that are most relevant to categorization and flexibly adjust their categorical decisions across contexts. For example, infants can categorize items based on one dimension and then switch to a different dimension within the same testing session (Ellis & Oakes, 2006; Horst et al., 2009; Mareschal & Tan, 2007). In one such study, 14- to 18-month-olds categorized objects as animals and vehicles or as balls and blocks, but changed their categorical decisions to reflect function (e.g., things that roll)- and material-related (e.g., things that are squishy) similarities when these properties were demonstrated (Horst et al., 2009). Furthermore, exemplar variability can lead infants to develop different types of categories (Oakes, Coppage, & Dingel, 1997; Ribar, Oakes, & Spalding, 2004). For example, exposure to a more uniform set of exemplars led 10-month-olds to differentiate between the categories of land and sea animals (Oakes & Spalding, 1997). This is in contrast to familiarization with a more diverse set of exemplars, which promoted the formation of a broader category of animals. Exemplar variability has also been shown to differentially impact infants' learning of other categorical representations (e.g., spatial categories; Casasola, 2005). Together, this research suggests that, early in development, infants can successfully categorize novel and familiar objects, and draw upon a variety of cues when making their categorical decisions.

As noted earlier, a critical aspect of categorization is the ability to incorporate object properties into existing categories, which in turn allows for generalization of properties when new members of a category are encountered. For example, an infant must associate the property of *barking* with the category of dogs before she is able to generalize *barking* to the new member of the category that she may encounter. To date, infants' ability to generalize properties from one novel category member to another has been examined in the context of generalized imitation paradigms. This body of work has demonstrated that infants' willingness to extend newly learnt properties to new category members is influenced by a number of factors. That is, in the absence of other cues, infants as young as 13 months of age will use perceptual similarity to guide their generalizations, favouring shape over other perceptual features such as color and texture (Graham & Diesendruck, 2010; Graham, Kilbreath, & Welder, 2004; Welder & Graham, 2001). When objects are labeled with count nouns, 13- to 22-month-olds will reason that objects belong to the same category and share common properties, even if those objects are perceptually dissimilar (Graham et al., 2004; Graham & Kilbreath, 2007; Welder & Graham, 2001). Conversely, when objects are labeled with distinct nouns, 15-month-olds will inhibit their generalizations to exemplars that are highly similar in appearance (Graham, Keates, Vukatana, & Khu, 2013). Together, this body of research suggests that infants flexibly adjust their property generalizations depending on the cues available.

Two early studies also examined property generalizations in infants younger than 12 months. Baldwin, Markman, and Melartin (1993) demonstrated that infants as young as 9 months could reason about the shared nonobvious properties of artifacts. In their study, 9- to 16-month-olds were presented with a set of target toys that could be acted on to produce an outcome (e.g., a can that wailed when shaken). The experimenter then observed whether infants would attempt to produce a specific outcome on test objects of varying degrees of similarity to the target. Their results suggested that, even after a brief exposure, infants developed specific expectations about object properties, and reasoned that a particular property was only shared among objects that were perceptually similar. McDonough and Mandler (1998) examined 9- and 11-month-olds inductive reasoning abilities, focusing on their expectations about the properties of the animal and vehicle domains. Here, an experimenter modeled an action on a target object (e.g., a dog drinking), and examined infants' willingness to imitate the same action on varying exemplars. Results indicated that infants broadly generalized the properties within each domain, but their generalizations did not cross domain boundaries. For example, infants extended the property of *drinking* to diverse members of the animal category (e.g., from a dog to a cat and a bird), but not to members of the vehicle domain (e.g., a truck and an airplane). Thus, although infants appropriately extended novel properties beyond basic-level categories, they also demonstrated an understanding of when it is appropriate to restrict their generalizations (e.g., did not expect vehicles to exhibit the properties of the animal domain; but see Younger and Johnson (2004) for alternate explanations). Together, this work suggests that infants begin to incorporate properties into their early categories and appropriately extend these properties to novel members of those categories.

The overarching goal of our studies was to provide further insights into the emerging categorization abilities of infants. In particular, we focused on infants' mapping of properties to novel animate categories, and their ability to extend these properties to new exemplars of those categories. In our studies, we examined 9- and 11-month-olds' ability to generalize a sound property from one category member to another. Little research has examined infants' generalizations in the context of *novel*, *animate* kinds. Yet, this ability is critical in early development, as infants are faced with an abundance of novel entities that they must incorporate into their existing knowledge.

We focused our investigation on novel animal categories that were akin to real-world basic-level categories. That is, within each category, members shared a significant number of attributes (i.e., texture, size, parts) and had similar shapes, which are key attributes of basic-level categories identified by Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976). Although it is well documented that young infants can discriminate real-world basic-level categories (e.g., Eimas & Quinn, 1994), little is known about how infants prior to 12 months of age make property generalizations in the context of basic-like categories. That is, while 9- and 11-month-olds will reason broadly about shared properties of global categories (McDonough & Mandler, 1998), it is unclear whether infants of the same age will restrict their generalizations to reflect an understanding of narrower categories. This differentiation, however, is important as many properties can be generalized only within a basic-level category (e.g., meowing is specific to the category of cats).

In our studies, we used a looking time paradigm to reduce the motoric demands of the imitation paradigm used in prior studies (Baldwin et al., 1993; Welder & Graham, 2001). When designing our task, we drew upon research demonstrating that young infants learn arbitrary relations between visual and auditory stimuli when the movement of the object and the sound are presented in synchrony (e.g., Bahrick, Hernandez-Reif, & Flom, 2005; Gogate & Bahrick, 1998; Slater et al., 1999). In our paradigm, we presented infants with two novel animals, each paired with a novel distinctive sound, and examined whether they would learn arbitrary associations between each animal and the sound it produced. Similar to the stimuli used in the intermodal relation studies, the stimuli in our experiments consisted of dynamic videos, in which the animals turned their heads and opened their mouths to produce a sound. Thus, the onset of the sound was contingent on the mouth movement (i.e., the sound and mouth movement were synchronous), making it more salient for infants to consider the sound as an intrinsic property of the animal. Following familiarization to the novel animal–sound pairings, we tested infants' learning of the original animal–sound association, as well as their ability to extend the sound property to new exemplars of familiarized animal categories. In keeping with the characteristics of real-world basic-level categories, we kept shape and other attributes constant within each animal category but varied the color of new exemplars. In other words, infants were expected to generalize the sound property to a new exemplar that differed only in color from its counterpart presented during familiarization.

