Flexible Attentional Learning in Infancy

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Abstract

One important component underlying lexical extension, categorization and induction tasks is the ability to flexibly attend to different dimensions in a variety of contexts. Flexible behaviors are well documented in young children, and it is often argued that (a) associations and associative mechanisms are too unconstrained to allow for such flexibility and (b) flexibility requires conceptual knowledge to determine what dimension is important in a given context. The current experiments examined whether infants could exhibit flexibility when presented with arbitrarily paired dimensions and contexts. Experiment 1 demonstrates that 12-month-old infants can readily learn arbitrary dimension-context contingencies after a few minutes of training (e.g., shape is important in Context 1 and color is important in Context 2). This finding demonstrates that the ability to flexibly attend to different stimulus dimensions can be achieved by associative means. Experiment 2 examined factors that affect flexible attention: Adding a redundant cross-modal cue attenuated rather than facilitated learning.

Keywords: Cognitive Development, Attention, Language Acquisition, Psychology, Human Experimentation.

Introduction

The ability to flexibly attend to different dimensions is an important component underlying many tasks, and it is well documented that children exhibit such flexibility. For example, when children extend words to novel entities, they often rely exclusively on shape when the entities are presented without eyes and they rely on shape and texture when the entities are presented with eyes (Jones, Smith, & Landau, 1991). Similar flexibility is found in categorization tasks. For example, when items are introduced as food, children categorize by color, however, when items are introduced as toys, children categorize by shape (Macario, 1991). Children also show flexibility when inducing a property from one entity to another. For example, when items are introduced as “parents and offspring”, children rely on one set of perceptual predictors, whereas, when items are introduced as “predators and prey”, they rely on a different set of perceptual predictors (Opfer & Bulloch, 2006).

Several theoretical proposals have been put forward to account for young children's flexibility. According to one position, it has been argued that associations are too unconstrained and that top-down knowledge is needed to determine what features are important (Murphy & Medin, 1985, Keil, 1991; Keil, Smith, Simons, & Levin, 1998). Furthermore, this conceptual knowledge has been claimed to be deployed in a deliberate and strategic manner rather than deployed automatically (cf. Gelman & Medin, 1993).

Other researchers have attempted to ground flexibility in low-level associative mechanisms (Colunga & Smith, 2005; French, Mareschal, Mermillod, & Quinn, 2004; Jones & Smith, 2002; Rogers & McClelland, 2004; Sloutsky, 2003; Sloutsky & Fisher, 2004, 2005). However, it is unclear how automatic processes can generalize similar stimuli in different ways (e.g., how can the same set of stimuli be categorized differently in different contexts?).

One way of solving this problem is to learn a contingency between a situation and a predictive dimension and there is evidence that preschoolers are capable of such learning (Sloutsky & Fisher, in press). In particular, 4-5-year-olds quickly learned to generalize by shape in one context and by color in a different context. This finding is remarkable given that (a) training stimuli were identical in both contexts (b) dimensions and contexts were arbitrarily chosen and (c) the acquired flexibility was a product of implicit attentional learning – children exhibited little awareness of what they had learned.

However, if learning in Sloutsky and Fisher (in press) was achieved by associative implicit learning, it is possible that the same flexibility can be achieved by young infants who have been shown to be highly sensitive to statistics in the input (e.g., French, et al., 2004; Saffran, Aslin & Newport, 1996; Smith & Yu, 2008) The current study tested this possibility.

In Experiment 1 12-month-old infants were presented with pairs of pictures, which were presented in one of two contexts. In Context 1 stimulus pairs shared the same shape, and in Context 2 stimulus pairs shared the same color (see Figure 1). After training, infants were either tested in Context 1 or in Context 2. At test, infants were presented with three test items. On Same test items, the dimension-context pairing was identical to training (e.g., infants tested in Context 1 were presented with stimulus pairs that matched in shape, which was consistent with training). On Switch items, the dimension and context switched (e.g., infants tested in Context 1 were presented with stimulus pairs that matched in color, which was inconsistent with training). On New test items, infants were presented with novel shapes with novel colors.

