

Multi-Modal Anchoring in Infants and Artificial Systems

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Abstract—Whereas the facilitating function of intersensory redundancy in the integration of different senses into a multi-modal representation of objects and events is unquestioned, semantic factors only recently are under scope of investigation in infant studies. Arbitrary artificial connections such as between colors and tones can be integrated at the age of 7 months when they are presented in temporal synchrony. Our studies are motivated by the synesthesia research in adults suggesting that emotional and semantic congruence of certain colors and tones (red and high tones, green and low tones) can be perceived. We pursue thus the question of whether such congruence might facilitate the integration of colors and tones in infancy as well. We report the findings of an infant habituation study in which we tested whether congruent stimuli are differentiated at the age of 4 months already. Results indicate a discrimination of a green/low event from a red/high event, possibly motivated by a facilitating factor inherent in the colors and tones. We discuss the role of a proto-semantic similarity in certain colors and tones and propose a synesthetic connection between them from early on in infancy. Based on this evidence, we emphasize an important role of semantic factors that have to be considered as crucial for cross-modal anchoring in artificial systems.

I. INTRODUCTION

Intersensory redundancy fulfills a fundamental function in the development of perceptual systems [1,2]. When they are presented in a temporally synchronous way, infants integrate arbitrary auditory-visual features as colors and tones at the age of 7 months, but not earlier [3]. However, to our knowledge until now it has not been investigated whether a more semantically motivated connection in the sense of adult semiotics would lead to an earlier integration of the senses, e.g., the reason why warning signals are red and of a high pitch (rather than red and low pitch), because we perceive them in convergence. In our study with adults, we found that red and high pitch are perceived to a large extent negatively [4,6]. Green, on the other hand, is related to positive associations [5,6], thus resembling to low pitch in its positivity [6].

II. INFANT HABITUATION STUDY

In this study, we examined whether infants integrate congruent color-tone connections at the age of 4 months, earlier than so far investigated [3]. Congruence is defined as eliciting similar emotions and associations in adults [6].

A. Method

1) *Participants*: Fourteen 4-month-olds (7 male, 7 female, range 116–134 days, $M = 125$ days). All infants were full-term, with normal hearing and vision, raised in monolingual German families and with no family history of color-blindness.

2) *Stimuli*: The visual stimuli consisted of four geometric objects of different shape with low semantic content (*Fig. 1*). They were presented by a hand performing a looming forward movement in all films. This presentation was synchronous to either a high (2500 Hz) or low (475 Hz) sinus tone.

3) *Procedure*: The infants viewed 3 RED color-HIGH tone events out of 4 possible events (*Fig. 1*). When the infant looked away for 1 sec, the next habituation trial was shown. The habituation phase ended when the infant's looking times decreased in 3 consecutive habituation film trials by 50% relative to the first 3 habituation trials. When the criterion was reached, 5 test trials were shown (*Fig. 2*): One familiar and one unfamiliar object (both red-high events), two uni-modal changes (one GREEN-high

event and one red-LOW event), and a bimodal change (a GREEN-LOW event). The test trials were presented in a randomized order and counterbalanced across participants.



Fig. 1: Habituation phase. Three sample objects - out of four – presented with a high sinus tone (above)

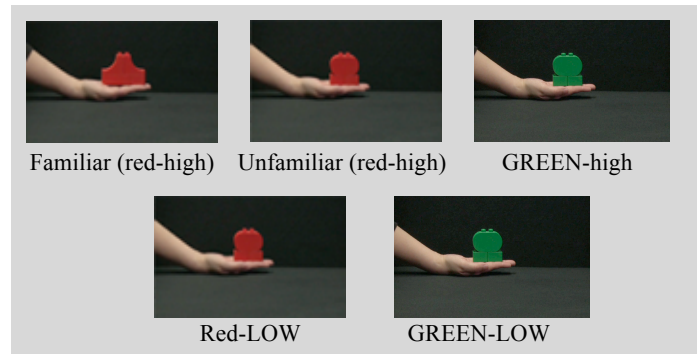


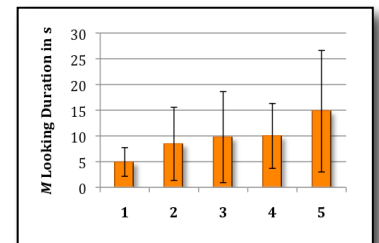
Fig. 2: Test Phase (right)

B. Results

We compared infants' looking durations to each test event with the familiar test event. Wilcoxon tests showed longer looking times for the GREEN-LOW event in contrast to the familiar RED-HIGH event ($M = 14.8$, $SD = 11.8$; $Z(10) = -2.40$, $p = .016$). No other test event was discriminated from the familiar test event (Fig. 3).

Fig. 3: Looking times for the different test events:

1. Familiar red/high event, 2. Unfamiliar red-high event, 3. Incongruent red-LOW event, 4. Incongruent GREEN-high event, 5. Congruent GREEN-LOW event



C. Discussion

These results suggest that already 4-month-old infants form arbitrary color-tone connections as they differentiate a green/low tone event from a red/high tone event. Two explanations may account for this early discrimination: Infants might have distinguished the bimodal change in contrast to the habituation event, which is easier to detect than a uni-modal change. An alternative explanation is that the discrimination was facilitated by the underlying (congruent) semantics in the green-low tone event. Infants may exhibit a certain predisposition to form these connections that may persevere into adulthood. The source of this initial proto-semantic knowledge may be seen in infant synesthesia [7], suggesting a cross-talk of sensory cortical areas. We therefore propose that a perceived congruence may support the formation of a connection between a color and a tone. Further studies could focus this problem, within a preferential looking paradigm that is sensible to the recognition of an intermodal relationship, determining the innate biases in the sense of infant synesthesia.

III. CONCLUSION

This study sheds light on how color and tone associations might develop from infancy by revealing certain predispositions in color perception that may be biologically based, as [5] and [7] suggest investigating.

Based on the provided results and concepts we motivate the development of an artificial multi-modal anchoring system that uses the temporally synchronous changes in attribute values as a basis [8]. Functional dependencies between attributes can thus be uncovered and used to facilitate the correspondence detection in ambiguous situations. This is a first step towards content-based strategies for cross-modal fusion. However, our infant study implies such processes on even earlier levels of representation.

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