In Experiments 1 and 2, we investigated whether 11-month-olds' will learn a novel animal–novel sound pairing and extend that sound property to new exemplars of a familiarized category. Across these two experiments, we manipulated the number of exemplars to which infants were familiarized (i.e., single versus multiple exemplars). In Experiment 3, we report on 9-month-olds' learning and extension of the sound property when familiarized with multiple exemplars.

EXPERIMENT 1

The goal of Experiment 1 was to investigate 11-month-olds' willingness to generalize a given property to a new member of a novel animal category when familiarized with a single exemplar of that category. Using a modification of the Switch task (Werker, Cohen, Lloyed, Casasola, & Stager, 1998), 11-month-old infants were familiarized with two novel animals, each producing a distinct sound (e.g., Animal A [red] with Sound 1 and Animal B [purple] with Sound 2). Following familiarization, infants were presented with three test trials: a *same* trial, an *extension* trial, and a *switch* trial. During the *same* trial, the familiar animal–sound pairing (e.g., Animal A [red] with Sound 1) was presented to assess whether infants have formed a memory for the familiar event. We expected infants' looking time to remain low during this trial. The *extension* trial involved the presentation of a new exemplar (in a new color) of one of the familiarized animals paired with the same sound as its counterpart during familiarization (e.g., Animal A [blue] with Sound 1). If infants viewed the new exemplar as a member of the same category as the familiarized animal and expected it to make the same sound, looking times on the *extension* trial were not expected to differ from looking times on the *same* trial. Finally, during the *switch* trial, infants were presented with a familiar animal and a familiar sound coupled in a novel pairing (e.g., Animal A [red] with Sound 2). If infants had learnt the animal–sound pairings, when presented with a mismatch pairing on this trial, their looking times were expected to increase in comparison to the *same* trial.

Method

Thirty-five 11-month-old infants were included in the final sample. An additional 15 infants were tested, but were excluded from analysis for the following reasons: failure to complete the experiment (i.e., did not complete the familiarization phase and did not proceed to test trials; $N = 13$), parental interference ($N = 1$), and failure to recover to the post-test ($N = 1$). All infants were born at full-term, were predominantly Caucasian (although this was not formally assessed), and were from predominately English-speaking homes. Information on infants' age, gender, as well as parental education, is reported in Table 1.

Stimuli

The visual stimuli consisted of animations of novel animals, representative of two distinct, basic-like categories (see Figure 1). Within each category,

TABLE 1
Infant Demographic Information as a Function of Experiment

		Experiment 2		
	Experiment 1	*Single Exemplar*	*Multiple Exemplar*	*Experiment 3*
Age*				
Mean	11.43 (.37)	11.39 (.22)	11.56 (.28)	9.60 (.24)
Range	11.11–11.97	11.11–11.84	11.14–11.97	9.11–9.97
Gender	20 females	8 females	13 females	12 females
	15 males	14 males	11 males	15 males
Parent Education** (%)				
High School	10.2	22.7	9.5	10.0
College Degree	23.2	27.3	23.8	26.0
University Degree	53.6	40.9	33.3	54.0
Graduate Studies	13.1	9.1	33.3	10.0

*Age = age in months.
**Includes maternal and paternal education.

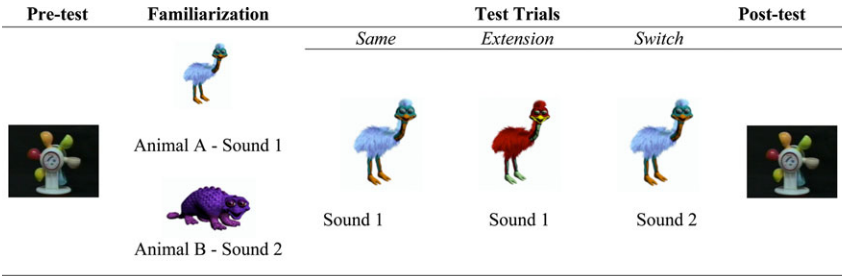

Figure 1 Experiment 1 design.

two exemplars that differed only in color were created. Thus, consistent with Rosch et al.'s (1976) definition of basic-level categories, animals within the same category shared similar attributes (e.g., shape, texture) and were clearly distinguishable from members of the other category. A waterwheel was presented during the pre- and post-test trials.

The auditory stimuli consisted of a sea lion sound (81.80 decibels and 384.45 hertz; obtained from the SeaWorld online sound library) and a rhesus monkey sound (83.17 decibels and 428.79 hertz; courtesy of A. Vouloumanos). The sounds were chosen because infants were likely to have little experience with them, and were sufficiently distinct from one another (See Figures A1 and A2 in Appendix for waveforms and spectrograms). The visual stimulus during the pre- and post-test was accompanied by music.

Apparatus

The experiment was conducted in a soundproof, dimly lit room. Infants faced a 122 × 91.5 centimeter monitor, while sitting on a high chair or on their parents' lap. Parents were instructed to have minimal interaction with their children and listened to music through headphones for the duration of the experiment. The auditory stimuli were played from a speaker placed above the monitor. All sessions were recorded for frame-by-frame coding of infants' looking times. The experiment was conducted using the Habit X 1.0 program (Cohen, Atkinson, & Chaput, 2004).

Procedure

Infants were tested in a within-subjects design. The testing phase began with the presentation of the pretest stimulus (i.e., a waterwheel accompanied by music) for 20 sec. Infants were then presented with the familiarization phase, followed by three test trials. The experiment concluded with the presentation of the post-test trial, which was identical to the pretest. See Figure 1 for an overview of the design.

