

The environment of young infants is replete with multimodal nonsocial and social events. Nonsocial activities occur whenever the infant views or manipulates objects within their immediate context. For example, infants shake rattles, roll or bounce balls, and push and pull blocks. Social activities include face to face interactions with caregivers, such as during feeding, diapering, bathing, and simple verbal and nonverbal communication. All of these interactions with different objects and people can entail a combination of visual, auditory, tactile, vestibular, and proprioceptive stimulation, affording the infant different pieces of information regarding the world around them. For example, when an infant shakes a rattle, it provides auditory, visual, and proprioceptive information. Similarly, when an infant encounters another person (e.g., the caregiver), multiple modalities detect and process aspects of their social intercourse. Recent research dealing with infant intersensory perception (Bahrick & Lickliter, 1998; Lewkowicz, 1996; Lewkowicz & Lickliter, 1994; Walker-Andrews, 1997) has emphasized the complexity of stimulus events, individual experiential histories, and experimental methodologies. The goal of the current proposal was to investigate infants' ability to perceive complex multimodal events using two dissimilar testing methodologies. More specifically, this research examined infants' discrimination of specific auditory manipulations within the context of two dynamic facial displays. Additionally, this research investigated infants' capacity to discriminate changes in the temporal relations between visual and auditory sensory information (i.e., face and voice).

Over the last 20 years many researchers have examined infants' intersensory perception using a variety of methodologies. Walker-Andrews (1997) presented a comprehensive review of infants' intersensory perception as it relates to social interactions. She was particularly interested in how infants perceive affective expressions early in their development. For example, when infants encounter their caregivers, they will see, hear, smell and feel similar sensations across interactions. Every perceptual cue may help them identify who is familiar and who is unfamiliar. Research has provided diverse empirical evidence of infants matching faces and voices on the basis of voice-lip synchrony (Dodd, 1979; Spelke & Cortelyou, 1980; Walker, 1982), multimodal affective expressions including happy, sad, neutral, and angry (Walker, 1982; Walker-Andrews, 1986), and gender of the speaker (Walker-Andrews, Bahrick, Raglioni, & Diaz, 1991). Infants as young as 4 months of age can utilize facial and vocal cues in their perception of social interactions. Overall, infants in their first year of life appear to be relatively efficient at perceiving social cues early in their development.

Although infants use a variety of cues in their perception of events, they seem particularly sensitive to those of a temporal nature. For example, empirical findings indicate that young infants are able to integrate auditory and visual inputs on the basis of temporal synchrony (Bahrick, 1987, 1992; Lewkowicz, 1986, 1992; Spelke, 1979). When 2-month-old infants were shown side-by-side visual displays of balls bouncing out of phase with one another, they preferred to look at the display that matched a soundtrack being played at the same time (Lewkowicz, 1992; Spelke, 1979). Thus, infants appear to be sensitive to the intersensory timing across modalities. In support of this argument, Lewkowicz (1992) found that infants who were habituated to a synchronous auditory-visual event exhibited recovery of the habituated response when the synchrony was disrupted, even though the events themselves were held constant.

In sum, researchers have amassed a great deal of experimental evidence showing infants' diffuse intersensory capabilities (i.e., auditory and visual perception). They have found that most infants exhibit an ever-broadening repertoire of intermodal perceptual skills over their first year of life. Despite this amassing developmental knowledge, researchers have continued to struggle in their search for an adequate theoretical rationale to explain *how* infants acquire various age-related perceptual milestones. For example, researchers often fail to agree on the particular role of internal or external sources of stimulation. Infants' behaviors can be affected by internal factors such as level of motivation or state of arousal, and infants may respond to external demands such as the presence of other infants or specific stimulus characteristics (i.e., amount, intensity, color or size).

Collectively, past intermodal research has provided insight into infant intersensory perception by allowing researchers to identify specific aspects of multimodal stimulation that influence infant attention and behavior in particular testing situations. However, investigations of intersensory perception have tended to overlook: (1) an examination of both modality-specific as well as amodal (i.e., perceptual information that is available in more than one modality, like synchrony) display features, (2) an appreciation of the developmental history of the sensory system(s), and (3) a clear enunciation of the task and/or contextual demand characteristics. Given that infant intersensory perception depends upon the nature of the stimulation, relative experience of the organism, and the current context, researchers seeking to identify necessary or sufficient aspects of the stimulation (i.e., unimodal or cross-modal input) that direct infant

attention and/or behavior in particular situations need to appreciate the changing nature of infant intersensory development both within and across sensory systems.

### **Infants' Intersensory Perception**

The extensive research of David Lewkowicz has examined infant intersensory perception using infants of various ages, multiple stimulus arrays, and specific testing procedures (Lewkowicz & Turkewitz, 1980; for a review see Lewkowicz 1994). In order to elucidate the complex nature of infants' attention to multimodal events, Lewkowicz has examined the competing role of auditory and visual stimulation. His early work on infant intersensory perception involved presenting infants with stationary and flashing checkerboards (Lewkowicz, 1985; 1988a; 1988b) and pulsing soundtracks (e.g., tones). More recently, Lewkowicz has shifted to more ecologically relevant multimodal displays, such as dynamic human faces (1996a; 1998). Essentially, Lewkowicz's research has examined how the developmental history of the infant and the specialization of the various sensory systems influence infants' attention to competing sensory input (e.g., visual and auditory).

Lewkowicz's (1988a, 1988b) initial work on the role of auditory and visual stimulation in multimodal contexts tested infants' attention when stimulation in the auditory modality competed with input from the visual modality. Using a fixed trial habituation design, infants 6- and 10 months of age were given 12 trials with a compound stimulus whose auditory and visual components were concordant in rate (habituation phase). The compound stimulus involved two relatively stationary displays, a flashing checkerboard (no movement) and a pulsing sound (little change over time).

The test trials were made up of compound stimuli that differed in the rate and/or duration at which the visual, the auditory, or both components were presented. Lewkowicz found that the 6-month-olds exhibited 'auditory dominance' in that they discriminated all auditory changes, but consistently failed to respond to changes in the visual component alone. In contrast, the 10-month-olds responded to changes in visual information as well as auditory information.

Although Lewkowicz's (1988a, 1988b) findings support the view that infants' discrimination of changes in auditory information reflects the earlier functional maturation of the auditory system, there are a number of other possible explanations as well. For example, the visual modality is organized to detect movement right from birth and infants are more responsive to moving displays than to spatially-static ones (see Lewkowicz, 1994 for brief review). Therefore,

Lewkowicz's selection of a flashing checkerboard display may have failed to adequately measure infants' visual processing capabilities.

Consequently, Lewkowicz (1992) repeated his previous series of experiments (fixed trial), but instead of the flashing checkerboard, he used a 'bouncing' green disc. Every time the disc reversed trajectory (i.e., bounced) at the bottom of the video screen, the infant heard a punctate sound. The infants were presented with 12 habituation trials and three different test trials: one where the rate at which the object bounced changed (visual alone), one where the rate at which the sound occurred changed (auditory alone), and one where the rate at which both the object and the sound were changed. In contrast to his earlier findings, Lewkowicz (1992) found that the infants were equally responsive to both the visual and the auditory changes, even as young as 2 months of age. Moreover, the infants responded more to the visual component than to the auditory component, which is opposite of what would be predicted from an auditory dominance perspective.

The conflicting results in Lewkowicz's two sets of studies shows the importance of a researcher's selection of necessary or appropriate stimuli (Gottlieb, Wahlsten, & Lickliter, 1998). When Lewkowicz changed the visual display from a motionless checkerboard to a moving green disc, it affected infant perception in that they attended to the two multimodal displays in unique ways. This led Lewkowicz (1992) to propose that infants' perception of multimodal events is dependent on the specific type of stimulation available in each modality and the specialization of the particular modality participating in the response (i.e., experiential history).

In more recent investigations into infant intersensory perception, Lewkowicz (1996a, 1998) has employed his standard fixed trial design to a socially relevant multimodal event, a human face. When infants encounter a human face, it is often accompanied by vocal input. In his investigations involving the human face, Lewkowicz sought to examine infant responsiveness to amodal and modality-specific cues. Amodal aspects of the human face include synchronous movement of the lips and variations in the voice, equal duration of lip opening and sound production, and overall head movement and voice intonation pattern (Lewkowicz, 1996a). Modality-specific cues include facial features such as hair and skin color, lip configuration, and eyebrow position. Furthermore, auditory-specific features such as pitch, timbre, and overall linguistic content can specify the human voice.

