INFANTS' PERCEPTION OF SYNESTHETIC-LIKE MULTISENSORY RELATIONS

by

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ABSTRACT

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Studies have shown that human infants can integrate the multisensory attributes of their world and, thus, have coherent perceptual experiences. Multisensory attributes can either specify non-arbitrary (e.g., amodal stimulus/event properties and typical relations) or arbitrary properties (e.g., visuospatial height and pitch). The goal of the current study was to expand on Walker et al.'s (2010) finding that 4-month-old infants looked longer at rising/falling objects when accompanied by rising/falling pitch than when accompanied by falling/rising pitch. We did so by conducting two experiments. In Experiment 1, our procedure matched Walker et al.'s (2010) single screen presentation while in Experiment 2 we used a multisensory paired-preference procedure. Additionally, we examined infants' responsiveness to these synesthetic-like events at multiple ages throughout development (four, six, and 12 months of age). Contrary to Walker et al. (2010), our results indicated that 4- and 6-month-old infants actually preferred the rising/falling object when it was accompanied by falling/rising pitch (Experiment 1) and that when given a choice between these two events simultaneously, it was not until 12

months of age did a preference for rising/falling objects accompanied by rising/falling pitch occur (Experiment 2). In sum, our findings indicate that the ability to match changing visuospatial height with rising/falling pitch does not emerge until the end of the first year of life and throw into doubt Walker et al.'s (2010) claim that 4-month-old infants perceive audiovisual synesthetic relations in a manner similar to adults.

DEDICATION

This manuscript is dedicated to my loving parents, Jean and Jeff Minar.

INFANTS' PERCEPTION OF SYNESTHETIC-LIKE MULTISENSORY RELATIONS

INTRODUCTION

The world we live in is multisensory in nature and thus offers information regarding a given stimulus through many sensory channels. This multisensory quality of the world manifests itself through co-occurring and often redundant information that provides a developing human with a vast array of external sensory input. While all these multisensory cues are seamlessly integrated in mature individuals, developing infants must first learn which sensory events belong together. For example, how is an individual to know that the growing intensity of a car’s “honk” belongs to the convertible quickly approaching and not the bus traveling in the opposite direction? The ability to recognize multisensory relations allows developing infants to perceive coherent objects and events, regardless of what combination of sensory modalities specify them. A fundamental question is how does the ability to perceive multisensory relations, in order to form a coherent percept of our world, develop throughout the first year of life (Bremner, Lewkowicz, & Spence, 2012)?

Infants begin to perceive their world and the relations between its multisensory attributes by attending to non-arbitrary properties that describe an event through many sensory channels. Invariant amodal properties are one example of these non-arbitrary properties. Amodal properties specify equivalent multisensory information across more than one sensory modality; this type of information is conveyed uniformly across two or more senses but is specific to none. For example, stimulus intensity is an amodal property because it can be perceived equally in audition and vision, as when an individual hears and sees the intensity of fireworks during 4th of July celebrations. Sensitivity to amodal characteristics is acquired through sensory experience and perceptual differentiation, eventually leading a developing infant to pick up on the redundant, equivalent information across the senses. This redundant quality of amodal properties makes them one of the first types of multisensory attributes available to naïve infants (Gibson, 1969; Marks, Szczesiul, & Ohlott, 1986; Spence, 2011). Audio-visual intensity, a characteristic that is perceived and matched by infants three to four weeks of age, is believed to be one of the earliest amodal properties young infants become sensitive to (Lewkowicz & Turkewitz, 1980). Infants also use other amodal properties as perceptual scaffolds by six months of age, such as audio-visual phoneme perception (Kuhl & Meltzoff, 1982), object substance (Bahrick, 1983), and duration (Lewkowicz, 1986).

Despite these demonstrations of early sensitivity to amodal properties, there are a number of discrepant findings in the literature as well. For example, some researchers have found that infants can perceive visual-tactual shape equivalence from birth (Meltzoff & Borton, 1979) and display haptic memory with relation to an object's shape as early as two months of age (Lhote & Steri, 1998), while others have not found this to be the case (Maurer, Stager, & Mondloch, 1999). Furthermore, other researchers have found that the ability to match shape via haptic memory does not develop until later in life, more specifically, around 12 months of age (Gibson & Walker, 1984; Gottfried, & Rose, 1980). Similarly, experimental findings regarding infants' ability to perceive audio-visual equivalence based on temporal rate is also unclear, as some have reported the ability in 4-month-old infants (Spelke, 1979) while others have failed to find evidence of this (Lewkowicz, 1985, 1992a). These discrepant findings illustrate that while there are many amodal properties inherent to an infant's environment, and that they are used as early perceptual building blocks, not all are utilized equally or consistently. Additionally, even though amodal properties are abundant in our everyday experiences, they alone cannot fully specify our multisensory world.