Familiarization phase

During familiarization, infants were presented with two animal–sound pairings on sequential trials (e.g., Animal A [red]–Sound 1 and Animal B [purple]–Sound 2). The familiarization phase ended when infants' looking time to the last block of familiarization trials decreased by 35% of their baseline looking (i.e., the first block of familiarization trials) or until a maximum of 24 trials had been presented. The trials were divided into six blocks such that infants were presented with each animal twice within each block. The order in which the animals appeared within each block was counterbalanced across participants (i.e., the order of presentation of the animals was randomly distributed within and across blocks). The specific exemplar shown during familiarization and the specific sounds associated with each animal were also counterbalanced across participants.

Each familiarization trial began when the infant looked at the video display and lasted 20 sec. The trial began with an animal standing in profile (2 sec), followed by the animal turning its head to face the front (2 sec). There was no sound information during the initial 4 sec of the trial. The remaining 6 sec consisted of the animal, with its head facing toward the infant, opening its mouth and making a sound, alternating between sound and silence at 1-sec intervals. This sequence was repeated for the remaining 10 sec.

Testing phase

The testing phase consisted of three test trials, each 20 sec in length. During the *same* trial, infants were presented with one of the familiar events (e.g., Animal A [red]–Sound 1). During the *extension* trial, infants were presented with a new exemplar of one of the familiarized animals making the same sound as its counterpart in the familiarization phase (e.g., Animal A [blue]–Sound 1). Finally, the *switch* trial involved the presentation of a mismatched animal–sound pairing (e.g., Animal A [red]–Sound 2). The presentation order of the same, extension, and switch trials was counterbalanced across participants.

Coding

To determine whether infants' looking time to the animal–sound pairing decreased over the course of familiarization, online looking times were recorded. However, looking times for all trials of interest (i.e., pre- and post-test trials, first and last blocks of familiarization, and test trials) were coded on a frame-by-frame basis. To measure interrater reliability, a second coder coded 20% ($N = 7$) of the looking time data. The intraclass correlation (ICC) was high (.99, $p < .001$). The coders were unaware of the study hypotheses and were not able to identify the specific test trial during coding.

Results

We first evaluated infants' looking times to the pretest, the first and last block of familiarization (mean number of familiarization trials = 20.34), and the post-test to examine any possible influence of fatigue. See Table 2 for mean looking times. A within-subjects ANOVA revealed a main effect of trial, F (3, 102) = 58.34, $p < .001$, $\eta_p^2 = .63$. Planned pairwise comparisons demonstrated that infants' looking time to the pre- and post-test trials did not differ ($p > .135$). Furthermore, infants looked longer to the first block of familiarization trials as compared to the last block of familiarization trials ($p < .001$), indicating that their looking time decreased significantly over the course of familiarization. However, infants' looking to the last block of familiarization was shorter than their looking to the post-test ($p < .001$), indicating that infants recovered their looking and regained attention to the post-test.

The primary analyses focused on infants' looking time to the test trials. We first used a 3 (trial type—*same*, *extension*, *switch*) × 2 (group—infants who met ($N = 20$) versus those did not meet predetermined criterion ($N = 15$)) mixed-model ANOVA to determine whether infants who had

TABLE 2
Mean Looking Time for Pretest, Post-test, and Last Familiarization Block as a Function of Experiment

	Pretest [Mean (SD)]	*Post-test*	*First block of familiarization*	*Last block of familiarization*
Experiment 1	17.46 (3.11)	18.37 (2.21)	17.39 (2.46)*	11.09 (3.02)*
Experiment 2				
Single exemplar	17.70 (3.36)	18.26 (2.81)	9.20 (1.00)**	7.80 (1.50)**
Multiple exemplar	17.26 (2.75)	18.73 (2.43)	9.16 (1.01)**	6.88 (1.66)**
Experiment 3	18.21 (2.47)	19.31 (1.14)	8.88 (1.22)**	7.89 (1.89)**

*Familiarization trials were 20 sec in length.
**Familiarization trials were 10 sec in length.

met the habituation criterion during the familiarization phase (i.e., their looking time from the first and last block of familiarization decreased by 35%) performed differently on the task. This analysis revealed no main effect of group (p = .072) nor any interaction with group (p = .950), suggesting that infants did not respond differently to test trials based on whether they had met the predetermined habituation criterion. We thus included all infants in our final analysis. Recall that if infants learned the animal–sound associations during familiarization and generalized the property to a new exemplar of the familiarized animal, they were expected to look longer to *switch* trials as compared to *same* and *extension* trials. The results of a within-subjects ANOVA yielded a main effect of trial type, $F(2, 68) = 3.27$, $p = .044$, $\eta_p^2 = .09$ (see Figure 2). Pairwise comparisons indicated that infants' looking time to *switch* and *same* trials did not differ (p = .344), suggesting that infants did not recognize the violation in the animal–sound pairing. Similarly, infants did not look significantly longer to *switch* than to *extension* trials (p = .127). However, infants' looking time to *extension* trials was higher than their looking time to *same* trials (p = .024), suggesting that they were responding to the change in color relative to the familiarization animal.

Discussion

The results of Experiment 1 suggest that 11-month-olds did not learn the animal–sound association presented during familiarization, as their looking times to the *same* and *switch* trials did not differ. Furthermore, infants did not generalize the sound property to a new member of the familiarized category, as their looking time increased to the *extension* trial, relative to the *same* trial.