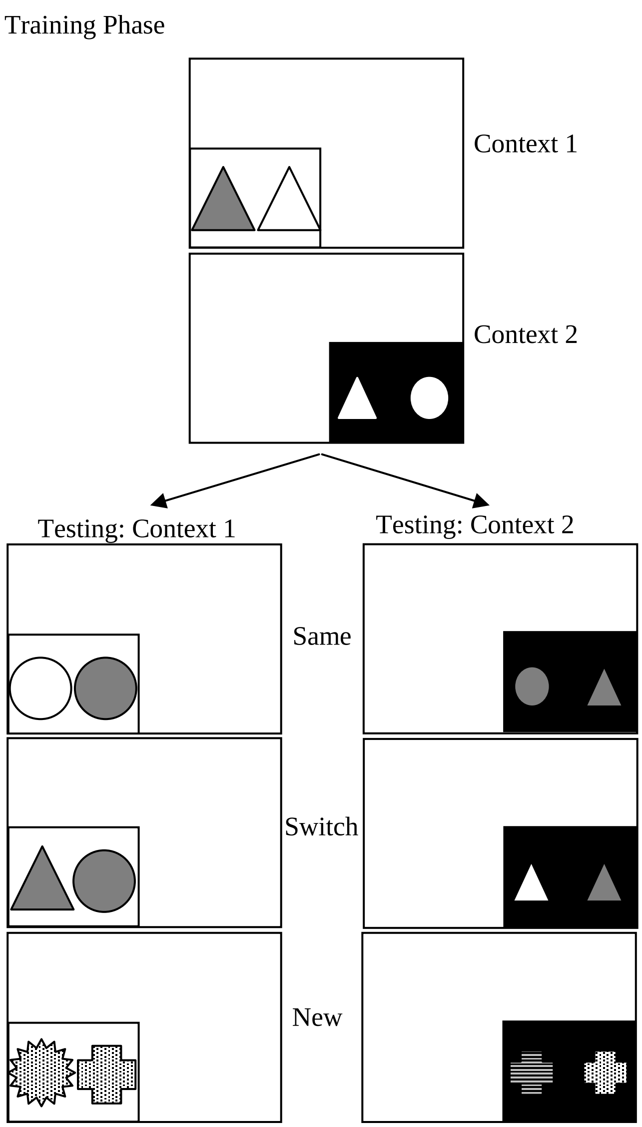

Figure 1: Overview of Experiment.

Experiment 1

The goal of Experiment 1 was to determine if infants could learn to flexibly attend to different dimensions in different contexts. Demonstrating this in young infants with arbitrarily chosen dimensions and contexts would provide further support that this flexibility can be achieved by associative learning.

Method

Participants Nineteen 12-month-olds (12 boys and 7 girls, M = 344 days, SE = 23 days) participated in this experiment. A majority of infants were Caucasian and none of the infants had auditory or visual deficits, as reported by parents. One infant was tested but not included in the final sample due to fussiness.

Apparatus Infants sat on parents' laps 100 cm away from a 152 cm x 127 cm projection screen, which was located approximately 5 cm above the infant's eye level. A Sony DCR-TRV40 camcorder was used to capture infants' fixations and was projected to a Dell flat panel monitor in the observation room. An NEC GT2150 LCD projector was mounted on the ceiling approximately 30 cm behind the infant. Two Boston Acoustics 380 speakers were 76 cm apart from each other and mounted in the wall. The speakers and camcorder were concealed by black felt and located directly below the projection screen. Two small lights were located behind the infant to ensure that the room was dimly lit throughout the entire procedure. In an adjacent room, a Dell Dimension 8200 computer with *Presentation* software was used to present stimuli to the infants, as well as to record the onset and offset of infants' visual fixations. Fixations to the visual stimuli were recorded online by pressing one of two buttons on a 10-button USB game pad when infants were looking at the stimuli and releasing the buttons when infants looked away from the stimuli. Fifty percent of the infants were also coded offline to establish inter-rater reliability, reliability between online and offline coders, r = .96.

Stimuli The training stimuli consisted of two geometric shapes: a circle and a triangle. Different exemplars were created by manipulating the color (red or blue) and size (small or large) of the shapes. Small shapes were presented to infants at 10 x 10 cm and large images were presented to infants at 20 x 20 cm. The stimuli were always presented in pairs on either a yellow background or on a green background.

In Context 1, training stimulus pairs matched in shape, whereas in Context 2, training stimulus pairs matched in color (see Training Phase in Figure 1). Three features differentiated Context 1 from Context

2: Image size, spatial location and color. Stimulus pairs presented in Context 1 were large, presented on the left side of the screen and were presented on a yellow background. Stimulus pairs presented in Context 2 were small, presented on the right side of the screen and were presented on a green background. The yellow and green backgrounds were 50 x 30 cm in size.

Procedure The procedure consisted of two phases: A training phase and a testing phase. The training phase consisted of 80 trials: 40 trials were presented in Context 1 and 40 trials were presented in Context 2 (see Figure 2 for examples of two trials presented in Context 1).