Another non-arbitrary multisensory characteristic that young infants become sensitive to are typical relations (Walker-Andrews, 1994). Typical relations are natural multisensory co-occurrences that specify characteristics of an object, or event, which are naturally constrained by an object's properties, such properties can include: size, shape, weight, material, etc. (Walker-Andrews, 1994). One distinction between amodal properties and typical relations is that typical relations do not have to specify equivalent information across more than one sensory modality, merely a natural co-occurrence that is typically perceived across modalities. For example, the relation between the low-pitched impact sound of heavy objects and the high-pitched impact sound of light objects demonstrates this type of multisensory event (Walker-Andrews, 1994). The reason typical relations, like amodal properties, also act as an early perceptual building block for young infants is because they are quite abundant in our world. Developing infants have been shown to be sensitive to a number of typical relations throughout the first year of life, as demonstrated by 5-month-olds' detection of the relation between a looming object and its increasing loudness (Walker-Andrews & Lennon, 1985) and 6-month-olds' detection of the relation between the pitch of a speaker's voice and the gender of his/her face (Walker-Andrews, Bahrick, Raglioni, & Diaz, 1991). Findings such as these demonstrate that infants can perceive the relations between non-equivalent multisensory attributes by the middle of the first year of life, aiding in the identification of multisensory objects or events.

In addition to amodal and typical multisensory relations, an infant's world is also characterized by events that are specified by arbitrary multisensory relations. Arbitrary multisensory relations are co-occurrences that are not constrained by object properties and, therefore, are idiosyncratic by nature. Some arbitrary relationships are artificial, as opposed to naturally occurring, and can be learned by young infants after a few minutes of exposure. For example, newborns can learn to associate colored lines with spoken words (Slater, Brown, & Badenoch, 1997) and 6- and 7-month-old infants can learn to associate the pitch of an object's impact sound with the object's color (Bahrick, 1994) as well as associate the pleasantness of food with the color of the container holding the food (Reardon & Bushnell, 1988). The ability to learn multisensory relations such as these demonstrates infants' growing ability link arbitrary attributes of their world together, even before their multisensory integration capabilities reach adult levels in some areas, such as spatial localization (Neil, Chee-Ruiter, Scheier, Lewkowicz, & Shimojo, 2006).

Arbitrary relations that occur naturally can also characterize an infant's world. These natural but arbitrary relations are also idiosyncratic and linked to specific objects and events. For example, the pairing of an individual's face with his/her unique voice is an arbitrary pairing. The specific relation between an individual's face and voice is only established after both are experienced at the same time, a relationship that newborns (Sai, 2005) as well as 5-month-olds (Cohen, 1974; Spelke & Owsley, 1979) are sensitive to with adequate exposure. While most infant research is done using audiovisual stimuli, it is important to remember that our world contains other natural but arbitrary sensory relations that are readily perceived by infants, as demonstrated by 2-week-old infants' ability to perceive the relation between their mother's axillary odors and the sight of her face (Cernoch & Porter, 1985). Overall, these findings illustrate that developing humans are not limited to non-arbitrary relations, but are rather active perceivers of arbitrary relations as well, highlighting the importance of sensory experience and interaction with our world.

While infants have access to amodal, typical, and artificial relations to characterize their multisensory world, their perception of synesthetic and synesthetic-like relations is currently unclear. Synesthetic relations are perceived by a small proportion of the adult population and involve an automatic multisensory percept that is induced in response to a unisensory cue (Simner, 2010). For example, one of the most common instances of synesthesia is when a synesthete sees the written letter "A" and the extra-visual percept of the color red is induced (Simner, 2010). The experiential and developmental mechanisms for this induced multisensory perception are still unknown and, as previously mentioned, most of the adult population rarely experiences this true synesthesia. In contrast, many typical adults do perceive synesthetic-like relations. A synesthetic-like relation, unlike true synesthesia, is a type of percept that is automatically induced by multisensory stimulation that does not involve an extra percept; these relations are similar to arbitrary relations in that they lack natural constraints imposed by object properties. Synesthetic-like relations are defined as multisensory percepts that contain "directionality", or the perceived matching of one attribute with another; this gives the perceiver a sense that they "belong" or "fit" together (Melara & O'Brien, 1987). For example, a common synesthetic-like relation is the link between the auditory pitch produced by an object and it's corresponding visual height; adults typically perceive an association between high-pitched noises and objects high in visual space and also between low-pitched noises and objects low in visual space (Ben-Artzi & Marks, 1995;Melara & O'Brien, 1987;Pratt, 1930; Roffler & Butler, 1968). These multisensory relations are described as "congruent" or "incongruent" by the adult observer. These synesthetic and synesthetic-like relations contain no obvious environmental link and the mechanisms guiding their development are still not clear (Maurer, Gibson, & Spector, 2012; Spector & Maurer, 2009). Therefore, further investigation regarding infants' perception of synesthetic and synesthetic-like relations is warranted.