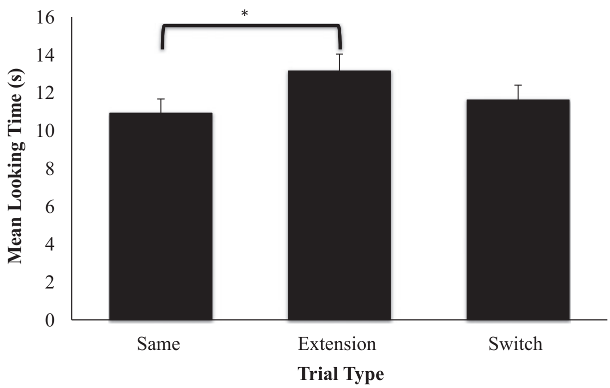

Figure 2 Mean looking time during same, extension, and switch trials for Experiment 1. **p* < .05.

The finding that infants failed to establish animal–sound mappings raises a number of questions. First, it is possible that infants' failure to learn the original animal–sound mapping and to extend the novel sound property was due to the demands of the task. That is, to successfully recognize the familiar event during the *same* trial, infants were required to encode the perceptual attributes of each animal and two unique sounds, to correctly track the relation between the animal and the sound throughout familiarization phase, and to retrieve this information, including the correct pairing, during test. Failure at any of these steps would lead to infants' inability to recognize the violation in pairing during *switch* trials. Furthermore, the *extension* trial entailed the presentation of a new element (i.e., color); thus, it is possible that infants' recovery in looking could reflect an increased interest to a novel feature rather than a lack of understanding that the sound property was associated with a particular category. Finally, the familiarization conditions may have not been optimal for promoting learning and generalization of the sound property. That is, it is possible that familiarization with a single exemplar of a category was not sufficient to direct infants' attention toward the sound as a critical and relevant feature of the animal, and more importantly, as a property of the broader category. We address these issues in Experiment 2.

EXPERIMENT 2

The primary goal of Experiment 2 was to determine whether familiarization with multiple exemplars would facilitate infants' ability to form an animal–sound mapping, and promote the generalization of the sound property to new exemplars. A secondary goal was to modify the testing procedure to reduce the demands of the task and decrease the potential influence of the novelty of the extension exemplar.

To achieve these goals, we implemented two changes to our design. First, we introduced a condition in which infants were familiarized to multiple exemplars of a category. Research across a number of domains has demonstrated that variability promotes a comparative process that allows young children to attend to critical information and thereby facilitates the learning and generalization of information (Casasola, 2005; Childers, 2011; Childers & Paik, 2009; Twomey, Ranson, & Horst, 2014). Similarly, comparison allows young children to detect commonalities among objects that may not be otherwise detected when categorizing (Gentner & Namy, 1999, 2004; Namy & Gentner, 2002; Namy, Gentner, & Clepper, 2007). That is, the presentation of multiple items allows for the extraction of common features that may have not been readily perceived or encoded when an object is presented alone. For example, in one study, 6-month-olds formed a category of cats when familiarized with pairs of exemplars, but not when the same exemplars were presented one at a time (Oakes & Ribar, 2005). Further, the facilitative role of comparison has also been shown in the context of categorizing unfamiliar objects (e.g., Graham, Namy, Gentner, & Meagher, 2010). Given the wealth of research suggesting that variability facilitates learning and generalization of information across a number of domains, we expected that familiarizing infants with multiple exemplars would promote a comparative process that would allow them to extract constant features across members of the same category (in our case, the properties of shape and sound) and thereby promote their learning of the animal–sound association and the extension of the sound property to a new category member.

Second, we modified the test trials, using a preferential looking paradigm, rather than the Switch paradigm, to address concerns related to task demands and the introduction of a novel element during *extension* trials. That is, infants were presented with two animals (one of each kind) side by side while they heard one sound. Here, we expected that infants may more easily recognize a correct animal–sound mapping when given a forced-choice between two animals (i.e., it may be easier for infants to match a sound to its respective animal as opposed to recognizing an animal–sound mismatch as required in the Switch task). In support of this notion, research examining early word–object mappings has demonstrated that infants' performance can vary depending on the testing procedure used. For example, although infants failed in mapping similar-sounding novel words when tested in a Switch task (Werker, Fennell, Corcoran, &

Stager, 2002), they successfully formed word–object mappings of the same words when tested in a preferential looking paradigm (Yoshida, Fennell, Swingley, & Werker, 2009). Thus, it is possible that reducing the demands of the task during test by asking infants to determine a "best fit" between an auditory and visual stimulus rather than a mismatch between the two may allow them to more easily identify the correct animal–sound mapping in this experiment. Further, the preferential looking paradigm addresses the concern of introducing a new element during the *extension* trials. That is, *extension* trials in this experiment entailed the presentation two new exemplars, one from each animal category. Given that both exemplars had a new feature (i.e., color), a greater amount of time spent looking toward one could not be accounted by novelty (as could have been the case in Experiment 1); rather, increased looking time toward one animal was expected to reflect infants' attempt to match the sound property to that animal.

In this experiment, we tested 11-month-old infants in two conditions. The *single exemplar* condition was similar to Experiment 1, such that infants were familiarized to two novel animal–sound pairings. We repeated Experiment 1 with the new testing procedure to differentiate whether infants' responses reflected the demands of the Switch task or whether the conditions of familiarization (i.e., familiarization with a single exemplar), in fact, did not promote learning and generalization of the sound property. Additionally, the inclusion of the *single exemplar* condition allowed for direct comparison with infants' performance in the *multiple exemplar* condition, and thus afforded us the opportunity to examine the role of exemplar variability on infants' learning and generalization of properties. Infants in the *multiple exemplar* condition were familiarized with three different-colored exemplars from each animal category, such that members of the same category always made the same sound. Infants in both conditions were then tested with *same* and *extension* trials using a preferential looking paradigm. During *same* trials, infants were presented with two of the familiarized animals side by side while they heard one sound. *Extension* trials involved the presentation of a new exemplar from each category, accompanied by a familiarized sound. Here, our predictions differ from those of Experiment 1, given the paradigm change. That is, in preferential looking paradigms (e.g., Yoshida et al., 2009), infants are expected to form a match between visual and auditory stimuli in cases when they have established a mapping between the two. Thus, they typically look longer to the match rather than to the mismatch pair. We expected that, if infants learned the original animal–sound association and generalized the sound property to the new member of the category, they would look toward the animal that matched the sound (i.e., the target animal) at rates greater than chance during both *same* and *extension* trials.