The initial series of investigations (Lewkowicz, 1996a) involved habituating infants to a video of a human face reciting a prepared script (visible and audible). Then, infants were tested by changing aspects of the auditory soundtrack, visible image, or both. During the habituation phase, each infant watched and listened to a recorded segment of an actor reciting a prepared script as if reading it to another adult (i.e., adult-directed speech). Then, the infant was given three test trials to determine to which aspect of the face and voice he or she had attended. The auditory test trial consisted of the familiar face paired with a novel voice uttering a different script. The visual test trial consisted of a novel face paired with the familiar voice uttering the familiar script. Finally, the combined test trial involved the presentation of a novel face and a novel voice and script. Both unimodal tests examined infants' abilities to discriminate modifications within a single sensory channel (i.e., face change or voice change). However, once an individual sensory channel was modified it created an asynchronous and mismatched pairing of various facial and vocal information. That is, there were different scripts uttered by the actors' lips and the corresponding voices. In contrast, the bimodal test trials examined infants' ability to discriminate changes in both modalities concurrently (i.e., novel face and voice) with no violation of synchronicity. Because Lewkowicz (1996a) wanted to perform a developmental analysis of infant intermodal perception, he tested infants of three different ages (4, 6, and 8 months of age). This enabled him to detect possible experiential or age-dependent changes in intersensory coordination.

The findings of Lewkowicz's (1996a) first two experiments supported his previous results with dynamic visual displays ("bouncing" discs). That is, the infants exhibited visual dominance across the three separate test trials. More specifically, all the infants failed to respond to changes in the auditory modality, despite the manipulations involving speaker gender in the second experiment (i.e., female voice to male voice). The two older age groups did, however, discriminate the changes in the both the visual (i.e., face to face) and bimodal test trials. These findings are surprising given the fact that (a) the lexical-syntactic content of the script changed, (b) speaker identity changed, and (c) the vocal and visual aspect of the face became desynchronized. Consequently, Lewkowicz (1996a) suggested that his selection of procedure and speech type (i.e., adult-directed) could have been insensitive to infants' auditory abilities. Thus, in his third experiment Lewkowicz decided to use what is known as infant-directed (ID) speech.

ID speech is the characteristic speech adults often utilize when conversing with infants or toddlers. It differs from adult-directed (AD) speech in that it is higher in pitch, has a wider pitch range, and has smooth and modulated pitch contours (Fernald & Simon, 1984; Papousek, Papousek, & Bornstein, 1985). In addition, ID speech is usually made up of shorter speech segments, longer between utterance pauses, and greater prosodic repetition (Fernald, 1985; Snow, 1977; Stern, Spieker, & MacKain, 1982). In studies in which infants are given the choice of hearing ID or AD speech, they often choose to hear ID speech (Cooper & Aslin, 1990; Fernald, 1985; Papousek & Papousek, 1981; Werker & McLeod, 1989).

In Lewkowicz's (1996a) third experiment he tested infants' intermodal perception of ID and AD speech using two groups. The first involved habituating infants to multimodal ID speech and testing them with multimodal AD speech. The second group of infants received just the opposite (i.e., AD first, ID second). To accentuate the difference between the ID and AD speech Lewkowicz had a female actor recite the ID conditions and a male actor recite the AD conditions. Werker and McLeod (1989) found that female actors speaking in the ID style elicited greater affective responsiveness than did the male actors. Therefore, the infants were tested with the "greatest possible difference in type of speech" (Lewkowicz, 1996a, pg. 358).

The overall procedure in the third experiment was the same as the procedure utilized in the previous experiments (i.e., fixed trial habituation and testing phases). The findings for the ID-AD group supported previous results with ID speech (Pegg, Werker, & McLeod, 1992). That is, all the ID-first infants spent a greater amount of time looking during the habituation phase when compared to the AD-first group. However, both the 4- and 6-month old infants failed to exhibit a decrease in their attention to the multimodal ID. That is, they were unable to completely habituate to the ID audio-visual display. Consequently, none of the 4- and 6-month-olds discriminated the visual, auditory, and combination test trials. Lewkowicz (1996a) suggested that the greater attractiveness of the ID speech might have made it more difficult for the infants to respond to any of the manipulations in the test trials.

The results of the AD-ID group stand in sharp contrast those of the ID-AD group. All three age groups were able to discriminate the visual and combination test trials, and the 6- and 8-month-olds exhibited a significant recovery in the auditory test trial. In addition, a secondary analysis indicated that, compared to the auditory test trial, infants in all three age groups looked longer during the visual and audio-visual test trials. Lewkowicz (1996a) suggested that these

findings provided additional support for the dominance of the visual modality in infants' intermodal perception of a dynamic multimodal display, particularly at younger ages. A second major finding in the AD-ID experimental group involved the auditory test trial in the two older groups of infants. The 6- and 8-month-olds in the AD-ID group were the only infants across all three studies that discriminated the vocal change.

In review, Lewkowicz's (1988a, 1988b, 1992, 1996a) findings suggest a specific developmental progression in infants' multimodal perception of ID speech. Initially, infant responsiveness seems to occur to the combined audio-visual characteristics of ID speech. Then, infants appear to become sensitive to the visible modifications alone (i.e., head and lip movement). Lewkowicz (1996a) suggested that the motion of the face and head itself might direct infants' early perception to ID speech. Lastly, infants develop the ability to differentiate the audible component of multimodal ID speech.

More recently, Lewkowicz (1998) has found additional support for this developmental model of ID speech perception. In two systematic studies, Lewkowicz tested 3-, 4-, 6-, and 8-month-olds using the fixed trial procedure. During the habituation phase, all the infants heard AD speech (female AD-experiment 1, male AD-experiment 2). Then, in the testing phase every infant heard female singing. Singing is characteristically similar to ID speech because it involves exaggerated rhythms, pitch contour patterns, and stress patterns (Trehub, Trainor, & Unyk, 1993). In fact, singing may contain even more exaggerated prosodic patterning than ID speech (Lewkowicz, 1998).

Once again, the findings supported his predictions regarding multimodal speech perception. All the infants exhibited a recovery in the visible and combination test trials, and every age group except the 3-month-olds (in the first experiment) successfully discriminated the auditory change from AD speech to female singing. Thus, the addition of gender as a discriminative cue made the auditory change salient even for the 3-month-olds (in the second experiment). Research on infants' perceptions of gender-related audio-visual characteristics highlights the pervasiveness of gender as a significant discriminatory cue (Jusczyk, Pisoni, & Mulleniz, 1992; Walker-Andrews, Bahrick, & Diaz, 1991). This led Lewkowicz to suggest that the combination of gender and prosody change (in experiment two) may have allowed even younger infants to make a successful auditory discrimination.

### **Issues involving Lewkowicz's Research**

Although the above presentation reflects a systematic program of research, there are several reasons to question Lewkowicz's developmental model regarding infants' intermodal perception of ID speech. The first major issue involves Lewkowicz's (1996a, 1998) method regarding how to habituate infants to complex multimodal displays (i.e., the fixed trial procedure). Infants have no control over the duration of stimulus presentation in the fixed trial procedure, and this lack of control highlights a critical flaw in producing habituation (Haaf, Smith, & Smitley, 1983; Horowitz, 1974; Millar & Weir, 1995). Infants in fixed trial procedures often have their looks shortened by the standardized offset of the experimental display (Miller & Weir, 1995). That is, infants who are focused on the display at the end of the trial get cut-off when the display terminates resulting in an underestimated looking time. In addition, the fixed trial habituation procedure limits the number of trials received by individual infants, essentially assuming that all infants habituate within the same number of exposures.

Horowitz (1974) discussed the drawbacks associated with fixed trial habituation procedure and suggested a possible alternative design, infant-controlled habituation. In her original work on infant visual attention Horowitz noticed that infants exhibited differential patterns of looking. Some would gaze at the stimuli at the end of the trial only to be cut-off and others would only take many short glances before deciding to fixate for an extended period of time. Therefore, Horowitz and her colleagues decided to leave the stimulus on for only as long as each infant looked at it (Horowitz, Paden, Bhana, & Self, 1972). They found two interesting findings: infants exhibited long looks, and there was a greatly reduced percentage of subject loss.

Infant control habituation procedures allow individual infants to manage the duration of stimulus exposure. Moreover, this procedure permits researchers to bring every infant to the same level of response decrement (Horowitz, 1974). The classic infant control design involves using each infant's first several looks as the standard for level of habituation (response decrement) for that infant. The initial two or three trials are averaged to provide the standard comparison looking time. Subsequent looks are then compared to this average length of fixations. Once the infant drops below 50% of the original average looking time, it is said that the infant has "habituated".

As such, Lewkowicz's designs may have underestimated infants' actual intersensory perceptual capabilities. Habituation procedures require that infants receive enough exposure to



become familiar to the particular display. Lewkowicz's studies, however, involving infants' multimodal perception of ID and AD speech (1996a, 1998) did not allow infants to exhibit equal rates/amounts of habituation (i.e., response decrement). Some infants may not have had adequate time to process aspects of the stimulus displays. One goal of the current study was to partially replicate Lewkowicz's (1996a) results using an infant-controlled habituation procedure.

The second and potentially much more important methodological issue involved with Lewkowicz's (1996a, 1998) research on multimodal speech perception involves a specific temporal relation, synchrony. If you recall, infants were presented with a display of an actor reciting a pre-prepared script (i.e., a matching face and voice). Then, in the testing phases infants' were given trials that consisted of modifications of the auditory input, visual input, or a combination of the two. The critical test trials, in terms of synchrony, involved the manipulations in only one modality. These unimodal test trials caused the movement of the face and lips to be out of synchrony with the vocal input, because neither sensory channel matched the other.