The perception of synesthetic-like relations has only recently been examined in developing infants by Walker et al. (2010). In this study, Walker et al. (2010) reported that 4-month-old infants, similar to adults, perceive the synesthetic-like relation between auditory pitch and visuospatial height and that they prefer congruent instances of this relationship; congruent instances being where the changing height of the visual display was accompanied by a sound whose changing pitch was congruent rather than incongruent (Walker et al., 2010). Because the infants in this study were relatively young, Walker et al. (2010) interpreted their findings as evidence that perception of these synesthetic-like relations is independent of sensory experience and that infant perception of synesthetic-like relations is innate. Ludwig, Adachid, & Matsuzawa (2011) made a similar argument based on parallel findings in non-human primates, stating that sensitivity to synesthetic-like relations is an evolved trait, independent of sensory experience. It should be noted, however, the belief that perception of these relations as innate is not universally shared. Some investigators attribute sensitivity to these types of relations to an experience-dependent, developmental process (Dolscheid, Hunnius, Casasanto, & Majid, 2012).

Lewkowicz (2011) has suggested that the evidence reported by Walker et al. (2010) does not support the conclusion that young babies are innately synesthestes, merely that infants can perceive a difference between what appear to be congruent versus incongruent synesthetic-like events. To support his argument, Lewkowicz (2011) points to previous studies that have presented similar stimuli and demonstrated that infants exhibit rather limited sensitivity to multisensory relations similar to those reported by Walker et al. (2010). For example, Lewkowicz (1992a) found that 4-month-old infants are able to make nonsynesthetic-like audio-visual matches on the basis of synchrony but not on the basis of temporal rate (Lewkowicz 1985; 1992a). Additionally, Lewkowicz (1994) found that infants showed only a limited ability to respond to temporal intersensory equivalence when using similar stimuli to those used in Walker et al. (2010). Overall, these findings illustrate that the ability to perceive different multisensory temporal relations emerges at different points in development after four months of age (Lewkowicz, 1992b). In light of these findings, the results of Walker et al. (2010) need to be further examined in order to determine how infant sensitivity to synesthetic-like relations develops.

Given the results of Lewkowicz (1985; 1986; 1992a; 1992b; 1994) and the recent results reported by Walker et al. (2010), it is important to first replicate Walker et al.'s findings and then extend them to determine how robust infants' response to synesthetic-like relations might be. Thus, the purpose of the current study was to accomplish both of these goals in two experiments. To replicate and extend the findings of Walker et al.

(2010), Experiment 1 examined whether 4-month-old infants can perceive the synesthetic-like relation between rising/falling pitch and changing visuospatial height using an identical single screen presentation but with stimuli that moved more rapidly than in the original study. We chose to use faster moving stimuli because, by definition, a synesthetic-like relation represents an automatic association and, thus, allows us to extend and test the robustness of Walker et al.'s (2010) claims. In case 4-month-old infants could not exhibit successful detection of the synesthetic-like relation, and to see if this ability changes over time, we also tested 6- and 12-month-old infants. This was based on the possibility that older infants might be more likely to perceive the synesthetic-like relation between visuospatial height and auditory pitch because previous research has demonstrated that infants older than six months of age can detect multisensory spatiotemporal illusory relations (Scheier, Lewkowicz, & Shimojo, 2003). To test the generality of Walker et al.'s findings, Experiment 2 utilized a multisensory paired-preference procedure to more explicitly examine infants' choice behavior. That is, here we measured infants' sensitivity to a synesthetic-like relation by requiring them to make an explicit choice between congruent and non-congruent audiovisual events. We expected that the results of these two experiments would replicate Walker et al.'s original findings at four months of age as well as demonstrate that older infants perceive synesthetic-like audiovisual relations (Experiment 1). Furthermore, we expected that infants of all ages would exhibit this ability in a forced-choice preference task (Experiment 2).

EXPERIMENT 1: EXTENSION OF WALKER ET AL. (2010)

Experiment 1 examined whether 4-, 6-, and 12-month-old infants can perceive the synesthetic-like relation between rising/falling pitch and changing visuospatial height using a single screen presentation method. This study was designed to replicate the procedure used by Walker et al. (2010) with the goal of finding that 4-month-old infants perceive the synesthetic-like relation between changing auditory pitch and visuospatial height and that they prefer congruent instances of this relation over incongruent instances. Additionally, this study differs from Walker et al.'s original because it included infants at two older age groups and presented faster moving stimuli.

Method

Participants

We tested a total of 73 infants in Experiment 1, with 24 infants at four months, 25 infants at six months, and 24 infants at 12 months of age. Only full-term infants with a birth weight of 2500 grams (5.5 pounds) or higher and a 5-minute APGAR score of 7 or higher were tested. All infants tested in this experiment were healthy during the time of testing.

Apparatus & Stimuli

One 17-inch computer monitor was used to display all test materials. All stimuli were created in Adobe After Effects and consisted of audiovisual movies presented in Windows Media Player. The movies consisted of a red ball bouncing up and down in front of a grid of small white dots on a black background. In half of the trials, a rising and falling pure tone was presented while the ball rose and fell (congruent trials) while in the other half, the same tone was presented while the ball fell and rose (incongruent trials). These stimuli were identical to those used by Walker et al. (2010) except that our stimuli moved twice as fast. Specifically, the duration of a single stimulus cycle (upward followed by downward motion) was 2.5 seconds in duration as opposed to 5 seconds in duration. Each animation was accompanied by the sound of a sliding whistle, whose fundamental frequency changed at a constant rate between 300 and 1700 Hz. Because this auditory stimulus accompanied the motion of the red ball, it changed pitch twice as fast as in the Walker et al. (2010) study. Additionally, the loudness of the sound also increased and then decreased between 54 and 80 dB within each phase of the animation.

