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SPATIAL AND TEMPORAL CONGRUITY
AND INTERSENSORY INTEGRATION IN INFANTS

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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Abstract

SPATIAL AND TEMPORAL CONGRUITY
AND INTERSENSORY INTEGRATION IN INFANTS

BY

KATHARINE RIEKE LAWSON

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Although the importance of intersensory integration for the development of perception of integral objects of multimodal properties has been suggested by major developmental theorists, there is little empirical information available concerning the nature of integration - particularly auditory-visual - in infancy. The literature does suggest that infants in the first 6 months are responsive to spatial incongruity of the auditory and visual aspects of a person or object and to temporal synchrony of auditory and visual stimuli. However, no analyses have been reported of the influence of these factors on the establishment of coordinated perception of auditory and visual stimuli as properties of a common object. The present research therefore explored the influence of spatial and temporal congruity of auditory and visual stimuli on 6-month-old infants' coordination of these stimuli.

The first of four studies explored the influence of maximal spatial and temporal congruity of the auditory and visual characteristics of an object. Infants were familiarized with an object which moved in synchrony with a periodic sound which came from the object. The infants were then tested for auditory-visual coordination by presenting the familiar and a novel object simultaneously, and at the same time presenting either the familiar or a novel sound from a speaker midway between the two objects.

Each infant was familiarized and tested with two different object-sound pairs (there were approximately 20 subjects in each study and each infant was a subject in only 1 study). Results indicated that, in the presence of the familiar sound, infants spent a significantly greater proportion of their total fixation time and a significantly greater duration of fixation looking at the familiar than the novel object. In contrast, in the presence of a novel sound, they did not look differentially at either object. This pattern was shown when data for the two object-sound pairs was analyzed separately and together.

The subsequent three studies explored the influence of different aspects of the spatial and temporal congruity used in the first study on the auditory-visual coordination shown in that study. During the familiarization period in each study, a particular aspect of congruity of the auditory and visual characteristics of an object was absent. The familiarization and test procedures in each study were otherwise identical to those of the first study. The familiarization conditions were the following: the object's movement was synchronized with the occurrence of a periodic sound but the object was presented at front midline while the sound came from the infant's side (Study II); the object moved continuously while producing a periodic sound (Study III); the object moved periodically while producing a continuous sound (Study IV). Infants did not show differential fixation following familiarization involving spatial incongruity or one type of temporal incongruity. However, following familiarization which involved temporal incongruity in the sense of continuousness of movement and periodicity of sound, differential fixation indicative of coordination was shown for one object-sound pair but not for the other; this suggests that coordination

may be established under this condition of temporal incongruity but its establishment is strongly related to specific stimulus characteristics.

The results of these studies indicated that 6-month-old infants demonstrated coordination of auditory and visual stimuli which had been previously highly congruent with respect to space and time. This coordination reflected the effect of relatively brief experience, rather than direct matching of stimuli on the basis of temporal synchrony or spatial congruity. However, the establishment of coordination was restricted: no coordination or weak coordination (i.e., for 1 of 2 object-sound combinations) was shown following familiarization in which an aspect of congruity was absent. These results are discussed in terms of coordination of the auditory and visual aspects of objects and possible alternative interpretations based on lower level auditory-visual interactions, and in terms of relevant perceptual and learning processes.

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The major problem to be investigated in this research can be summarized very briefly, if somewhat anecdotally. For adults, the sound of quacking is generally associated with a bird which has a stocky low build, short legs and neck, webbed feet, etc. There are several major ways that this percept might become established, aside from associations based on verbal and conceptual mediation. Generally, the percept is based on experience with the animal as it makes its characteristic sound; in other words, with experience with particular auditory and visual stimuli which are temporally and spatially congruent. However, it may not be necessary that the adult have extensive experience with the quacking duck to link these characteristics; for example, if an adult hears a repeating sound, and visual search reveals an animal whose pattern of movement is synchronized with the pattern of sound, the conclusion is likely to be that that animal is generating the sound. Whether such a percept would be established in similar ways very early in development is not clear, and this question is the focus of the present research.

