Anticipatory eye movements reveal infants' auditory and visual categories

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Introduction

Over the past 20 years, a number of advances in experimental methodologies have provided a wealth of knowledge concerning infants' discriminative capacities, preferences and memory. However, only a few of these methodologies have been able to assess categorization and in particular, categorization of multi-dimensional stimuli. Additionally, available assessments require many repetitions of the same stimulus and/or implicitly direct the infant's attention to a predefined (relevant) dimension.

In the present studies, we demonstrate use of the anticipatory eye movement (AntiEM) paradigm (McMurray & Aslin, 2000, 2002) to assess visual and auditory categorization and present a new methodology based on tracking moving objects behind an occluder. These methods yield a measure of categorization of multi-dimensional stimuli that avoids previous pitfalls. We demonstrate the reliability of this new paradigm, two ways to examine the structure of categories, and also its power to reveal individual differences in categorization.

The AntiEM Methodology

AntiEM allows infants to perform a two-alternative-forced-choice task on a series of stimuli. Infants are trained to make anticipatory eye-movements to the left or right in response to two *training stimuli*. After training, categorization of new *generalization stimuli* can be assessed. By varying the composition of the training stimuli and the generalization stimuli, we assessed multidimensional categorization in two ways:

1) Feature Weighting (Exp. 1 & 2): The infant is trained on stimuli varying along **two** dimensions and tested on all possible novel combinations. Consistent generalization along one of these dimensions indicates a preference for one dimension over another when forming categories.

2) Category structure (Exp. 3): The infant is trained on stimuli varying on one dimension and then tested on stimuli which vary on one or more "extraneous" dimensions. By determining when performance degrades, one can see which dimensions tend to be naturally grouped together.

Experiment 1: Feature Weighting

Purpose: Do infants weight orientation or texture (spatial frequency) more when forming visual categories?

Training: 3 Vertical Bars (V3) and 6 Horizontal Bars (H6)

Testing: 3 Horizontal Bars (H3) and 6 Vertical Bars (V6)

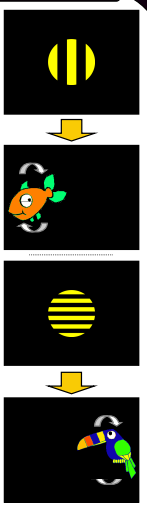
Subjects: 18 Five to seven-month-olds

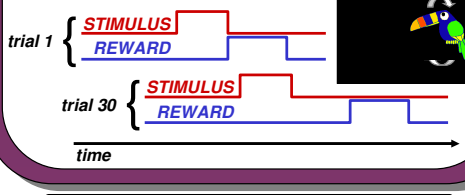
Each trial begins with the presentation of one of two training stimuli. These stimuli orient the infant's gaze to the center of the screen and serve as the stimulus to be categorized.

Experiment 1: Feature Weighting

After the training-stimulus, a short animation-(reward) appears on one side of the screen or the other. The location of the reward is consistently paired with the identity of the visual stimulus.

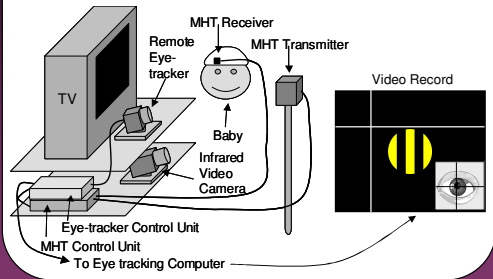
During training, the delay between the training-stimulus and the reward increases, prompting the infant to make anticipatory eye movements toward the side of the screen where (s)he expects the reward to appear. During testing, reinforced training stimuli alternate with unreinforced generalization stimuli.





Assessing Eye Movements

Eye movements are assessed using an ASL 504 remote eye-tracker coupled to a magnetic head tracker. The result is a real-time, 30 hz record of gaze position in screen coordinates.



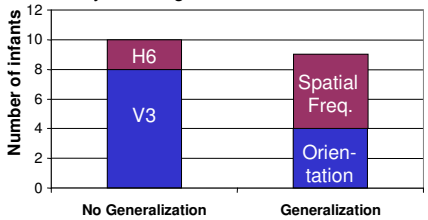
Experiment 1: Results

Training Results (30 trials)

- 73% Correct (t(18)=4.230, p=.0005).
- 15 out of 19 infants showed correct anticipation behavior to training trials (H6 and V3)

Generalization Results (M=18.9 trials)

Each infant's "dimensional-bias" was based on their responses to novel stimuli (H3 and V6). Infants who generalized showed eye-movements consistent with either orientation or spatial frequency. Infants who did not generalize looked consistently to the right or left.

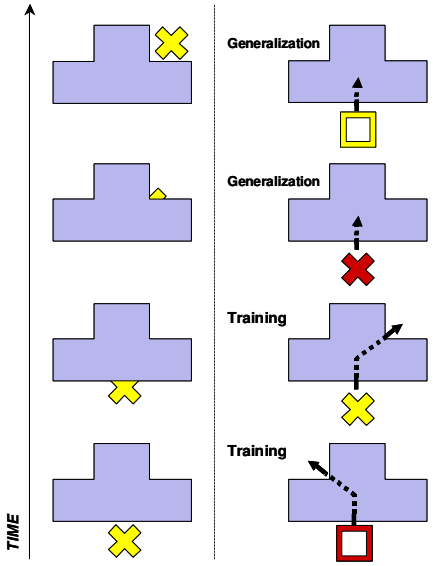


- 9 Infants showed generalization, 10 did not.
- No consistent preference for spatial frequency or orientation—individual differences are detectable using AntiEM paradigm.
- Of the 9 who generalized, all scored better than 50% on the training trials ($X^2(18)=4.6$, p=.03).
- Generalization preference strength correlated with training strength (R=.472, p=.04): generalization derives from learning.

Experiment 2: Occlusion

Purpose: Can infant's natural tendencies to anticipate an object's emergence from behind an occluder be used in the AntiEM paradigm?

How do infants weight color and shape in forming categories?



- Infants anticipate non-linear trajectory after 16 trials (p<.0001).
- 9/22 subjects consistently anticipated the correct trajectory.
- Degree of learning was correlated with generalization (p=.008)
- All 5 generalizers preferred color.

Experiment 3: Word Recognition

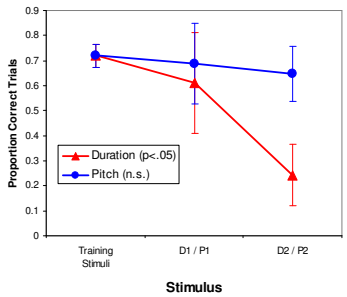
Purpose: Can we use the occlusion-based method to assess word recognition?

Are pitch and duration intrinsic properties of word-categories?

- **Training:** "Lamb" (object moves towards left). "Teak" (object moves towards right). 20 trials.
- **Testing:** Lamb and Teak. Pitch shifted by 20% and 40%. Duration by 33% and 66%.
- **Subjects:** 28 Five to Seven month olds.

Training Results (20 trials)

- Infants anticipate non-linear trajectory (p<.001)
- 11/28 scored better than chance.
- No effect of pitch (p>.2).
- Large effect of duration (p=.002); performance fell with change in duration.



Conclusions

- AntiEM has sufficient repeated measures (M=20.0 trials) to assess multidimensional categories and individual differences.
- Poorer learning with occlusion, but more "responses" (Exp 1: 2.8 s/trial; Exp 2&3: 4.5 s/trial)
- Spatial freq. and orientation weighted equally.
- Color outweighs shape.
- Word categories include duration, but not pitch.