Method

Participants

The final sample consisted of forty-six 11-month-old infants (N = 22 for the *single exemplar* condition; N = 24 for the *multiple exemplar* condition). An additional 17 infants participated in the experiment, but were excluded from analysis due to failure to complete the experiment (N = 8), parental interference (N = 1), excessive fussiness (N = 2), failure to look at both sides of the screen during test trials (N = 4), and experimenter error (N = 2). Information on infants' mean age, gender, and parental education is reported in Table 1.

Stimuli and apparatus

Two new exemplars of the animals used in the previous experiment were created for the *multiple exemplar* condition. Exemplars differed only in color (see Figure 3). The sound stimuli and the apparatus were identical to those used in the Experiment 1.

Procedure

The experiment began and ended with the presentation of the waterwheel. All infants were presented with 24 trials, each 10 sec in length. Figure 3 provides an overview of the design.

Familiarization phase. The familiarization phase consisted of 24 sequential trials. The number of exemplars presented differed depending on the condition. The familiarization phase of the *single exemplar* condition was similar to that of Experiment 1. That is, infants were familiarized with one exemplar from each animal category (e.g., Animal A [red]–Sound 1 and Animal B [purple]–Sound 2) across a series of 24 trials. In contrast, infants in the *multiple exemplar* condition were presented with three different-colored exemplars from each animal category (Animal A [red, light blue, and orange]–Sound 1, and Animal B [purple, dark blue, and pink]–Sound 2) across 24 trials (each exemplar was presented four times). The exemplars presented during familiarization, the order in which the animals appeared, and the sound paired with each category were counterbalanced across participants.

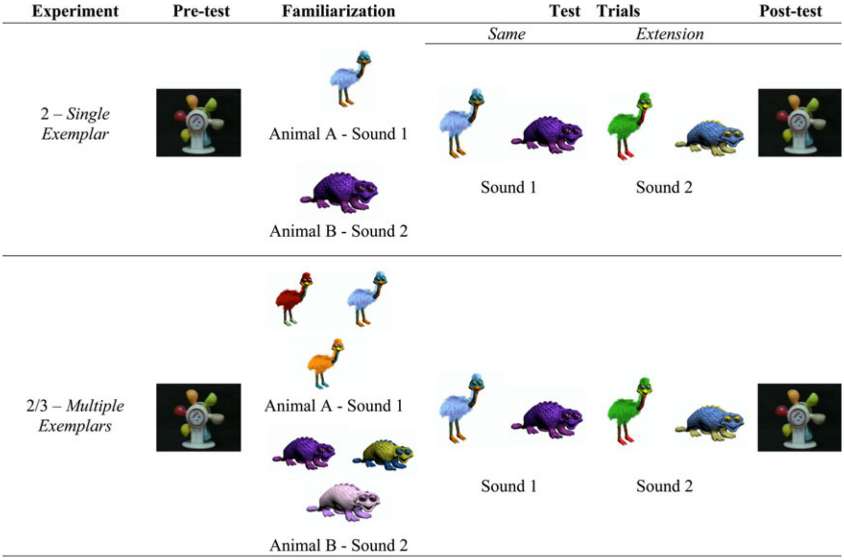

Figure 3 Experiment 2 and 3 design.

Testing phase. Infants were tested in a preferential looking paradigm. Videos of Animal A and Animal B were presented side by side, while one sound was emitted from a central speaker. The animals faced the infants and opened their mouths in synchrony, alternating between sound and silence at 1-sec intervals. During *same* trials, infants saw two of the familiarized animals (one from each representative category) and heard one of the sounds (e.g., Animal A [red] and Animal B [purple]–Sound 1). *Extension* trials involved the presentation of a new member of each familiarized category (e.g., Animal A [green] and Animal B [yellow]–Sound 1). Infants were presented with two *same* and two *extension* trials in the following fixed order: same, extension, same, extension. Each trial lasted 20 sec. Given that 11-month-olds in Experiment 1 demonstrated difficulties learning the animal–sound pairing during familiarization, infants were always presented with same trials first to ensure that they formed an animal–sound mapping, prior to being required to generalize the sound property to novel exemplars. Previous research has suggested that children benefit from exposure to a familiar event (e.g., being allowed to use an object in the same way as it was modeled in an imitation paradigm) prior to being asked to generalize a given property (e.g., Haryu, Imai, & Okada, 2011; McDonough & Mandler, 1998; Pauen, 2002). The specific exemplars of each animal category that appeared during the same and extension trials were counterbalanced across participants.

Using the videotapes, center fixations were coded for the pre- and post-test trials and first and last block of familiarization trials, while left and right looks were coded for the test trials. Interrater reliability for 20% (N = 9) of the data was high (ICC = .98, p < .001). Coders were unaware of the study hypotheses and could not identify the target animal on the test trials.

Results

To determine whether infants recovered their looking following familiarization, we examined their looking times to the pre- and post-test trials and the first and last block of familiarization trials. Given differing trial lengths, looking times to the familiarization trials (10 sec), and pre- and post-test (20 sec) could not be directly compared. Thus, a proportion of looking score was calculated for each trial by dividing looking time during the trial by total trial length. A 4 (trial type—pretest, first block of familiarization, last block of familiarization, and post-test) × 2 (condition: single exemplar, multiple exemplar) mixed-model ANOVA revealed only a significant main effect of trial type, F (3, 132) = 22.38, p < .001, η_p^2 = .34. Planned follow-up pairwise comparisons indicated that infants' proportion looking time during the pretest (M = .87, SD = .15) did not differ significantly from their proportion looking time during the post-test (M = .93, SD = .13; p = .081). Infants' proportion looking time decreased over the course of familiarization, as proportion looking time to the first block of familiarization (M = .92, SD = .10) was significantly higher than proportion looking time to the last block of familiarization (M = .73, SD = .16; p < .001). Infants, however, looked for a longer proportion of time to the post-test than to the last block of familiarization, suggesting that they regained attention following familiarization (p < .001).