Procedure

Testing took place in a dark, quiet, sound-attenuated booth. Each infant sat in an infant seat, or on the caregiver's lap, and viewed the computer monitor at eye-level from a distance of approximately 50 cm. This procedure was identical to that used in Walker et al (2010) and consisted of a presentation of three trials of each type, in an alternating fashion, for a total of six trials. Half the infants viewed the congruent trial first and half the incongruent first. Each trial had a maximum duration of 60 seconds but infants could terminate the trial if they looked away from the stimulus-presentation monitor for more than two seconds. An experimenter, who was blind with respect to the stimulus being presented, recorded the amount of time infants looked at each movie.

Results

Our aim was to extend and replicate the findings of Walker et al. (2010) by measuring the duration of looking directed at congruent and incongruent synesthetic-like events. At each age, raw looking times were first cleaned using the boxplot method of outlier detection as described by Cohen, Cohen, West and Aiken (2002). This method is an alternate approach that relies on the interquartile range (IQR) of infants' scores to detect outliers as opposed to the typical + 2 standard deviation method, which relies on the mean to detect outliers. The advantage of using the boxplot method is that it overcomes the problem of masking, which is the possibility of one outlier concealing the presence of another outlier, which can occur when using the mean as a measure of central tendency. Since infant data are inherently noisy and may contain multiple outliers, we felt the boxplot method was a more appropriate technique to measure central tendency and would provide a more accurate method of outlier detection. The boxplot method identified three 4-month-old infants whose data were subsequently removed and excluded from analysis, leaving a total N = 70 (4-month-olds = 21, 6-month-olds = 25, 12-month-olds = 24).

Next, a 2x3x3 mixed repeated-measures ANOVA was used to analyze infants' raw looking times, with trial type (congruent or incongruent) and trial pairs (1, 2, or 3) as within-subjects factors and age (four, six, and 12 months) as a between-subjects factor.

The ANOVA yielded a trial type main effect ($F(1, 67) = 4.074$, $p < .05$), a trial pairs main effect ($F(2, 66) = 121.810$, $p < .01$), and an age effect ($F(2, 67) = 10.217$, $p < .01$). The ANOVA also yielded a significant trial pair x age interaction ($F(4, 134) = 3.637$, $p < .05$). The results of Experiment 1 can be seen in Figures 1 and 2 and are broken down by looking time per trial or averaged across the study respectively. These findings indicate that there were effects of both trial type (congruent or incongruent) and trial pair (1st, 2nd, or 3rd), indicating that differences in looking time occurred as a function of both trial type and trial pair. Furthermore, the trial type x age interaction indicates that looking at the two types of stimuli differed as a function of age. Follow-up paired samples t-tests were then used to investigate these looking time differences on a trial-by-trial basis as well as averaged across the whole experiment.

The trial-by-trial comparisons showed that 4-month-old infants looked longer at the incongruent event ($M = 16.22s$, $SD = 13.26s$) than at the congruent event ($M = 10.45s$, $SD = 6.97s$) during trials 5 and 6 of the experiment ($t(21) = 2.256$. $p < .05$) and that 6-month-old infants looked longer at the incongruent event ($M = 17.15$ s, $SD = 14.83$) than at the congruent event ($M = 12.72s$, $SD = 9.33s$) during trials 3 and 4 of the experiment ($t(24) = 1.712$. $p < .05$; this is indicated by asterisks Figure 1). No other significant differences were found. Similarly, a comparison of mean looking times for each condition, respectively, across all trials indicated that 6-month-old infants looked significantly longer at the incongruent event ($M = 19.40s$, $SD = 8.63s$) than at the congruent event ($M = 15.66s$, $SD = 8.16s$); ($t(24) = 2.496$. $p< .05$). No significant results were found for 12-month-old infants. Taken together, the results indicate that by the end of the experiment, 4- month-old infants looked longer at the incongruent event while the 6-month-old infants looked longer at the incongruent event overall.

Discussion

We found in Experiment 1 that 4-month-old infants looked significantly longer at synesthetic-like incongruent events by the last trial and that 6-month-old infants looked longer at synesthetic-like incongruent events overall. These constitute novel findings regarding infants' multisensory abilities relating to the perception of changing visuospatial height and auditory pitch. Additionally, no significant results were found for the 12-month-old infants in Experiment 1. The claims made by Walker et al. (2010) that 4-month-old infants look longer at congruent synesthetic-like events is not supported by the current experiment, nor does their claim apply to older infants. The current results indicate that 4- and 6-month-old infants are sensitive to the relation between visuospatial height and auditory pitch but that this is the wrong relation from the standpoint of adults perceiving the same synesthetic-like events. The results of Experiment 1 do not shed light on whether or not a preference for congruent synesthetic-like events, as perceived by adults, even emerges by the end of first year of life.