According to Lewkowicz (1994), synchrony plays a role in subsequent sequential differentiation of infant responsiveness to other temporal features such as duration, rate, and rhythm. Thus, synchrony is the primary amodal cue guiding infants' initial intermodal perception of complex events. Consequently, looking back at Lewkowicz's multimodal speech research, it is possible that infants' failure to discriminate the unimodal test trials can be explained by the lack of intersensory redundancy (Bahrick & Lickliter, 1998). The intersensory redundancy hypothesis posits that young infants will exhibit differential attention to sensory information presented bimodally. More specifically, Bahrick and Lickliter (1998) suggested that information presented concurrently (i.e., synchronously) in two sensory modalities selectively directs infant attention and perceptual differentiation to the amodal properties prior to information presented in only one modality. In a series of elegant studies, Bahrick and Lickliter tested 5-month-old infants' ability to discriminate changes in rhythm when presented either bimodally and unimodally. The findings indicated that when the rhythm was presented concurrently in the auditory and visual modalities it was differentially attended and discriminated but when it was presented in only one sense modality it was relatively neglected and was not discriminated.

According to Bahrick and Lickliter (1998), when perceptual information (i.e., rhythm) is presented bimodally it: 1) causes amodal properties to become “foreground”, 2) leads to preferential perceptual processing and learning of bimodal properties prior to other unimodal properties, and 3) allows for coordinated perception when infants simultaneously process visual, auditory, or tactile stimulation in unitary objects and events. Therefore, infants’ intersensory processing may help them to perceive complex events more efficiently and accurately. In particular, it allows them to perceptually differentiate redundant amodal properties prior to modality-specific stimulus properties such as color and pitch.

Consequently, when the infants in Lewkowicz’s (1996a) studies failed to notice or respond to the changes in synchrony on the visual and auditory only change trials, they also may have missed the opportunity to abstract the redundant intersensory information. Recent research has demonstrated that infants detection of amodal relations leads to more advanced intermodal learning of certain arbitrary relations (Gogate & Bahrick, 1998). For example, arbitrary relations between an object and its verbal label are first learned only when they are perceived in synchrony (i.e., movement and vocal display, Gogate & Bahrick, 1998). The second goal of the current study was to systematically examine the ability of synchronicity to modify infants’ discrimination of changes in vocal information when attending to a multimodal display.

In sum, the current set of experiments investigated 4-month-olds infants’ abilities to discriminate specific auditory and temporal manipulations (e.g., speaker voice and synchronicity) using an infant controlled habituation procedure (Experiment 1) and a fixed trial procedure (Experiment 2). All the auditory test trials in both studies were presented either in synchrony or out-of-synchrony with the speaker’s corresponding facial movements. The infant controlled habituation procedure was expected to be more sensitive to infants’ individual variability in looking patterns (Horowitz, 1974) and reveal infants’ attention to adult speech in a multimodal context. In addition, infants were expected to show greater looking times to changes in auditory information on the synchronous test trials when compared to the asynchronous test trials due to the redundant sensory information (Bahrick & Lickliter, 1998).

### Experiment 1

This first experiment tested 4-month-olds’ perception of changes in vocal information using dynamic audio-visual displays and an infant controlled habituation procedure. Every infant was habituated to an adult face (male or female) reciting a section from a popular

children's book, *Santa Mouse*. One group of infants was habituated to an adult male face and voice (AD speech) and the other was habituated to an adult female face and voice (ID speech). Following the habituation phase, all the infants were presented with either synchronous or asynchronous test trials. For example, following habituation to the male audiovisual display, the first group of infants viewed a test tape containing the familiar man's face paired with an unfamiliar woman's voice reciting the same rhyme in ID speech. Half of these infants received a test trial in which the man's face (e.g., lip movements) and the woman's voice were in synch, while the other half received them out of synch. Given the greater sensitivity of the infant-controlled procedure, it was hypothesized that both groups of infants would exhibit significant response recoveries to the changes in the auditory soundtrack (a main effect for test trial). Moreover, this response recovery was expected to be more robust when it involved the synchronous test trial (a test trial x condition interaction).

## Method

### Participants

Twenty 4-month-old infants participated in Experiment 1 ( $M = 129.3$  days,  $SD = 6.1$ : fourteen females and six males). The data of eight additional infants were eliminated from the study (three for excessive fussiness, four for equipment failures, and one infant fell asleep). The parents of these infants were recruited for participation through birth announcements in the Roanoke Times and World News. Upon receipt of the birth announcements, the parents were sent a letter describing the study. A few days after the letter was mailed the parents were contacted by phone to see if they were interested in having their infant participate in the study. Demographic information was obtained from each parent via a questionnaire given on the day of testing. The demographics of the final sample were as follows: 100% were white/Caucasian; 100% were from married homes; 80% were delivered vaginally; 80% were breast-fed; and 45% were first born. The average age of the infants' mothers was  $M = 31$  years,  $SD = 5.70$ ; the combined formal education level of the infants' parents was  $M = 8$  years post high school,  $SD = 4.71$  years; the average combined household income of infants' parents was  $M = 53,000$  dollars,  $SD = 24,000$  dollars.

### Audiovisual displays

There were six audiovisual recordings used in this experiment, two for the habituation phase and four for use in the testing phase. All the videotapes were made using a Sony Hi8

video camera (model CCD-TRV72) and an Adobe Premiere 5.0 video editing computer program on an IBM PC 300 PL. In addition, all the audiovisual editing was performed with a Panasonic editing controller (model AG-A770P), a Panasonic digital audiovisual mixer (model WJ-MX12), and a professional/industrial Panasonic videocassette recorder (model AG-7750). The two recordings used in the habituation phase consisted of a male and a female actor reciting identical segments from a children's text (*Santa Mouse*). Past research (Lewkowicz, 1998; Werker & McLeod, 1989) has found that infants are particularly responsive to vocal manipulations involving gender and speech style. Consequently, the design of this experiment included a female actor who spoke in an ID style and a male actor who spoke in an AD style.

The two habituation tapes contained matching visual and auditory stimuli (e.g., female ID face + female ID voice). The four test recordings, however, contained manipulated audiovisual pairings. The infants habituated to the female ID tape received the familiar female ID face paired with the novel male AD voice (either in synchrony or out of synchrony). Similarly, the infants habituated to the male AD tape received the familiar male AD face paired with the novel female ID voice (synchronous or asynchronous).

All the test tapes were constructed within an Adobe Premiere 5.0 video editing computer program, which allowed the researcher to manipulate the exact timing of the auditory and visual displays. To create the synchronous test tapes both speakers recorded a second soundtrack of their ID and AD nursery rhyme while viewing their own as well as the other speaker's videotape and synchronizing their style of speech to the corresponding lip movements of each. That is, they matched (in real time) the periods of voicing and non-voicing with the mouth movements of themselves and the other speaker. Consequently, all changes in the vocal input matched the corresponding lip and mouth movements to preserve the infant's perception of temporal synchrony (Lewkowicz, 1994, 1996b).

The synchronous test tapes were created by lining up the matching and appropriate soundtrack with the "new" unfamiliar recordings both visually (i.e., on the computer screen) and with special markers placed at the specific periods of voicing and nonvoicing presented in the video portion of the familiar face. That is, every utterance was matched up with the familiar actor's facial movements corresponding to each segment of the text (i.e., whenever the actor's mouth opened and closed). In sum, these "temporal" procedures helped to insure that any recovery in looking time by the infants' receiving the synchronous test conditions actually

related to the auditory manipulations per se and not their sensitivity to the absence of amodal intersensory characteristics such as synchrony, rate, or duration.

The asynchronous test tapes were constructed in much the same way, minus the second synchronous auditory recording. Each familiar visual display was paired with the second actor's vocal soundtrack; however, the second actor's recording was at a different point in the script. That is, the actor's lip and head movements failed to correspond to the periods of voicing and non-voicing. These audio-visual displays were separated by an average of 5 seconds.

### Apparatus

Infants were tested while sitting on their parent's lap in the experimental room. The parent was seated in a chair facing a black wooden 3-sided enclosure (80-cm (length) X 80-cm (width) X 60-cm (height)). To the parent's right and rear was a white wall, and to his/her left was a black covering (piece of cardboard). This covering served to restrict the infant's peripheral view. Separating the parent and the infant from the front panel was a 40-cm X 80-cm wooden shelf painted black and covered with a white foam pad. This shelf provided the infant with support and a safe to place to touch during the experimental session. A 27.5 cm by 21 cm television monitor (RCA model E13209 BC) was positioned behind an opening in the front panel of the enclosure offset 7.6 cm to the right of midline, approximately 35 cm away from the infant. A small speaker (Jamo compact 60) was located directly below the television screen. A video camcorder (Panasonic model AG-180) was also behind the front panel with its lens positioned behind a hole (3.5 cm radius) in the front panel. The camcorder recorded the infants' responses and provided a view of each infant to an observer.