To examine infants' performance during critical trials as a function of condition, we first calculated a proportion of looking score for *same* and *extension* trials by dividing looking time to the target (i.e., the animal that matched the sound) by total looking time during the trial. A 2 (trial type—same and extension) × 2 (order—first block versus second block of test trials) × 2 (condition) mixed-model ANOVA indicated only a significant main effect of condition, F (1, 44) = 21.20, p < .001, η_p^2 = .33. Infants in the *multiple exemplar* condition (M = .57, SD = .14) looked for a significantly longer proportion of time to the target across test trials than infants in the *single exemplar* condition (M = .48, SD = .13). All other effects were nonsignificant (ps > .105).

Although the above analysis suggests that infants in the *multiple exemplar* condition spent a significantly greater proportion of time looking toward the target than infants in the single exemplar condition, it does not indicate whether infants' looking toward the target was significantly different from chance. In the next analysis, we averaged across trial blocks to obtain a mean proportion of looking for *same* and for *extension* trials (given that the effect of order was not significant in the ANOVA reported above; see Figure 4). In the *single exemplar* condition, infants' proportion of looking to the target animal did not differ significantly from chance (50%) during the *same* (M = .49, SD = .10) or *extension* (M = .47, SD = .15) trials, t (21) = .68, p = .500, and t (21) = .80, p = .432, respectively. These findings further support the results of Experiment 1, demonstrating that infants did not form an animal–sound mapping and did not extend the sound property to a novel member of a familiarized category when familiarized with a single exemplar. In contrast, infants in the *multiple exemplar* condition looked to the target animal at rates higher than chance during both *same* (M = .59, SD = .09) and *extension* (M = .56, SD = .12) trials, t (23) = 4.74, p < .001, and t(23) = 2.56, p = .017, respectively. Thus, when presented with multiple members of a category, infants learnt the original animal–sound pairings and extended the sound property to a new member of familiarized categories.

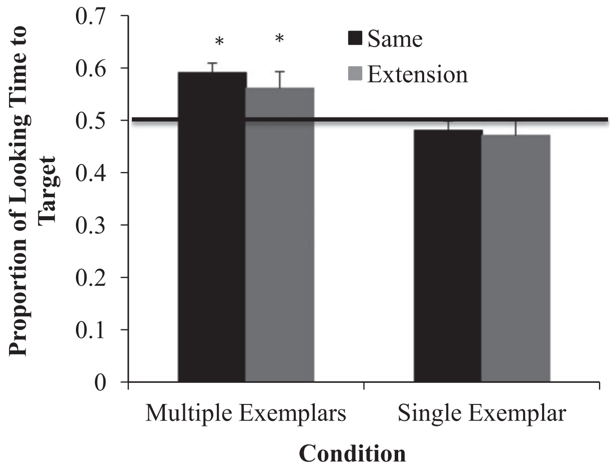

Figure 4 Mean looking time during same, extension, and switch trials for Experiment 1. *p < .05.

Discussion

Consistent with the results of Experiment 1, 11-month-old infants in the *single exemplar* condition did not learn the original animal–sound mapping and did not generalize the sound property to novel members of the familiarized category. Thus, infants' performance did not differ as a function of the testing procedure used (i.e., Switch task versus Preferential looking design); rather, the findings suggest that familiarization with a single exemplar is not sufficient to promote learning and generalization of the sound property.

In contrast, infants in the *multiple exemplar condition* learnt the familiarized animal–sound pairing and generalized the sound property to novel exemplars of the familiarized category, demonstrating that infants' tendency to form an animal–sound mapping, as well as their tendency to generalize the sound property to a new member of the category was facilitated by familiarization with multiple exemplars of a category. The facilitative role of the comparative process promoted by the presentation of multiple exemplars will be discussed further in the General Discussion.

EXPERIMENT 3

The goal of Experiment 3 was to examine 9-month-olds' ability to establish property–category associations. Given that 11-month-olds only generalized the sound property to new members when familiarized with multiple category exemplars, we tested 9-month-old infants in the same condition. That is, similar to the *multiple exemplar* condition of Experiment 2, infants were familiarized to multiple exemplars representative of two distinct categories and tested with *same* and *extension* trials in a preferential looking paradigm. We expected that, if 9-month-olds, like 11-month-olds, benefited from the presentation of multiple exemplars for the learning and generalization of the sound property, they would look toward the target animal at rates greater than chance for both *same* and *extension* trials.

Method

Participants

Twenty-six 9-month-old infants were included in the final sample. Seven additional infants participated in the experiment but were excluded for the following reasons: excessive fussiness ($N = 2$), failure to complete the experiment ($N = 2$), failure to look at both sides of screen during test trials ($N = 2$), preference for one animal (defined as looking to one animal for more than 70% of total looking time during test trials; $N = 1$), and experimenter error ($N = 1$). Information on infants' mean age, gender, and parental education is reported in Table 1.

Stimuli and apparatus

The stimuli and apparatus were identical to those of the previous experiments.

Procedure

The procedure was identical to the *multiple exemplar* condition in Experiment 2 (see Figure 3). Center fixations were coded for the pre- and post-test trials and the first and last block of familiarization trials, while left and right looks were coded for the test trials. A second rater coded 20% of the data ($N = 4$), and the interrater reliability was high (ICC = .988).

Results

As in Experiment 2, proportion looking scores were calculated to directly compare familiarization trials to pre- and post-test trials. A repeated-measures ANOVA revealed only a main effect of trial type, F (3,76) = 9.65, $p < .001$, $\eta_p^2 = .28$. Infants' proportion of looking to the pretest ($M = .92$, $SD = .12$) and post-test ($M = .97$, $SD = .06$) did not differ ($p = .100$). However, infants' proportion of looking to the first block of familiarization ($M = .88$; $SD = .12$) was significantly higher than their proportion of looking during the last block ($M = .78$; $SD = .19$; $p = .024$). Similarly, infants' proportion of looking was greater for the post-test as compared to the last block of familiarization ($p < .001$).