EXPERIMENT 2: PERCEPTION OF SYNESTHETIC-LIKE EVENTS USING A MULTISENSORY PAIRED PREFERENCE PROCEDURE

Experiment 1 indicated that infants four and six months of age looked significantly longer at the incongruent synesthetic-like event, either during the last pair of test trials or throughout the entire study, respectively. While these results were unexpected, Lewkowicz's (2011) stated that a single screen test procedure may not be the best measure of infants' perception of synesthetic-like events. To further test the robustness of Walker et al.'s findings, Experiment 2 used a multisensory paired-preference procedure, which forced young infants to make an explicit choice between a congruent and incongruent synesthetic-like event. The procedure of this study was first proposed by Lewkowicz's (2011) and was deemed to be a more robust test of infants' perception of synesthetic-like audiovisual relations.

Method

Participants

We tested a total of 86 infants in Experiment 2, with 34 infants at four months, 28 infants at six months, and 24 infants at 12 months of age. Only full-term infants with a birth weight of 2500 grams (5.5 pounds) or higher and a 5-minute APGAR score of 7 or higher were tested. All infants tested in this experiment were healthy during the time of testing.

Apparatus & Stimuli

All stimuli and test materials were identical to Experiment 1 except that two side-by-side 17-inch computer monitors, with a speaker placed between them, was used during testing.

Procedure

The procedure was the same as in Experiment 1 except that infants viewed side-by-side images of two bouncing balls moving 180 degrees out of phase with respect to one another. Across the four trials (two silent and two in-sound), the initial direction of motion (upward vs. downward) alternated between each side. Each trial had a fixed length of 30 seconds. The first two trials consisted of the presentation of silently moving objects while the last two trials consisted of the presentation of these objects together with the whistle sound (playing from the speaker between the two monitors). Across the two in-sound trials, the sound corresponded to the object on each monitor, respectively. This way, the sound was “synesthetically congruent” with the bouncing ball on one monitor and “incongruent” with the ball on the other monitor. The initial direction of motion alternated between testing conditions, counterbalancing which side is congruent first across infants. Duration of looking at each monitor was recorded by a camera situated between the two monitors and coded offline by an experimenter

Results

The aim of Experiment 2 was to test for the perception of synesthetic-like audio-visual relations with a multisensory paired-preference procedure designed to require infants to make an explicit choice between a congruent and incongruent synesthetic-like event. Again, the raw looking times for each age group were cleaned using the boxplot method of outlier detection (Cohen et al., 2002). We chose to use the boxplot method on raw looking times for each age group because this would again overcome the problem of masking. We identified two 4-month-old infants whose data were subsequently removed and excluded from analysis, leaving a total of 84 participants, which included thirty-two 4-month-olds, twenty-eight 6-month-olds, and twenty-four 12-month-olds.

Next, we calculated the proportion-of-total-looking-time (PTLT) that each infant directed at the congruent stimulus in each trial. The PTLT score was obtained by dividing the duration of looking directed at the congruent stimulus in each trial by the total duration of looking at the congruent and incongruent stimuli. Then, we compared the PTLT scores for the congruent stimulus during the in-sound block and compared that to the PTLT score for the same event in silence. We used a 2x2x3 mixed, repeated-measures ANOVA to analyze these scores with trial within block (1st or 2nd) and sound condition (silent, in-sound) as within-subjects factors and age (four, six, and 12 months of age) as a between-subject factor. This analysis allowed a PTLT score to be obtained in response to each silent event which was then compared to the PTLT score obtained during the same event during the in-sound test trial; this allowed us to determine whether the presence of the congruent sound increased looking at the congruent event relative to looking at the same event in silence.

The ANOVA indicated that there were no main effects for trial or sound; this is likely due to the fact that proportion scores have inherently less variance than raw looking times. The results can be seen in Figure 3. Despite these findings, follow-up paired sample t-tests indicated that the 12-month-old infants looked in greater proportion at the in-sound congruent event (M = .579 PTLT, SD = .274) than the same event in silence (M = .469 PTLT, SD = .238) during the second trial of the in-sound block ($t(23) = 1.876$, $p < .05$). These results indicate that even though there were no age-related main effects in responsiveness as a function of trial or sound, 12-month-old infants looked in greater proportion at the audiovisually congruent event during the last test trial.

Discussion

Experiment 2 followed up on Lewkowicz's (2011) suggestion that a more robust test of infants' perception of synesthetic-like audiovisual relations would be one involving a paired-preference procedure that requires infants to make a choice between an audio-visually congruent versus incongruent event. The results from Experiment 2 indicated that neither 4- nor the 6-month-old infants exhibited any overall differences in looking at the congruent and incongruent events, a rather puzzling finding given the results of Experiment 1. Perhaps the increased complexity of the task, comparing two simultaneous bouncing objects as opposed to focusing on one, was too great a challenge for infants younger than 12 months of age and thus no explicit preference emerged. In contrast, the 12-month-old infants looked in greater proportion at the congruent synesthetic-like event during the last in-sound test trial. These results indicate that by 12 months of age infants exhibit a preference for what adults deem as congruent synesthetic-like events over the incongruent one. These findings suggest that the ability to perceive these types of audiovisual relations emerges by the end of the first year of life. These results also indicate that the preference for these types of multisensory relations emerges considerably later than at four months of age, as was reported by Walker et al. (2010). In addition, the preference only emerged by the second in-sound test trial and, thus, followed experience with two silent trials and one in-sound test trial.