The observer utilized a Power Mac 7100/80 computer to control the presentation of the audiovisual stimuli, time between stimulus presentations, and store the length of infant visual fixations. The observer controlled the presentations of the visual display, the speech recordings, and recorded individual looking times via a hand-held microswitch attached to the computer. Attached to this computer was also a custom-built control board and two videocassette player/recorders (Sanyo model VHR-5214; Panasonic model AG-1960). All the videotapes of the male and female actors were played on one of these two VCRs and were presented via the television monitor to the infant. The audio output was sent through an amplifier (Harmon-Kardon model PM635) and presented through the panel speaker at 70-75dB SPL (A-scale;

measured at the infant's head) as determined by a sound-level monitor (Radio Shack, Cat. No. 33-2050).

The observer was deafened by continuous, loud vocal music (delivered over headphones) and viewed the infant on an 11.5 cm X 9 cm television monitor (Sony Solid State model 21 CFR) during testing (this monitor was connected to the camcorder which broadcasted the infant's face). A small red light in front of the observer (attached to the top of the monitor) indicated when the infant's visual display was on.

#### Procedure and design

The procedure selected for this experiment was a modified version of the infant-controlled habituation procedure (Horowitz, 1974). Once the infant was judged to be awake the habituation phase of experimental testing began. The first trial started when the observer judged that the infant was looking at the television monitor and signaled the computer by pressing a button. Half of the infants were habituated to the male display, whereas the other half were habituated to the female display. Each infant's mean looking time to the video screen across the first three trials was computed and stored by the computer for later reference. This mean looking time was then compared to the average of every three consecutive trials. When this 'running' average dropped to 50% or less of the mean of the first three trials, the habituation criterion was met.

Following habituation, all of the infants (i.e., male-first and female-first) received two no change post-habituation trials (hereafter called lag trials) to allow for the assessment of spontaneous regression effects (Bertenthal, Haith, & Campos, 1983). Because infants often exhibit attention patterns in which long looks follow short looks or vice versa, changes in infant looking time may be unrelated to the change in the stimulus. If this were the case, infants could look longer on the lag trials even though the auditory stimulus did not yet change. Following the two lag trials each infant received four test trials to assess visual recovery using one of the test tapes. Infants habituated to the female ID tape received the familiar woman's face paired with a synchronous or asynchronous male voice. Likewise, the infants habituated to the male AD tape received the familiar man's face paired with a synchronous or asynchronous female ID voice. The dependent variable was the total amount of looking time during each test trial. Trained observers recorded infants' visual fixations by initiating all trials when the infant fixated on the monitor and terminating the trials when the infant looked away.

### Analyses

Initial analyses were conducted to examine infants' looking times during the two additional trials before the vocal manipulation (i.e., lag trials) to determine if infants exhibited any spontaneous regression effects. Therefore, the mean looking times of the last two trials (pre 1-2) during which the infants met the habituation criterion were compared to the mean looking times of the two lag trials (lag 1-2). The results indicated no significant difference in infants' looking time over trials pre 1-2 and lag 1-2 (pre 1-2,  $\underline{M}$ =10.09,  $\underline{SD}$ =9.87; lag 1-2,  $\underline{M}$ =12.54,  $\underline{SD}$ =12.86,  $t(19) = -2.02$ ,  $p > .05$ , two-tailed). The infants failed to show a significant increase in their visual attention before the auditory change took place.

In order to test for auditory discrimination, infants' mean looking times on the last two lag trials were compared to their mean looking times across the three postcriterion trials (minus the fourth trial) in a mixed ANOVA with order (Female ID first vs. Male AD first) and synchrony (synchronous vs. asynchronous) as the between subjects factor and test trials (pre-criterion vs. post-criterion) as the within-subjects factor (see Table 1). The results of this analysis showed a significant main effect for test trials,  $F(1, 16) = 5.01$ ,  $p < .05$ , indicating that the mean looking time across the three postcriterion trials ( $\underline{M}$ =18.68 sec,  $\underline{SD}$ =15.63) was significantly longer than the mean looking time on the two lag trials ( $\underline{M}$ =12.54 sec,  $\underline{SD}$ =12.86). There were no other significant main or interaction effects. The mean looking times across infants on the first three trials of the session (baseline), the two lag trials, and the first three postcriterion trials (post1-3) are presented in Figure 1.

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Insert Figure 1 about here

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Additional secondary analyses using the four trials prior to the auditory manipulation (pre 1-4) and the four trials after the change (post 1-4) were conducted to determine if infants would still demonstrate auditory discrimination after including all four trials before the auditory switch. Thus, infants' mean looking times across the four trials before the vocal change (pre 1-4) were compared to their mean looking times across the four post-change trials (post 1-4) in a mixed ANOVA with order (Male AD first vs. Female ID first) and synchrony (Synchronous vs. Asynchronous) as the between-subjects factors and test trials (pre 1-4 vs. post 1-4) as the within-

subjects factor. The results of this analysis showed a main effect of test trials,  $F(3, 16) = 5.74$ ,  $p < .03$ , indicating that the mean looking time across trials post 1-4 ( $M = 16.61$ ,  $SD = 12.48$ ) was significantly longer than the mean looking time on trials pre 1-4 ( $M = 11.32$ ,  $SD = 11.14$ ). There were no other significant main or interaction effects. The mean looking times across infants on the first three trials of the session (baseline), the last four trials before the change (pre 1-4), and the four trials after the change (post 1-4) are presented in Figure 2.

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Insert Figure 2 about here

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Given previous research on infants' attention to multimodal ID speech (Lewkowicz, 1996a; Pegg, Werker, & McLeod, 1992; Werker & McLeod, 1989) additional analyses were conducted to explore possible looking preferences for the female ID multimodal display. Previous research in our lab (Cooper & Aslin 1990, 1994) has shown that infants often demonstrate initial differences in looking times based on the order of presentation (i.e., first trials). Therefore, an analysis was conducted using only the first trials from each session. The results of this analysis revealed no significant difference in infants' looking times to either ID or AD displays (ID first;  $M = 20.46$ ,  $SD = 12.46$ ; AD first;  $M = 50.93$ ,  $SD = 63.36$ ,  $t(18) = 1.49$ ,  $p > .05$ , two-tailed). An additional analysis was conducted using infants' mean looking times across the first three trials of the session (baseline). These results also indicated no significant difference in infant attention to ID or AD audiovisual displays (ID first;  $M = 23.02$ ,  $SD = 12.40$ ; AD first;  $M = 32.91$ ,  $SD = 27.14$ ;  $t(18) = 1.05$ ,  $p > .05$ , two-tailed). Finally, infants' trials to criterion (i.e., habituation) were calculated for infants receiving either female ID displays or male AD displays. Correspondingly, these results showed no significant difference in the number of trials needed to reach criterion (female ID first;  $M = 6.4$ ,  $SD = 2.84$ ; male AD first;  $M = 10.2$ ,  $SD = 10.03$ ;  $t(18) = 1.15$ ,  $p > .05$ , two-tailed).

### Discussion

The results of Experiment 1 showed that 4-month-old infants can discriminate changes in speakers' voices without corresponding changes in the speakers' faces. However, the possibility



remains that infants also discriminated the change from synchronous displays to asynchronous displays. Experiment 1 does not provide any evidence that would answer this alternative explanation. After the infants were habituated to a synchronous audiovisual display (i.e., a matching face and voice) they showed renewed visual regard to the mismatched pairings. The infants showed a significant attentional response to the male face paired with a female voice and the female face paired with a male voice. Surprisingly, temporal synchrony did not seem to play a role in infants' auditory discrimination. That is, the timing of the visual events (e.g., the lip and head movements) and the auditory events (e.g., the male and female voices) did not affect infants' ability to notice changes in the speakers' voices. Moreover, across multiple measures, the infants in this experiment failed to show any significant differences in looking time between the female-ID and male-AD displays despite past research showing a preference for ID speech during the first year of life in both unimodal (Cooper & Aslin, 1990; Fernald, 1985; Papousek & Papousek, 1981) and multimodal contexts (Pegg, Werker, & McLeod, 1992).

These results do not coincide with Lewkowicz's (1996a) work involving infants' perception of multimodal events (i.e., a talking human face). Lewkowicz (1996a) did not find any evidence of 4-month-old infants discriminating changes in the auditory modality-alone without corresponding changes in the visual modality. He only found unimodal auditory discrimination in infants as young as six months of age. In order to more directly compare the results of Experiment 1 to Lewkowicz's research on infants' intersensory perception a second experiment was conducted, utilizing a habituation methodology akin to Lewkowicz's (1996a, 1998) fixed trial procedure.

## Experiment 2

Given the relative insensitivity of the fixed trial procedure, it was predicted that, in general, infants would not discriminate the change in vocal information under these test conditions. However, it was also expected that infants receiving synchronous displays would show higher recovery of looking to the vocal change when compared to infants receiving the asynchronous displays (a significant trial x condition interaction).