To examine whether infants' responses differed as a function of order or trial type, we conducted a 2 (order—first versus second block of test trials) × 2 (trial type) within-subjects ANOVA. This analysis did not yield any significant main effects or interaction (ps > .05). We next examined whether infants' proportion of looking to the target animal differed from chance levels (50%). Given that there was no significant effect of trial order, we calculated an average proportion of looking for *same* and for *extension* trials. The results revealed that, similar to 11-month-olds, 9-month-olds' proportion of looking to the target animal was significantly greater than chance during *same* trials (M = .54, SD = .08), t (25) = 2.26, p = .033, suggesting that they formed an animal–sound mapping. In contrast to 11-month-olds, however, 9-month-olds' proportion of looking to the target animal did not differ from chance during *extension* trials (M = .50, SD = .13), t(25) = .05, p = .959.

Discussion

Nine-month-old infants formed an animal–sound mapping when familiarized with multiple exemplars of a category. However, they did not look to the target animal at rates significantly different from chance during *extension* trials, suggesting that they did not generalize the sound property to new exemplars of familiarized categories. Thus, the findings suggest a developmental trajectory in infants' ability to generalize a property to new members of a category.

GENERAL DISCUSSION

Our experiments provide several insights into infants' categorization abilities, and more specifically, their ability to associate properties with novel animate categories. First, our findings demonstrate that, by 11 months of age, infants can generalize a given property to new members of an animal category. However, they do so only when presented with multiple exemplars of a familiarized category. When familiarized with a single exemplar of a category, 11-month-olds failed to form an animal–sound mapping and to generalize the sound property to new members. This finding was consistent across two different paradigms (i.e., a Switch task and a Preferential Looking task), demonstrating that a single exemplar was not sufficient to promote learning and to allow infants to generalize properties from one category member to another.

The facilitative effect of multiple exemplars in our experiments is consistent with an abundance of research across a number of domains, suggesting that variability promotes learning and generalization of information. For example, in the domain of language, variation from different sources (e.g., speaker identify, affective quality) augments infants' phonological processing (e.g., Rost & McMurray, 2009) and facilitates their ability to detect words from a continuous speech stream (Houston & Jusczyk, 2000; Singh, 2008). Furthermore, the opportunity to compare across multiple variable exemplars can assist young children in acquiring the meaning of novel verbs (Childers & Paik, 2009) and spatial terms (Casasola, 2005), in retaining newly learnt name–object mappings (Twomey et al., 2014), and in generalizing novel labels to novel exemplars (Perry, Samuelson, Malloy, & Schiffer, 2010). Similarly, within the categorization domain, presentation with multiple exemplars has been shown to facilitate the formation of categories for both familiar and novel objects (Gentner & Namy, 1999, 2004; Namy & Gentner, 2002; Namy et al., 2007; Oakes & Ribar, 2005). Our findings add to this existing body of research by demonstrating that exemplar variability is also critical for promoting learning of category–property associations.

How do multiple exemplars facilitate 11-month-olds' ability to learn and generalize the novel sound property? Prior research has suggested that the presentation of variable category members promotes a comparative process, allowing young children to attend to the shared features within a given category (Gentner & Namy, 1999; Graham et al., 2010; Namy & Gentner, 2002). In one particular study, Quinn and Bhatt (2010) found that exemplar variability across trials, but not within trials, promoted the formation of a category for novel shapes. These authors posited that the presentation of variable exemplars drew infants' attention toward shared commonalities and away from individual exemplar features, helping them in forming the category. Our results are consistent with this interpretation. That is, infants who were presented with multiple exemplars succeeded in learning and extending the sound property because they were able to identify the features that were most relevant to and shared within the category (e.g., shape and sound). At the same time, less attention was devoted to irrelevant or exemplar-specific features (e.g., color). In other words, variability allowed infants to detect the shared commonalities, thereby promoting the formation of a category and the generalization of the sound property within that category.

Our finding that 11-month-olds familiarized with a single exemplar of a category failed to learn the animal–sound pairing or generalize the sound property is consistent with a growing body of research, demonstrating that infants younger than 12 months of age have difficulty learning multiple relations among features in dynamic events (Baumgartner & Oakes, 2011, 2013; Perone & Oakes, 2006; Perone, Madole, Ross-Sheehy, Carey, & Oakes, 2008; Perone, Madole, & Oakes, 2011). For example, when infants are asked to learn the relation between the appearance, action, and outcome of an action, research has revealed a developmental trend in infants' ability to form associations among these features. That is, while 8-month-olds do not learn any of the associations (Baumgartner & Oakes, 2011), 10-month-olds demonstrate learning of the object appearance and action relation (Perone & Oakes, 2006), and, by 12 months of age, infants learn both the relation between appearance and sound, and that between appearance and action (Baumgartner & Oakes, 2011). Furthermore, the finding that 11-month-olds did not generalize the sound property when familiarized with one exemplar is consistent with other findings from categorization research. For example, Kovack-Lesh and Oakes (2007) found that 10-month-olds formed exclusive categories when given the opportunity to compare pairs of different items, but not pairs of identical items. Thus, it is possible that, when provided with a single exemplar in our study, infants attempt to encode all the features of a given animal (e.g., texture, color) rather than focusing their attention toward critical features. This approach would lead to an increase in learning demands, and may result in infants' inability to form an animal–sound mapping and thereby extend the novel sound property to new members of a category. Together, our findings indicate that the opportunity to compare across exemplars plays a critical role in promoting infants' property generalization to new members of a category.