GENERAL DISCUSSION

The present study attempted to: 1) replicate and extend the findings of Walker et al. (2010) using a single screen presentation and 2) to extend Walker et al.'s findings by testing infants with a paired-preference procedure that more explicitly assessed their ability to choose between a congruent synesthetic-like event over an incongruent one. Together, the results from both experiments demonstrated that infants respond differentially to certain types of synesthetic-like relations – in the present case the relation between changing visuospatial height and auditory pitch – but, overall, these results did not provide clear and systematic evidence that young infants can perceive such relations. Specifically, the results from Experiment 1 showed that 4-month-old infants looked longer at incongruent events by the end of the experiment and that 6-month-old infants looked longer at incongruent events throughout the experiment. It is puzzling why 4- and 6-month-old infants chose to look longer at the incongruent synesthetic-like events in our study but not in the study conducted by Walker et al. (2010). One possible reason for this can be found in the increased number of infant participants between the two studies. The original Walker et al. (2010) study tested only 4-month-old infants (N = 16) whereas our Experiment 1 (single screen presentation) tested a total of 70 infants (4-month-olds = 21, 6-month-olds = 25, 12-month-olds = 24), making it possible that their results were an artifact of small sample size and, thus, their findings do not reflect a robust phenomenon. Therefore, the results from Walker et al. (2010) and the claims that infant perception is innately synesthetic and that young infants prefer congruent synesthetic-like events to incongruent synesthetic-like events are not supported by the current findings. It is interesting to note that similar results of increased looking at incongruent synesthetic-like events have been reported in 4-month-old infants before, specifically on the linguistic mappings between the pointedness of an object and a concurrent auditory consonant-vowel pairing (Ozturk, Krehm, Vouloumanos, 2013). The consistency between our findings and those of Ozturk et al. (2013) is interesting and suggests that, despite the differences between the two studies, young infants may be sensitive to some aspect of this synesthetic-like relation, but not in an adult-like manner.

It is interesting that younger infants tested with the single screen procedure (Experiment 1) looked longer to the incongruent stimuli. One possible explanation for 4- and 6-month-olds' greater looking at the incongruent event could stem from a novelty effect, or an increased attention to new and unusual stimuli. More specifically, infants in the current study might display a novelty preference for stimuli not reflected in their prior experiences, such as the incongruent synesthetic-like relation between the visual motion of the ball and the auditory component of the whistle.

One possible source responsible for the formation of expectations regarding these synesthetic-like events may be found in infant-directed speech (IDS). For example, research has demonstrated that infant-directed speech is different from adult-directed speech in that it conveys varying melodic qualities and a distinct prosodic pattern (Fernald & Simon, 1984). This prosodic pattern consists of varying intonation contours and repetitive high-pitched tonal peaks that are reliably used to emphasize words and sentence boundaries for infants starting early in development and lasting through 14 months of age (Fernald & Mazzie, 1991; Fernald & Simon, 1984). Additionally, the prosodic pattern of IDS has been linked to specific behavioral co-occurrences that are demonstrated by the speaker, such as closer proximity to the infant, high repetitiveness of motion, and increased range of bodily motion (Brand, Baldwin, & Ashburn, 2002). Therefore, it is possible that young infants might be exposed to typical behavioral action patterns - such as head movements, bouncing, and the raising and falling of one's arms - that coincide with the rising and falling prosody of IDS; this type of repetitive exposure throughout the first year of life could result in experience with congruent synesthetic-like body movements. Previous research on infant perception of rhythm has already demonstrated that short-term vestibular and proprioceptive experience can influence young infants' preference for auditory rhythms (Philips-Silver & Trainor, 2005). Therefore, it is possible that IDS can influence young infants' preferences relating to synesthetic-like events. If this is the case, it is possible that 4- and 6-month-old infants look longer at incongruent events during the single screen presentation due to a violation of these expectations, otherwise known as a novelty effect. If infant-directed speech were one of the sources guiding young infants' surprise in Experiment 1, it would explain the longer looking to the incongruent event. Only by 12 months of age, after a year of infant-directed speech, might a clear preference for congruent synesthetic-like events emerge (Experiment 2).

Overall, the findings illustrate that 4- and 6-month infants can perceive a relationship between visuospatial height and auditory pitch in a test involving the presentation of a single event and that they look longer at what adults deem as incongruent stimuli. Unfortunately, these findings do not generalize to infants' performance in a test involving a forced choice between an audiovisually congruent and incongruent event. This may be due to the increase in task complexity. Furthermore, the results demonstrate that when given a choice between a congruent synesthetic-like event and an incongruent synesthetic-like event (Experiment 2) it is not until 12 months of age that infants exhibit a preference for the congruent stimuli. These findings lend support to the notion that a preference similar to those of adults does not emerge until late in the first year of life.