## Method

### Participants

Twenty 4-month-old infants participated in Experiment 2 ( $M = 130.9$  days,  $SD = 4.7$ : twelve males and 8 females). The data of five additional subjects were rejected from the study

(two for excessive fussiness, two for equipment failure, and one for a sibling intrusion). Again, the parents and infants were recruited for participation through birth announcements in the Roanoke Times and World News. Upon receipt of the birth announcements, the parents were sent a letter describing the study. A few days after the letter was mailed the parents were contacted by phone to see if they were interested in having their infant participate in the study. Demographic information was obtained from each parent via a questionnaire given on the day of testing. The demographics of the final sample were as follows: 95% were white/Caucasian, whereas 5% were African American; 100% were from married homes; 95% were delivered vaginally; 85% were breast-fed; and 35% were first born. The average age of the infants' mothers was  $M = 30$  years,  $SD = 4.74$ ; the combined formal education level of the infants' parents was  $M = 10$  years post high school,  $SD = 2.60$  years; the average combined household income of infants' parents was  $M = 61,000$  dollars,  $SD = 44,000$  dollars.

### Stimuli

The six audiovisual recordings used in the Experiment 1 were again utilized in the current experiment: two in the habituation phase and four in the testing phase.

### Apparatus

The apparatus was the same as those in Experiment 1.

### Procedure

The infants were tested using a modified version of Lewkowicz's (1996a,1998) fixed trial procedure with separate habituation and testing phases. Infants in the current study received one critical test trial (auditory alone), whereas, infants' in Lewkowicz's multimodal research received three test trials (auditory alone, visual alone, and a combination audiovisual change). Therefore, every infant in the current experiment received twelve 20-second trials in the habituation phase (i.e., male AD face and male AD voice) and one 20-sec auditory trial in the test phase. The thirteen fixed trials were separated from each other by a blank and silent screen for 3 s.

Once the infant was judged to be awake and alert the habituation phase of the experiment began when the observer pressed the key signaling the computer to start the procedure (trials 1-13). On every 20-sec trial the audiovisual display was presented continuously, regardless of each individual infant's looking pattern. Then, at the end of a trial the television monitor and auditory channel (i.e., speaker) were turned off by the computer. Three seconds later the next trial began,

until all thirteen trials were complete. For every display trial, the observer recorded infants' looking times by pressing the signal button. That is, during every 20-sec trial infants could exhibit several separate glances toward the display. Consequently, the observer pressed the button once to signal the onset of a look and then again to mark the end of a look. The computer stored each distinct look by registering the trial number on which it occurred, the duration of the look, and the auditory channel being presented. This permitted the observer to record infants' multiple looks separately for each display trial.

#### Analyses

To test for auditory discrimination, infants' mean looking times on the last trial in the habituation phase (trial 12) was compared to their mean looking times on the auditory test trial (post 1) in a mixed ANOVA with order (Male AD first vs. Female ID first) and synchrony (Synchronous vs. Asynchronous) as the between-subjects factors and test trials (trial 12 vs. post 1) as the within-subjects factor (see Table 2). There was a significant three-way interaction (synchrony x order x test trials) interaction,  $F(1,16) = 4.90, p < .05$ . However, further analyses showed that the effect was carried by those infants' hearing the male voice first. Infants' mean looking times (across both male- and female-voice) on trial 1 (baseline), the last habituation trial (trial 12), and the auditory change trial (post 1) are presented in Figure 3.

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Insert Figure 3 about here

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A subsequent mixed ANOVA with synchrony as the between subjects factor and test trials (trial 12 vs. post 1) as the within-subjects factor for just those infants who were presented with the male display first showed a significant two way interaction (synchrony x test trial),  $F(1,8) = 20.36, p < .01$ . Additional analyses into this interaction showed that the effect was carried by those infants hearing the synchronous test trials (male-synchronous: pre 1;  $M=7.77, SD=5.17$ ; post 1;  $M=12.43, SD=5.64$ ;  $t(4) = 4.09, p < .03$ , two-tailed). The infants hearing the asynchronous test trials did not exhibit significantly longer looking times (male-asynchronous: pre 1;  $M=15.45, SD=4.54$ ; post 1;  $M=11.89, SD=7.06$ ;  $t(4) = -2.51, p > .05$ , two-tailed).

Therefore, the infants who heard the male AD speech first and were tested with synchronous female ID speech discriminated the auditory change. Infants' mean looking times (male-voice first) on the last habituation trial (trial 12) and the auditory change trial are presented in Figure 4.

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Insert Figure 4 about here

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When the same ANOVA was conducted on the infants hearing the female voice first, there were no significant main or interaction effects (all  $p$ s  $>.05$ ). Infants' mean looking times (female-voice first) on the last habituation trial (trial 12), and the auditory change trial (post 1) are presented in Figure 5.

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Insert Figure 5 about here

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Additional analyses were conducted in order to allow for a direct comparison of infant habituation across experimental methodologies (i.e., infant controlled vs. fixed trial). The primary analysis in Experiment 2 involved a comparison across two individual trials (i.e., trial 12 vs. post 1). In order to provide a comparable analysis from Experiment 1, infants' mean looking times (in Experiment 1) on the last precriterion trial (pre 2; before the two lag trials) was compared to their mean looking time on the first post-change trial (post 1) in a mixed ANOVA with order (Male AD first vs. Female ID first) and synchrony (Synchronous vs. Asynchronous) as the between-subjects factors and test trials (pre 2 vs. post 1) as the within-subjects factor. As expected, the results of this analysis showed a main effect of test trials,  $F(1, 16) = 5.18, p < .05$ , indicating that the mean looking time on post 1 ( $M=18.32, SD=20.7$ ) was significantly longer than the mean looking time on pre 2 ( $M=7.14, SD=4.77$ ). There were no other significant main or interaction effects.

Next, the data from Experiment 1 and Experiment 2 were compared directly in order to test for differences across habituation procedures. In this analysis, infants' mean looking times on the last trial in the habituation phase in both experiments was compared to their mean looking

times on the initial auditory test trial (post 1) in a mixed ANOVA with order (Male AD first vs. Female ID first), synchrony (Synchronous vs. Asynchronous) and procedure (infant controlled vs. fixed trial) as the between-subjects factors and test trials (last habituation trial vs. post 1) as the within-subjects factor. There was a significant interaction (procedure X test trials).

Additional analyses showed that this interaction effect was carried by the infants in the infant controlled procedure. There was no significant difference for the infants in the fixed trial procedure ( $p > .05$ ). Infants' mean looking times (across Experiment 1 and Experiment 2) on the last habituation trial and the first auditory change trial are presented in Figure 6.

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Insert Figure 6 about here

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Additional analysis also show a significant difference in the last habituation trial (pre 1) across procedure (Infant controlled;  $M=7.14$ ,  $SD=4.77$ ; Fixed Trial;  $M=12.50$ ,  $SD=5.58$ ;  $t(38)=-3.27$ ,  $p < .05$ , two-tailed). In contrast, there was no significant difference in the first test trial across procedure (Infant controlled;  $M=18.32$ ,  $SD=20.70$ ; Fixed Trial;  $M=13.45$ ,  $SD=6.41$ ;  $t(38)=1.01$ ,  $p > .05$ , two-tailed). Thus, the infants in Experiment 1 looked significantly less on the last habituation trial than did the infants in Experiment 2. However, this difference did not carry through to the initial test trial when all the infants received the familiar face paired with the novel voice.

### Discussion

In contrast to the 4-month-olds tested in Experiment 1, the only evidence for discrimination in Experiment 2 was within the subgroup of infants who experienced the male AD display first and were tested with a synchronous vocal change. The subgroup of infants who experienced the female ID display first did not show a similar recovery in looking time to the synchronous male AD voice within the fixed trial procedure. Therefore, infants' auditory discrimination in Experiment 2 was dependent on which voice they heard first and the presence of temporal synchrony. These results provide some evidence against the alternative explanation for the results of Experiment 1, that infants may have utilized the loss of temporal synchrony to discriminate the change across trials in addition to the change in voice. In Experiment 2, infants

did not show a similar pattern of looking behavior. However, this difference could be a result of the less sensitive testing procedure (i.e., fixed trial). Thus, the alternative explanation (i.e., loss of synchrony) still requires further investigation. These results regarding the male voice first-synchronous subgroup also support previous research regarding infant attention to perceptual objects and events of uneven salience. In general, infants exhibit greater changes in attention when they are presented events of lower salience prior to events of higher salience (Lewkowicz, 1996a; Walker-Andrews & Lennon, 1991; Werker & McLeod, 1989). For example, Lewkowicz (1996a) found that 4- and 6-month-old infants who were presented with female ID speech prior to male AD speech could not discriminate changes in the auditory and visual modalities. However, when the infants were presented with male AD speech first they did show discrimination to unimodal information.