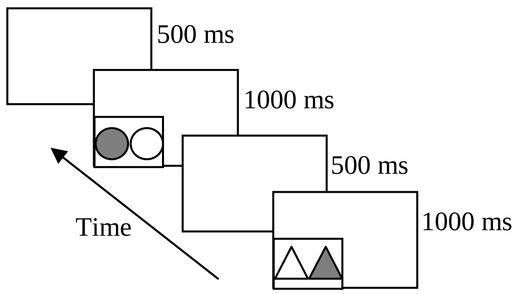

Figure 2: Example of training stimulus pairs and stimulus duration.

Each trial consisted of a stimulus pair, which was presented for 1000 ms with a 500 ms inter-stimulus interval. Training trials were blocked (see Figure 3), and the order of presentation (i.e., Context 1 first or Context 2 first) was randomized within each block.

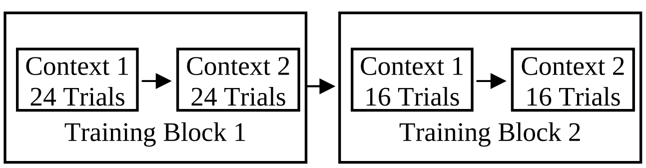

Figure 3: Blocks 1 and 2 of the training phase. Context order was randomized within each block.

After training, infants immediately moved to the testing phase. Ten infants were tested in Context 1 (where items matched in shape) and nine infants were tested in Context 2 (where items matched in color). There were three test item types: Same, Switch and New. As in training block 2 (see Figure 3), each test item consisted of 16 trials (i.e., each test item was presented for 24 seconds). On Same test items, the relation that was trained in one context was presented in that same context at test (see Figure 1 for examples). On Switch test items, the relation that was trained in one context was now presented in a different context. On New test items, infants were presented with novel stimuli. New items presented in Context 1 always shared the same color and New items presented in Context 2 always shared the same shape- both inconsistent with training. The first two test items presented to infants were always Same and Switch items, and the order of these test items were randomized for each infant. The last test item was always a New item.

If infants encode individual stimuli then they should increase looking on New test items because the shapes were novel. However, encoding stimulus features and relations were not sufficient for noticing a change on Switch test items because features and relations were all familiar (e.g., matching color and matching shape were equally familiar to young infants). The only way infants could notice a change on these test items is if they learned the dimension-context contingencies during training: Items match in shape in Context 1 and items match in color in Context 2.

Results and Discussion

Analyses focused on infants' looking on Same, Switch and New test item types. Paired *t*-tests indicated that infants looked longer on Switch items (M = 13.69, SE = 1.10) and New items (M = 13.92, SE = 1.22) compared to Same items (M = 11.73, SE = 1.16), ts (18) > 1.83, ps < .05 (one-tailed).

These findings demonstrate that infants encoded the individual shapes (as indicated by increased looking on New test items) and that they also learned that items matched in color in Context 1 and matched in shape in Context 2 (as indicated by increased looking on Switch test items). These findings are remarkable given that infants were only given one minute of training in each context.

Experiment 2

The goal of Experiment 2 was to determine if adding another feature to differentiate the contexts would facilitate learning. Recall that three features differentiated Context 1 from Context 2 in Experiment 1 (i.e., image size, location and color). In Experiment 2, four features differentiated the two contexts (i.e., image size, location, color and sound). In the current experiment infants heard one auditory stimulus while images were presented in Context 1 and they heard a different auditory stimulus when images were presented in Context 2.

Two outcomes can be predicted. First, it is well documented that infants accumulate more looking to images paired with auditory input than when presented in silence (Balaban & Waxman, 1997; Baldwin & Markman, 1989; Xu, 2002). Furthermore infants appear to be sensitive to word-category pairings, with words potentially affecting the categories that infants learn (Balaban & Waxman, 1997; Plunkett, Hu & Cohen, 2008; Xu, 2002, but see Robinson & Sloutsky, 2007; in press). Therefore it is possible that correlated auditory cues might help infants learn the dimension-context contingencies in the current experiment.

At the same time, however, it is also well documented that auditory input can attenuate visual processing (Robinson & Sloutsky, 2004; 2007; in press; Sloutsky & Napolitano, 2003). Given these cross-modal interference effects, it was predicted that adding a correlated auditory cue would hinder rather than facilitate learning.

Method

Participants Twenty-two 12-month-olds (9 boys and 13 girls, *M* = 333 days, *SE* = 22 days) participated in this experiment. Demographics were identical to Experiment 1. Two infants were tested but were not included in the final sample due to fussiness. Ten infants were tested in Context 1 (where items matched in shape) and 12 infants were tested in Context 2 (where items matched in color).