Our findings call into question the claim that infant multisensory perception is innately synesthetic and that infants prefer what adults deem as congruent synesthetic-like events before experience with them even occurs. Future research is needed to investigate why younger infants systematically look longer to what adults deem as incongruent synesthetic-like multisensory relations. Future research is also needed to investigate specifically how typical experience contributes to young infants' perception and preference for synesthetic-like relations, which will, in turn, contribute to the overall knowledge and understanding of young infants' perceptual capabilities and how they change over time.

FIGURES

Figure 1. Results from Experiment 1. Depicted are mean looking times for congruent and incongruent events as a function of trial for each age group. Asterisks indicate significant differences and error bars indicate the standard error of the mean.

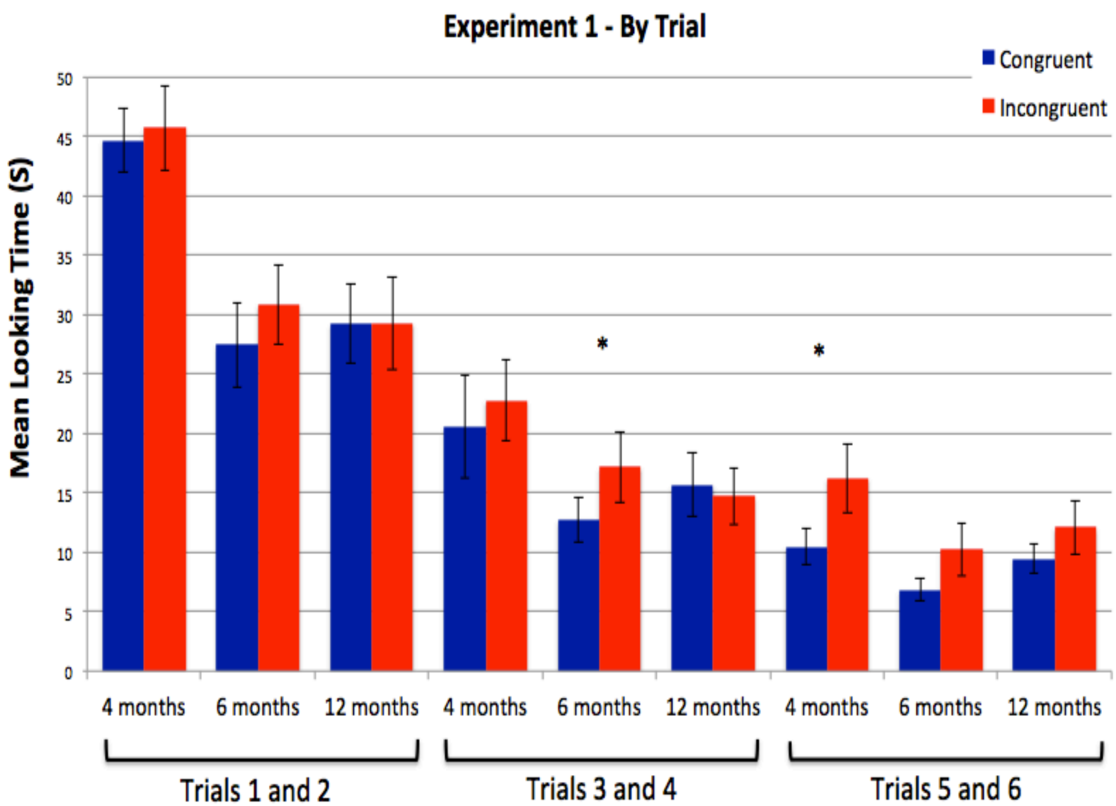


Figure 2. Results from Experiment 1. Depicted are mean looking times for congruent and incongruent events, collapsed across trials within blocks. Asterisks indicate significant differences and error bars indicate standard error of the mean.