The secondary analyses involving the interaction between procedure and test trials found that only infants tested in the infant controlled habituation procedure showed a significant discrimination when presented with the auditory change trial. The infants tested with the fixed trial procedure (Lewkowicz's 1996a,1998) did not discriminate the change in auditory information (except in the male AD first synchronous subgroup). One explanation for infants lack of auditory discrimination could be that they did not receive enough exposure to the audiovisual displays. Secondary analyses show that the infants in Experiment 2 exhibited significantly longer looks on the final habituation trial when compared to the infants in Experiment 1 who were tested with the infant controlled procedure. This suggests that infants in the fixed trial procedure did not receive enough exposure to the original habituation display. The four-month-olds in Experiment 2 did not have control over the number of test trials they were presented or each individual trial's duration (as in Experiment 1). In sum, the infants in Experiment 1 and Experiment 2 appeared to show dissimilar patterns of attention to the multimodal displays.

### General Discussion

Results of these experiments found that 4-month-old infants could discriminate vocal changes within the context of dynamic multimodal displays. However, this perceptual competence was evident only within the context of the infant controlled habituation procedure (Experiment 1). Infants tested with the fixed trial habituation procedure (Experiment 2) showed limited discrimination, constrained by the type of familiarization display. Specifically, infants

discriminated a change in vocal information when they were familiarized with a male face+AD voice and tested with the same male face but a synchronous female ID voice. Infants who were familiarized with the female face+ID voice first or tested with asynchronous voices showed no evidence of vocal discrimination.

The evidence for discrimination of vocal information from the current investigation supports earlier work in our research lab (see Cooper 1998 for a review). That is, past work in our lab using the infant-controlled procedure has found positive evidence for discrimination of filtered ID vs. AD speech (Cooper & Aslin, 1994), male voices (Ward & Cooper, 1999), fundamental frequency contours (McCartney & Cooper, 1999), and linguistic content (Theaux, 1998). Although most of these studies have tested infants' discrimination for speech patterns in the presence of static visual displays (e.g., checkerboards), the ability of the procedure to produce positive effects suggests that when we shift to dynamic displays (such as faces + voices) we should maintain our use of this sensitive procedure.

The crucial difference between the fixed trial and the infant controlled habituation procedure is individual control, manifested in infants' looking patterns (Horowitz, 1974). The infants tested in the infant controlled procedure were brought to the same level of response decrement prior to the presentation of the test trials. In contrast, infants in Experiment 2 received a preset number of exposure trials regardless of how long they attended to the displays.

Secondary analyses on the combined effects of Experiment 1 and Experiment 2 accentuate this procedural discrepancy. That is, this cross-experimental analysis found that infants in Experiment 1 discriminated the change in vocal information, whereas the infants in Experiment 2 did not. Also, the infants in Experiment 2 looked significantly longer on the trial prior to the change in vocal information than the infants in Experiment 1. Therefore, infant controlled habituation procedures appear, given the results of the current experiments, to be more sensitive to individual differences in looking behavior. This procedural effect helps explain why Lewkowicz (1996a) did not find evidence of 4-month-olds attending to changes in auditory information within a dynamic multimodal display.

A second important finding from the current two experiments deals with the negligible effects of temporal synchrony on infants' discrimination patterns. Infants in Experiment 1 and Experiment 2 showed similar looking patterns to both synchronous and asynchronous test trials. The only group of infants in both experiments who showed a significant response to temporal

synchrony were infants in the male AD subgroup in the fixed trial procedure. Therefore, under the conditions of infant-controlled and fixed trial habituation, the timing of the visual and auditory sensory information (i.e., face and lip movements + periods of voicing and non-voicing) did appear to play a substantial role in guiding infants' attention to the changes in the speaker's voice. These results sharply contrast previous work involving infants' attention to temporal synchrony (Bahrick, 1987, 1992; Lewkowicz, 1986, 1992; Spelke, 1979). More specifically, it conflicts with research on infants' attention to dynamic faces and voices presented both in synchrony and out of synchrony (Dodd, 1979; Kuhl & Meltzoff, 1984). Dodd (1979) found that 10- to 16- week-old infants attended significantly longer to in-synchrony facial and vocal displays when compared to out-of-synchrony displays. Similarly, Kuhl and Meltzoff (1984) found that infants looked longer at video displays matching specific vowel sounds than when presented with mismatched video displays.

There are some critical methodological differences between the current experiments and past work on facial and vocal displays. First of all, Dodd's (1979) work utilized a live actor who interacted with the infants via a mirror and a microphone-recording device. In addition, the out-of-synchrony displays were created by presenting the vocal portion 400 msec after the visual reflections. Therefore, the synchronous displays involved comments and facial features specifically designed for each infant during the testing session. The experimenter was interacting with each infant on an individual basis because the infant's reactions determined the experimenter's visible behavior. In other words, the experimenter's actions were contingent on infant responsivity, and vice versa. Thus, the asynchronous audiovisual displays involved much more than temporal discrepancies, they also involved mismatched emotional components (Walker-Andrews, 1997) and cross-modal correspondence (Bushnell, 1994). Infants were provided with temporal (synchrony), spatial (location), and contingency (interactive) cues only on the synchronous audiovisual trials. When the vocal component was delayed 400 msec, all the cross-modal information was in disarray and out of order.

Kuhl and Meltzoff's (1984) research involved presenting infants with one auditory soundtrack that corresponded to one of two side-by-side video displays of an actor mouthing a particular vowel sound (cross-modal matching). This matching procedure placed the infant in a situation in which he or she selected between two dynamic faces using the auditory information as a guide (Spelke, 1979; Walker, 1982; Walker-Andrews, 1986). Consequently, Kuhl and



Meltzoff's (1984) intersensory task was somewhat less demanding on infants' attention and memory systems because the infants were not required to view one multimodal event and compare it to ensuing percepts. The current set of experiments had infants contrast separate audiovisual events using previous intersensory experience to direct looking during later test trials. Thus, infants were expected to compare current precepts with the information just investigated. This perceptual task may demand greater attentional resources, in terms of memory recollection, especially if the infants have not completely processed the necessary sensory information (Experiment 2).

It appears that the fundamental difference between the current study and previous work on the role of temporal synchrony in complex social displays resides in the task demands placed on the infant. Dodd (1979) measured infants' inattention (i.e., looking away) using synchronous and asynchronous periods whereas, Kuhl and Meltzoff (1984) measured infants percentage of attention directed toward one of two video displays (left or right). The current experiments tested infants ability to discriminate specific auditory manipulations following dissimilar amounts of exposure (infant controlled vs. fixed trial). All of the infants were habituated to one matching and appropriate face and voice and then tested with the familiar face paired with a novel voice. Neither Dodd (1979) nor Kuhl and Meltzoff (1984) examined infants' ability to compare independent audiovisual events using memory or previous experience. They did not utilize habituation procedures, which necessitate some basic form of recollection so that the infant can compare ongoing stimulation with previous events.

The inability to find an effect for temporal synchrony in the current studies also contrasts with recent work on the role of intersensory redundancy (Bahick & Lickliter, 1998; Gogate & Bahrick, 1998) in early perception. To review, the intersensory redundancy hypothesis posits that infants will exhibit differential attention to sensory information presented bimodally. According to Bahrick and Lickliter (1998) information presented in two sensory modalities (synchronously) directs infant attention and perceptual differentiation to amodal properties of events prior to information presented via only one modality. Thus, synchronous audiovisual displays in the test phases of Experiment 1 and Experiment 2 should have directed infant attention to the manipulated vocal information. Yet, this was not the case for the majority of infants in either habituation procedure. There was no significant difference between the looking

times of infants viewing synchronous test tapes and infants viewing asynchronous test tapes, except in the aforementioned subgroup within the fixed trial procedure.

One possible explanation for this apparent disparity lies in the nature of the stimulus displays across the experiments. In Bahrick and Lickliter (1998) the infants viewed a bright red hammer, moving up and down, striking a wooden surface and creating distinct rhythm patterns. In comparison, the infants in the current experiments viewed a dynamic male or female face with multiple moving features (e.g., eyes, lips, head, etc.) paired with a dynamic male or female voice. There is a notable discrepancy across experiments in terms of sensory information presented in the stimulus displays (e.g., social vs. nonsocial, faces vs. objects). The hammer striking a wooden surface is a more discrete event than the audiovisual display of a talking male or female face. To illustrate, Kuhl and Meltzoff (1984) investigated infants' ability to detect the correspondence between a single vowel sound and the corresponding facial movements, a simplified version of the present experiments. These infants did show a significant preference for the matching visual display, supporting the intersensory hypothesis. Thus, when infants were presented with a simplified multimodal display (i.e., adults mouthing a vowel sound), they were afforded the opportunity to perceive the redundant sensory information.

Additional support for this nature of the stimulus display (i.e., type of sensory information) argument comes from the recent work by Morrongiello, Fenwick, and Chance (1998) who investigated newborn crossmodal learning using a violation-of-expectancy test. Morrongiello et al. were interested in testing newborn infants' ability to learn arbitrary sight-sound pairings, so they habituated infants to three test displays: (1) dis-location, (2) change in toy, and (3) change in location. In the dis-location condition, infants were habituated to a toy and sound from the same location and they were tested with the toy and sound in opposite locations (of midline). In the change in toy condition, infants were habituated to two different toys and a sound collocated only to one of the toys. These infants were tested by presenting the sound with the other toy. Finally, the infants in the change in location were habituated to one toy collocated with a sound, and they were tested with the toy and sound moved to another location.