Our findings also revealed developmental differences in young infants' ability to associate a property with a category, versus with an individual. That is, unlike 11-month-olds, when 9-month-olds were presented with multiple exemplars, they did not generalize the novel sound property to new members of a category, despite having learnt the original animal–sound pairing. Thus, at 9 months of age, multiple exemplars facilitate learning, but do not appear to promote the generalization of a given property. However, future research is needed to differentiate whether 9-month-olds are simply not able to extend object properties in the context of basic-like categories at this age or whether they require additional support (e.g., longer familiarization phase; more diverse exemplars) prior to generalizing a given property.

Together, our results offer insights into the factors that impact the generalization of properties within a category at different developmental levels. First, we demonstrated that, in the context of *novel animate* kinds, 11-month-olds require exemplar variability to make property extensions. This is in contrast to infants' reasoning about other types of object categories. That is, prior research has demonstrated that by 9 months of age, infants generalize properties, even after a brief exposure to a single exemplar of an artifact category (Baldwin et al., 1993; Graham et al., 2004) or a single member of a familiar, global-level category (McDonough & Mandler, 1998). Our findings add to this body of work, suggesting that, when presented with novel animate kinds, infants require additional support in making their generalizations, as they benefitted from exemplar variability. Second, our findings indicate that property extensions in the context of basic-like animate categories may be more difficult for infants in their first year of life. Unlike prior research suggesting that by 9 months of age infants can reason inductively about properties of artifacts (Baldwin et al.,

1993) and familiar animals at the global category level (McDonough & Mandler, 1998), we did not find evidence of property generalization in 9-month-old infants in our task. Thus, this may be a later emerging ability.

Broadly, we demonstrate that by 11 months of age, infants are able to from categories of novel animate kinds and generalize properties within those categories. However, several questions remain regarding infants' ability to extend properties from one category member to another. First, our experiments do not directly examine the mechanism by which infants make their generalizations. That is, there is ongoing debate as to whether property generalizations reflect an understanding of object kind on the part of the infant (Xu et al., 1999; Carey, 2000; Mandler, 2000; Waxman & Gelman, 2009) or whether they are rooted in the ability to detect and correlate perceptual or sensory features without having a deeper understanding of category membership (Sloutsky, 2003; Sloutsky & Fisher, 2004; Sloutsky et al., 2007; Smith, Jones, & Landau, 1996). The goal of our experiments was to determine whether infants establish relations between a category and its associated properties prior to delineating the mechanisms by which they accomplish this task; thus, we do not directly address this debate. We note, however, that the stimuli in our studies shared high perceptual similarity, and infants likely based their property generalizations on this information (as no other information was provided for these novel animate kinds). It remains an open question whether 9- and 11-month-olds would draw upon more conceptual information to generalize properties. Second, we focused our investigation on a sound property, as it represented an intrinsic property of the animals. However, it remains an empirical question whether infants will benefit from multiple exemplars or show similar developmental patterns in their generalizations of other types of properties.

In summary, the present experiments revealed a developmental trend in infants' ability to form associations between object properties and broader categories, such that 11-month-olds, but not 9-month-olds, generalized a given property from one member of a novel animal category to another. At 11 months of age, however, infants made property extensions only when familiarized with multiple exemplars of a category, suggesting that the presentation of variable members allowed them to detect shared commonalities within a category and facilitated the generalization of properties. Thus, our studies provide further insight into early infants' early categories by shedding light into the factors that impact infants' generalizations of properties about different object categories at different developmental levels.

ACKNOWLEDGMENTS

This research was supported by a Discovery grant from the Natural Sciences and Engineering Research Council of Canada and funds from the Canada Foundation for Innovation and the Canada Research Chairs program awarded to SG. EV was supported by graduate scholarships from the University of Calgary and the Social Sciences and Humanities Research Council of Canada. A special thank you to the families who participated in these studies. We would also like to thank Athena Vouloumanos and Scot Parker for their help with stimuli, as well as Vanessa Schell, Nicola Yee, Elisea De Somma, and Vivian Huang for their assistance with this research.

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APPENDIX

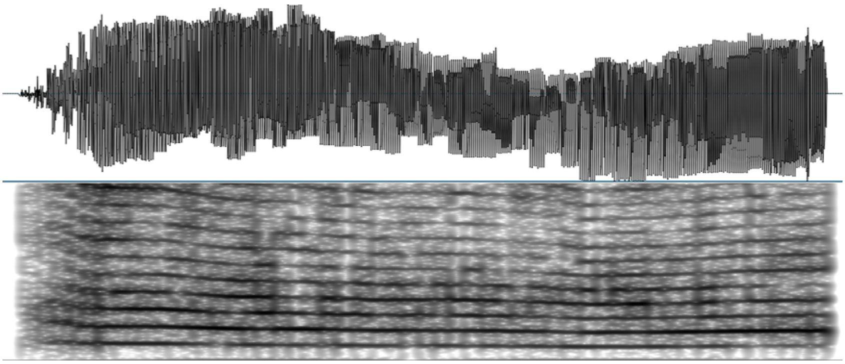

Figure A1 Sea lion Sound Waveform and Spectrogram.

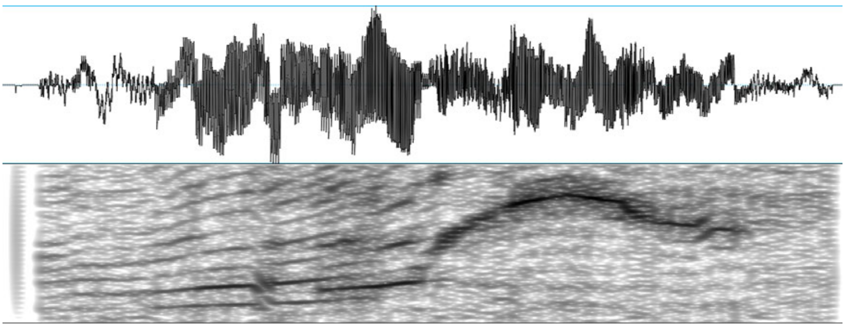

Figure A2 Monkey Sound Waveform and Spectrogram.