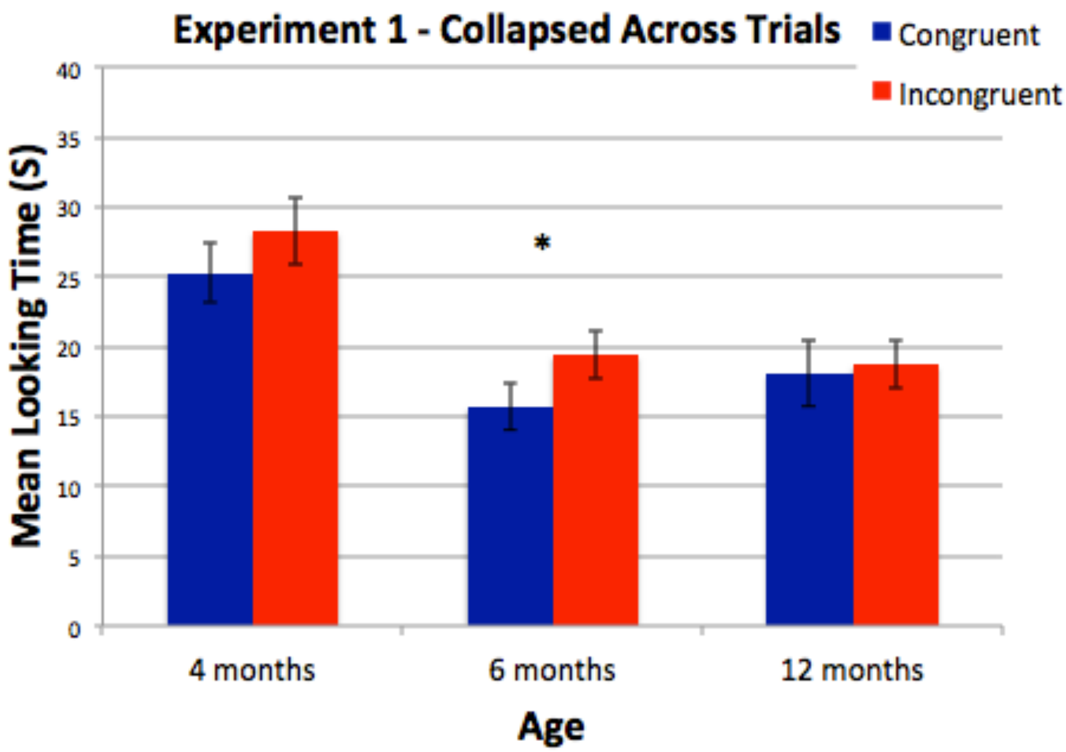
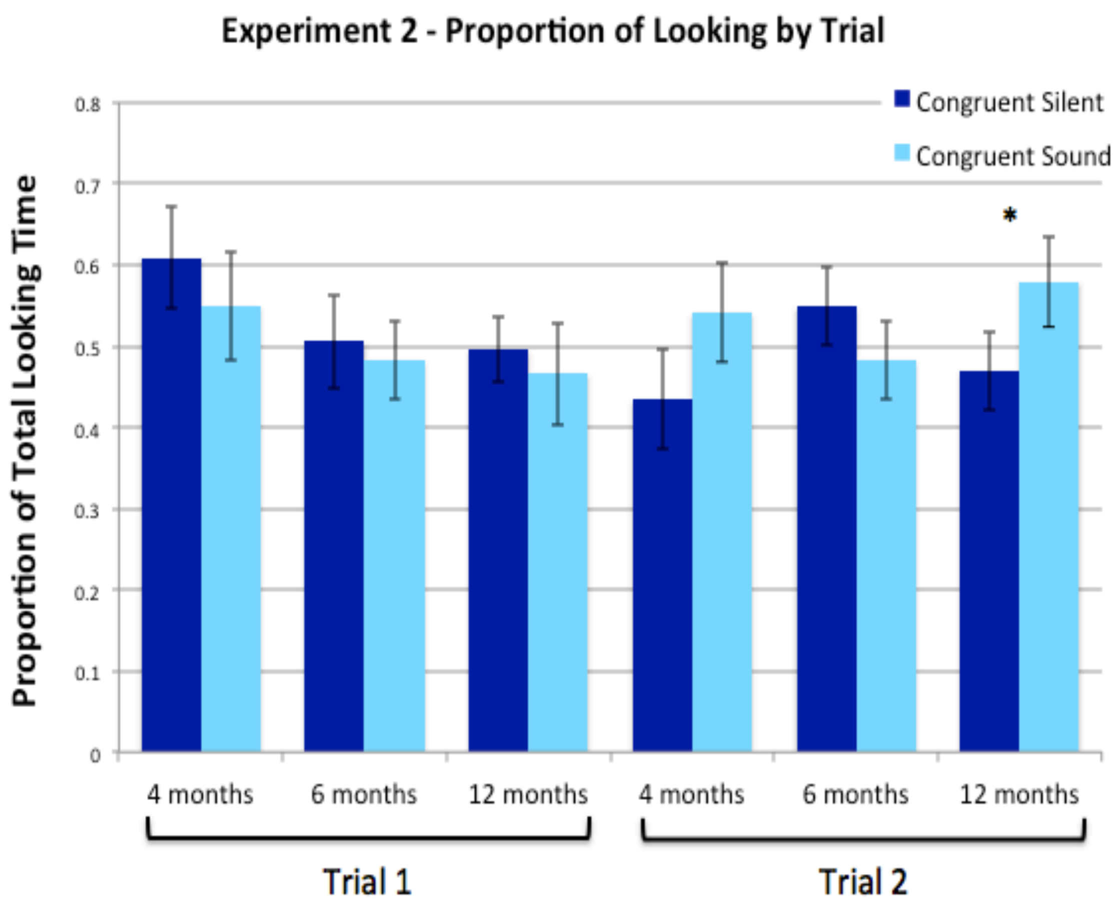


Figure 3. Results from Experiment 2. Depicted is proportion of looking time scores in response to the congruent visual stimulus in the silent and the in-sound trials as a function of trial. Asterisks indicate significant differences and error bars indicate the standard error of the mean.



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