Morrongiello et al. (1998) found that newborns in the dis-location and change in toy conditions exhibited a significant recovery in looking time in the testing situation, whereas, the infants in the change in location did not show a similar increase in looking time. Morrongiello et al. suggested that the neonates were reacting to the separation of the sight and sound during the

test phase and that the temporal synchrony between the toy and sound provided sufficient ambiguous information as to which toy was associated with the sound. That is, the neonates utilized the colocation information to disambiguate the situation and associated each toy with a particular sound. Only when the toy and sound remained collocated in time and space did the infants fail to exhibit an increase in looking time. In sum, even newborns appear capable of associating objects and sounds using redundant sensory information (temporal synchrony + spatial colocation) provided that they are tested with relatively concise or discrete stimulus events.

This discussion on the nature of stimulus display and infants' ability to detect intersensory redundancy helps clarify the discrepant results of the current multimodal investigation and previous intersensory work. Evidence supporting the intersensory hypothesis involves research utilizing simplified utterances (i.e., vowel sounds) (Kuhl & Meltzoff, 1984), recordings of a hammer contacting a wooden surface (Bahrick & Lickliter, 1998), and synchronous collocated toy and sound pairings (Morrongiello et al., 1998). In contrast, the recordings utilized in the current set of experiments afforded far more substantive social and nonsocial information, due to the complicated and changing nature of the visual and auditory information. Dynamic human faces relay information about: emotional cues (Caron et al., 1988; Walker-Andrews & Lennon, 1991), visible signs of motion (Volkman & Dobson, 1976), speaker gender (Leinbach & Fagot, 1993), as well as intricate auditory details such as style of speech (Cooper & Aslin, 1990; Fernald & Simon, 1984; Papousek et al., 1985; Werker & McLeod, 1989), pitch contour information (see Cooper 1998 for review), and syllabic changes (Jusczyk, 1997). Faces are probably the most salient perceptual event present in infants' immediate environment, for they relay a vast amount of perceptual information (Lewkowicz, 1996a). It appears that stimulus selection can play a crucial role in the measurement of infants' intersensory perception.

Dixon and Spitz (1980) investigated how adults judge asynchrony in social and nonsocial multimodal events. The social event involved a man reading prose, while the nonsocial event was a hammer hitting a wooden peg. During the procedure, the participants pressed a key that signaled the auditory and visual channels were in sync, then as the timing was adjusted the participants released the key when they detected an asynchronous relationship. Dixon and Spitz (1980) found that adults were faster at detecting temporal asynchrony during the presentation of

the hammer hitting the peg compared to the man reading prose. Their explanation centered around individuals' perceptual histories or past experience with acoustic and visual events (i.e., talking faces). According to Dixon and Spitz, adults have accumulated a level of perceptual knowledge concerning human faces that allows them to tolerate glaring differences in sights and sounds experienced when a person talks. This supports Lewkowicz (1996b) proposal regarding infants' developing temporal windows for synchronous and asynchronous events.

Lewkowicz (1996b) tested infants (and adults) ability to discriminate changes in temporal synchrony using "bouncing" green disks paired with a punctuate sound (when the disk reached the bottom of the video screen). The participants were familiarized with a bouncing disk and the sound, and then tested with a series of asynchronous test trials. Using this stimulus array Lewkowicz (1996b) delimited a temporal window for infants coinciding with their ability to detect the asynchrony of redundant sensory information (i.e., auditory-visual or visual-auditory). His results suggest that infants have a larger "time window" in terms of perceiving the unity of two separate sensory events when compared to adults. However, his results are based on computer generated dynamic discs and not active human faces that afford far more substantive social and nonsocial information. Infants, who are far more perceptual naïve, would seem to tolerate even greater temporal asynchrony for they have much shorter experiential histories involving both social and nonsocial events. Moreover, if Lewkowicz (1996b) were to test infants and adults with dynamic faces he would probably find larger temporal windows. Faces are far less discrete than either bouncing disks or hammer and pegs. Dixon and Spitz's (1980) work suggests that social and nonsocial events contain dissimilar amounts of temporal information regarding crossmodal information.

### **Implications for Future Intersensory Work**

The results of the current research emphasize the importance of experimenters' selection of appropriate research methods and specific test stimuli when examining infants' intersensory perception. This latest research shows infants' looking behavior changing according to which habituation procedure they received. The infant controlled procedure resulted in 4-month-olds exhibiting auditory discrimination. Whereas, the fixed trial procedure may be relatively less sensitive to infants' attention towards complex multimodal events (i.e., talking faces). Infant controlled habituation procedures allow infants to attain similar levels of response decrement

prior to testing for specific discriminatory abilities. Each infant in Experiment 1 directed the number and duration of test trials presented (i.e., infant-controlled procedure).

The current investigation's failure to find a robust effect for temporal synchronicity appears to be dependent on the type and amount of information in the testing displays (e.g., attentional salience) and the amount of experience infants have encountering social and nonsocial events. If the test displays afford relatively extensive amounts of sensory information (e.g., elaborate scripts, changing audiovisual displays), infants' attention to temporal synchrony appears to decline in effectiveness. Alternatively, infants who are presented with more discrete test displays (e.g., hammer and pegs, bouncing disks) exhibit a clear awareness to redundant sensory information (Bahrick & Lickliter, 1998; Lewkowicz, 1992, 1996b). It appears that over development, infants' experience with dynamic faces and voices affords them "wider" perceptual windows for detecting temporal synchronicity. Thus, they tolerate greater asynchrony within social events. Younger infants (i.e., four-month-olds) do typically confront objects contacting surfaces or computer generated displays. Therefore, nonsocial multimodal displays are relatively novel perceptual events for infants in the first six months of life when compared to faces and voices.

Future investigations into infant intersensory perception could replicate Lewkowicz's (1996b) work on infants' "temporal windows" using dynamic facial and vocal displays. This would enable researchers to compare infants' attention to complex social and nonsocial events. Dodd and Spitz's (1980) research showing adults' sensitivity to particular audiovisual displays would suggest that infants might show wider "temporal windows" for complex social events. This experiment could also lend support for the nature of stimulus array argument, due to the focus on infants' attention to dynamic faces and voices. In general, continuing research into infants' intersensory development is necessary to explicate the relationship between intersensory redundancy (synchronicity) and the influence of overall amount of sensory information within specific test stimuli.

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Footnotes

<sup>1</sup>By looking at individual subject data, it appeared that the infants exhibited a significant decrease in their attention on the final postcriterion trial (post 4). That is, infants seemed to habituate to the novel vocal channel after three exposure trials.

Table 1

Mixed ANOVA Table for Experiment 1: Order x Synchrony (between subjects factors) and Test trials (within-subject factor)—Means, (SDs) in sec

		<b>Synchrony</b>				
		<b>Yes</b>		<b>No</b>		
<b><u>Voice</u></b> <b><u>First</u></b>		Mean Lag	Mean Post 3	Mean Lag	Mean Post 3	<b><u>Totals:</u></b>
	<b>Male</b>	19.41 (24.99)	21.39 (22.17)	10.13 (5.85)	24.40 (20.28)	18.83 (20.28)
	<b>Female</b>	13.86 (3.33)	14.33 (9.47)	6.76 (2.43)	14.58 (8.58)	12.38 (8.58)
	<b><u>Totals:</u></b>	16.63 (17.06)	17.86 (16.50)	8.45 (4.58)	19.49 (15.57)	

Table 2

Mixed ANOVA Table for Experiment 2: Order x Synchrony (between) and Test trials (pre-criterion vs. post-criterion) (within)

		<u>Synchrony</u>				<u>Totals:</u>
		<b>Yes</b>		<b>No</b>		
<u>Voice</u> <u>First</u>		Pre 1	Post 1	Pre 1	Post 1	
	<b>Male</b>	7.77 (5.17)	12.43 (5.64)	15.45 (4.54)	11.89 (7.06)	11.89 (5.51)
	<b>Female</b>	10.91 (5.65)	11.85 (8.40)	15.86 (3.56)	17.62 (3.70)	14.06 (5.68)
	<u>Totals:</u>	9.34 (5.37)	12.14 (6.75)	15.65 3.85)	14.75 (6.11)	

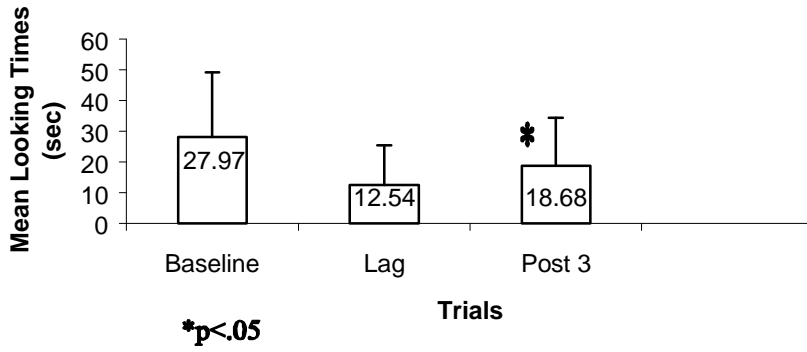


Figure 1

Experiment 1- Infant Controlled Looking Times (Lag vs. Post 3)

