

Anticipatory eye movements (AntiEM): A new method for assessing multi-dimensional categorization in 6-month-olds

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Introduction

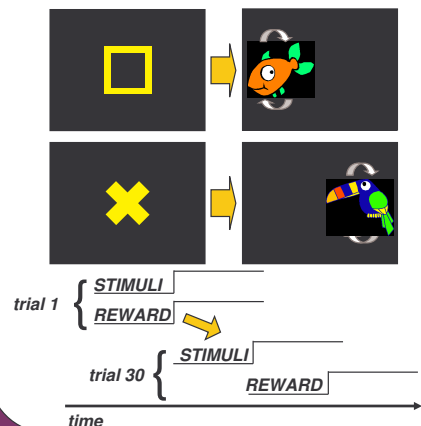
Over the past 20 years, a number of advances in experimental methodologies have provided a wealth of knowledge concerning infants' discriminative capacities, preferences and memory. However, only a few of these methodologies have been able to assess categorization and in particular, categorization of 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 study, we extend the anticipatory eye movement (AntiEM) paradigm (McMurray & Aslin, 2000) to visual categorization to yield a measure of categorization of multi-dimensional visual stimuli that avoids these pitfalls. We demonstrate the reliability of this new paradigm, two ways to examine the structure of visual categories, and also its power to reveal individual differences in categorization.

The AntiEM Methodology

Each trial begins with the presentation of one of two visual training stimuli. This orients the infant's gaze to the center of the screen and serves as the stimulus to be categorized.

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



Methods (cont)

Over training trials, the delay between the visual stimulus and the animation-reward is increased. This prompts the infant to make anticipatory eye movements during this delay-period toward the side of the screen where (s)he expects the reward to appear.

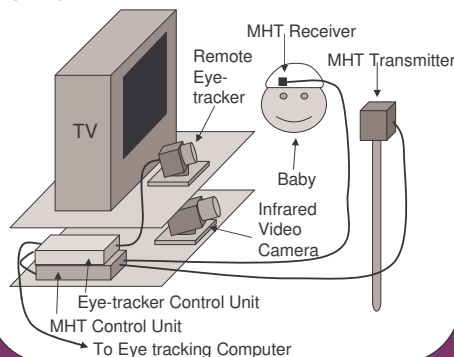
After training, the infant is presented with new visual stimuli (unrewarded) and categorization can be assessed by determining the direction of anticipatory eye-movements. By varying the composition of the training stimuli and the generalization stimuli, we can assess multidimensional categorization in two ways:

1) Category structure: The infant is trained on stimuli varying on one dimension. (S)he is 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.

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

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: Category Structure

Purpose: Do visual shape categories degrade in the presence of variation in color or orientation?

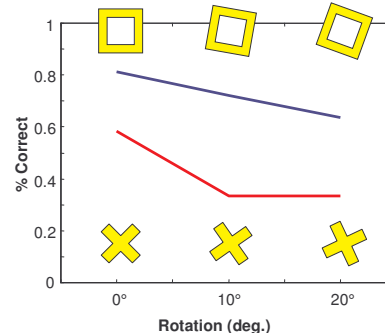
Subjects: 8 five to seven-month olds.

Training: Yellow square and cross
30 Training Trials

Testing: Squares and crosses
(Orange, Red) x (10°, 20°)
22.8 Test Trials (mean): 50% training stimuli, 50% generalization.

Experiment 1: Results

- 7 (out of 8) subjects scored better than chance.
- Mean (of the successful ones) = 70% +/- 11%



- Significant Effect of **Shape** ($p=.003$): Squares were learned better than Crosses.
- Significant Effect of **Orientation** ($p=.018$): Small rotations hindered performance.
- No effect of **Color** ($p>.1$): Infants ignore color when making shape judgments.

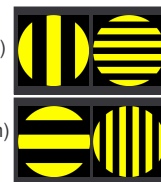
Experiment 2: Feature Weighting

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

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

Testing: 3 Horizontal Bars (H3)
6 Vertical Bars (V6)
18.9 Test Trials (mean)

Subjects: 18 Five to seven-month olds



Experiment 2: Results

Training Trials

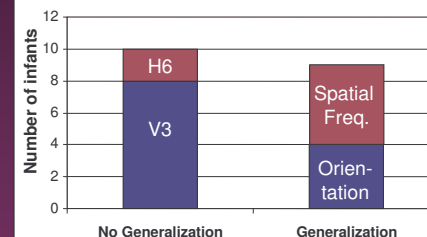
- Mean: 73% Correct ($t(18)=4.230$, $p=.0005$)
- 15 out of 19 infants showed correct anticipation behavior to training trials (H6 and V3)

Generalization Trials

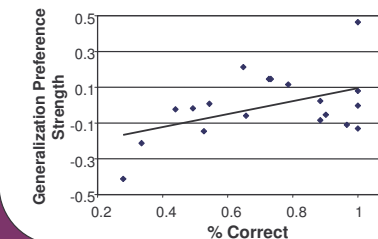
Each infant's "dimensional-bias" was based on their responses to novel stimuli (H3 and V6).

Category	V6 Response	H3 Response	Type
V3	V3	V3	No Generalization
H6	H6	H6	
Orientation	V3	H6	Generalization
Spatial Frequency	H6	V3	

- 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.



Conclusions

Theoretical

- Early visual categories may be orientation-specific but not color specific.
- Infants do not show a consistent preference for orientation or spatial frequency, although some individual infants do.

Methodological

- AntiEM is valuable for looking at category structure and feature weighting for multi-dimensional visual categories in infants.
- Generalization is tied to learning—AntiEM is addressing fundamental generalization behavior.