Stimuli and Procedure The visual stimuli, stimulus pairings (i.e., same shape and same color) and the testing items were identical to Experiment 1. In contrast to Experiment 1, an additional feature was added during the training phase. In particular, when images were presented in Context 1, infants heard one auditory stimulus, whereas, when images were presented in Context 2, they heard a different auditory stimulus. Auditory stimuli were short sound clips (i.e., Organ and Trumpet), which were taken from Marcell et al. (2000). Auditory stimuli were shortened to 1.7 s and they were presented every 6 s during training. Auditory stimuli were presented at 68-72 dB.

Results and Discussion

Analyses focused on infants' looking on Same, Switch and New test item types. In contrast to Experiment 1, paired *t*-tests indicated that infants looking on Switch items (*M* = 13.18, *SE* = 1.10) and New items (*M* = 11.93, *SE* = 1.22) did not differ from their looking on Same items (*M* = 13.86, *SE* = 1.32), *t*s (22) > 1.27, *p*s > .22 (one-tailed). Furthermore, poor learning in the current experiment could not be explained by less interest in the pictures during the training phase: Infants in the current experiment accumulated more looking during the training phase (*M* = 90.69) than infants in Experiment 1 (*M* = 74.28 s).

These findings suggest that adding a correlated cross-modal cue did not facilitate learning. Rather, it appeared to attenuate learning. In particular, there was no evidence in the current experiment that infants encoded individual stimuli (as indicated by comparable looking on Same and New test items). Furthermore, there was no evidence in Experiment 2 that infants learned the dimension-context contingencies (as indicated by comparable looking on Same and Switch test items). These findings suggest that not all redundant context cues facilitate associative learning, thus presenting additional evidence for auditory overshadowing early in development.

General Discussion

The current study reveals several important findings. First, after relatively little exposure to stimulus pairs, infants ably learned that items presented in one context matched in shape and similar items presented in a different context matched in color. This finding has important implications for understanding of flexible attentional shifts. A second important finding is that adding additional cross-modal correlated features hindered rather than facilitated learning. Recall that in Experiment 1, image size, location and color were all perfectly correlated, and infants learned the dimension-context contingencies in these conditions. In Experiment 2, the same correlated features were presented to infants, as well as a correlated feature presented to the auditory modality (i.e., one sound was presented in Context 1 and a different sound was presented in Context 2). Under these conditions, infants failed to encode individual images and they also failed to exhibit flexible attention. These latter findings have implications on the development of cross-modal processing, and the allocation of attention within and across sensory modalities.

Flexible Implicit Learning

It is well documented that children flexibly attend to stimuli in a variety of tasks including lexical extension, categorization and induction tasks. This finding has led some researchers to conclude that associations are too unconstrained to allow for flexibility and that top-down knowledge is needed to determine what features are important in a given context (Murphy & Medin, 1985, Keil, 1991; Keil, Smith, Simons, & Levin, 1998).

While there is little disagreement that conceptual knowledge can affect performance on a variety of tasks, the current findings in conjunction with Sloutsky & Fisher (in press) demonstrate that conceptual knowledge is not necessary for flexible attention. Recall that 12-month-old infants in Experiment 1 learned that shape was an important dimension in one context and that color was an important dimension in a different context. Given the age of the participants, the fact that contexts and dimensions were arbitrarily chosen and that infants were not given explicit instructions, it is likely that the flexibility found in the current experiment was acquired through low-level attentional mechanisms.

Unimodal and Cross-Modal Correlated Cues

While infants exhibited flexible attention in Experiment 1 when the correlated cues were presented within the same sensory modality, they failed to exhibit such flexibility in Experiment 2 when correlated cues were presented across sensory modalities. This suggests that not all correlated features have the same attentional weights and that cross-modal presentation attenuated rather than facilitated learning. Recall that the three correlated visual features were also presented to infants in Experiment 2, however, infants did not appear to be able to use this information when it was accompanied by auditory input. One explanation for this finding is that sounds overshadowed or attenuated processing of the visual input. This explanation is consistent with research examining infants' and children's processing of arbitrary auditory and visual pairings (Robinson & Sloutsky, 2004; 2007; in press; Sloutsky & Napolitano, 2003), and can adequately account for the findings of Experiment 2.

In summary, the current study demonstrates two important findings. First, 12-month-olds exhibited flexible attention by learning that shape was an important dimension in one context and by learning that color was an important dimension in a different context. Second, adding redundancy across sensory modalities hindered rather than facilitate learning.

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