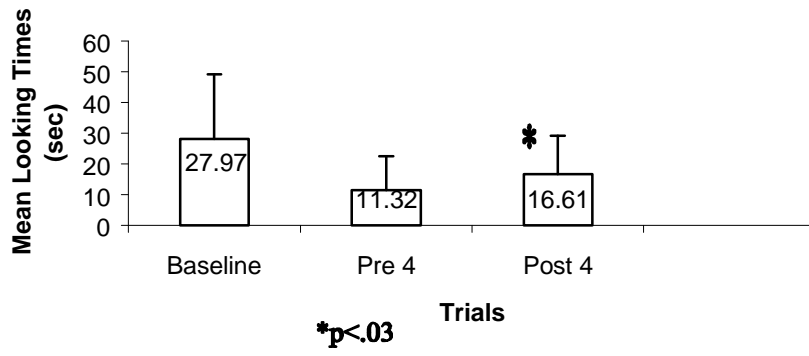


Figure 2

Experiment 1- Infant Controlled Looking Times (Pre 4 vs. Post 4)

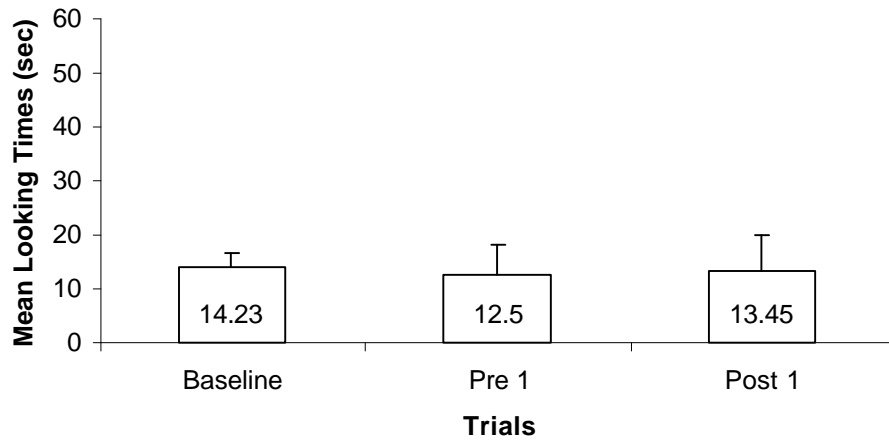


Figure 3

Experiment 2- Fixed Trial Looking Times (Pre 1 vs. Post 1)



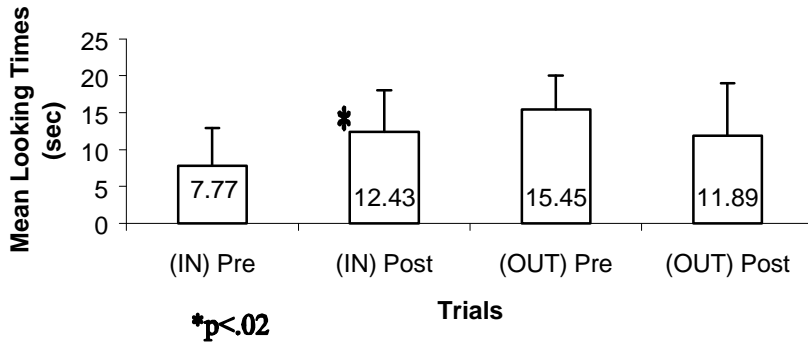


Figure 4

Experiment 2- Fixed Trial Procedure: Male-Voice First Only (Synchrony)

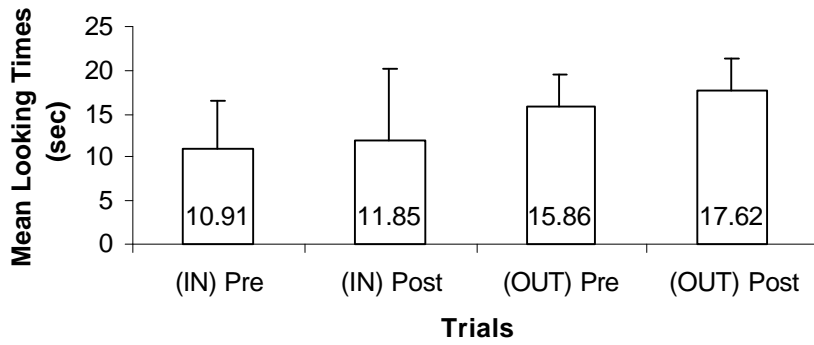


Figure 5

Experiment 2- Fixed Trial Procedure: Female-Voice First Only (Synchrony)

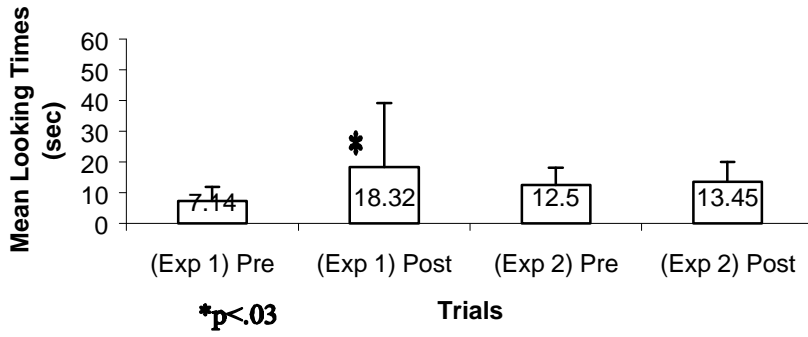


Figure 6

Cross Experimental Analyses: Experiment 1 vs. Experimental 2

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Professional Organizations

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Papers and Conference Presentations

McCartney, J.S., & Cooper, R.P. (1999). A lack of evidence for sustained attention to infant-directed pitch contours in four-month-olds. International Journal of Behavior Development, under review.

McCartney, J.S., Theaux, H., Alexander, K., Cooper, R. P. (1998, April) Four-month-olds do not Prefer but can Discriminate ID and AD pitch contours. Poster presentation at the International Society for Infant Studies, Atlanta, Georgia.

Theaux, H., McCartney, J.S., Alexander, K.A., Cooper, R. P. (1998, April) Six-month-olds' discrimination of information in infant-directed speech. Poster presentation at the International Society for Infant Studies, Atlanta, Georgia.

Ward, C., McCartney, J.S., & Cooper, R. P. (1996, April) Infants' preferences for paternal ID speech or unfamiliar male ID speech. Poster presentation at the International Society for Infant Studies, Providence, Rhode Island.

### Teaching Experience

- 1998        Instructor, Virginia Tech Psychology Department. Summer 1998. Taught Social Psychology course.
- 1998        Instructor, Virginia Tech Psychology Department. Spring 1998. Taught 2 Motivational Psychology Lab classes.
- 1997        Instructor, Virginia Tech Psychology Department. Fall 1997. Taught 2 Social Psychology Lab classes.
- 1997-1996   Instructor, Virginia Tech Psychology Department. Fall 1996, Spring 1997. Taught 2 Developmental Psychology Lab classes.
- 1996-1995   Graduate Teaching Assistant, Virginia Tech Psychology Department. Teaching aid for Physiological Psychology, Advanced Developmental, and Sensation and Perception psychology courses.
- 1995-1994   Instructor, Virginia Tech Psychology Department. Taught 2 Introductory Psychology Lab classes.
- 1994-1993   Substitute Teacher, Anne Arundel County Board of Education, Annapolis, MD 21401. Taught grades K-5.

### Research Experience

- 1997        Six-month-olds' discrimination of information in infant-directed speech  
Supervised by Dr. Robin P. Cooper, Virginia Tech.
- 1996        Thesis: Four-month-olds do not prefer but can discriminate ID and AD pitch contours. Supervised by Dr. Robin P. Cooper, Virginia Tech.
- 1995        Infants' preference for their Mothers' AD speech or Unfamiliar Female ID speech. Supervised by Dr. Robin P. Cooper, Virginia Tech.

1994 Lack of preference for the paternal voice in four-month-olds. Supervised by Dr. Robin P. Cooper, Virginia Tech.

1993 EEG differences in response to auditory stimuli in college aged subjects. Supervised by Dr. Barry Smith, University of Maryland at College Park.

#### Professional Experience

1998 Special Instructor/ Early Intervention Specialist, New River Valley Community Services, Blacksburg VA (June 1998-present)  
Primary responsibilities: provide developmental assessments for developmentally delayed and handicapped infants and toddlers, plan and implement training programs, and collaborate with families, caregivers and other service providers.

#### Activities

1999 Project Success Facilitator, Office of Academic Enrichment Programs (Spring 1999)  
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