Perception of many objects and events in the environment requires two or more sensory systems working in cooperation; for any given object, a set of qualities of one modality (e.g., visual characteristics) may predominate but other qualities specific to a sensory modality (e.g., quack) or not specific to a particular sensory modality (e.g., temporal pattern) fill out the total object. Sensory systems can cooperate or interact in a number of ways which facilitate the establishment of integrated perception of objects. The relative importance of these different modes of intersensory integration may vary with particular objects, with the sensory systems involved, and with the developmental stage of the perceiver. Although the early ontogeny of intersensory integration has been an important part of several major theories of perceptual and cognitive development, there is little empirical information available to suggest how the perception of integral objects of multimodal attributes develops, particularly in young infants. The present research explored several factors which might, for young infants, be influential in the establishment of the perception of auditory and visual stimuli as properties of a common object. It explored the influence of spatial and temporal congruity of auditory and visual stimuli on the infant's coordination of these stimuli. Infants were given experience with objects and sounds having different types of spatial and temporal congruity. It was reasoned that if the infants subsequently associated the two events, this association would clearly be a basis for, and might be reflective of, perception of these events as attributes of a common object.

A variety of interrelationships between the sense systems ispossible (see Ettlinger, 1977; Ryan, 1940; Turkewitz,& McGuire, 1978; Wright, 1970). The auditory and visual systems might function independently in early development, with stimulation in one modality having no effect on responsiveness to stimulation in the other modality. Sense systems might interact indirectly, through general facilitative or inhibitive functions. For example, input in one modality might alter general arousal levels which, in turn, alter the limits of function in another modality (for example, within modality thresholds can be altered by concurrent stimulation in another modality). Indirect interaction could also result when input in one modality elicited reflexive responses which altered perception in another modality (for example, reflexive changes in head position can alter the probability of perception of concurrent input in another modality). Interaction between sense systems might be more specific, so that input in one sense system may alter perception in another sense system qualitatively (for example, synesthesias such as the perceived darkening of visual displays in the presence of low tones) or even spatially (for example, a sound and light must be farther apart to be judged as spatially separate than a pair of sounds or a pair of lights). Input in different modalities could also be related on the basis of conditioning, so that stimulation in one modality might signal the appropriate response to stimulation in another modality.

In another type of interrelationship, information detected through a particular sense system is perceived as equivalent to information detected by other sense systems. As generally used, intersensory equivalence refers to the perception that a characteristic specified by one sense system is the same as, or identical to, that specified by another sense system (for example, texture can be perceived as the same on the basis of looking and touching). In addition, intersensory equivalence is sometimes used to refer to perception that qualitatively different characteristics identify a common source interchangeably (for example, a face and a voice can independently identify a particular person). Intersensory equivalence is generally investigated through one of two paradigms; at least one investigator (Ettlinger, 1977) has sharply distinguished the nature of integration reflected in these two paradigms.

In cross-modal matching, the subject matches a stimulus presented in one modality with an identical stimulus presented in another modality. In cross-modal transfer, the subject learns a discrimination in one modality and then performs or learns the same discrimination more readily in another modality.

The present research is concerned with another type of integration - intersensory coordination, in which input detected through one sense system is consistently associated with input of another system, so that these inputs are perceived as properties of a common object. This type of interrelationship is frequently referred to as association, but coordination is used here to avoid implications about mechanism (particularly, establishment by classical conditioning) which are carried by the term association. Coordination could be facilitated by other types of intersensory integration. For example, a particular feature (animated speech) might increase arousal and hence increase attention to the combination of that feature and one in another modality (face) as coming from a common source. Or, particular features may be more readily associated on a synesthetic basis (bright objects with bright sounds). Stimuli of different modalities which are perceived as equivalent in the sense of interchangeability for identifying a common source would, by definition, be coordinated (auditory and visual stimuli which independently identify a common object would have to be consistently related to each other as attributes of that object). Coordination could be facilitated by perception of equivalence in the sense of identity in quality or quantity, although perception of equivalence would not necessarily indicate that the stimuli were attributes of a common object (auditory and visual stimuli which exhibit a characteristic which is perceived as the same would be more likely to be perceived as attributes of a common object). However, coordination does not require perception of equivalence in either sense.

Theoretically, the various types of intersensory integration might be ordered along some dimension of complexity, such as mechanism of establishment or extent of requirements for establishment. Each type might have a different developmental history. However, there is little information available to classify the types of integration on the basis of these or other criteria, or to trace their developmental histories.

Historically, interest in cross-modal integration in the perception of objects has focussed on equivalence, as expressed Molyneaux's question to Locke (Morgan, 1977) whether a man born blind and restored to sight in adulthood would recognize objects immediately by sight which he had previously known only by touch. Berkeley in 1709 proposed the thesis that visual qualities are necessarily associated with tactual qualities and derive their meaning from touch. Others have argued the reverse - that vision dominates and teaches other sense systems (see, for example, Harris, 1966; Posner, Nissen, & Klein, 1976), or that the senses are natively integrated (Hayek, 1952). Whatever the origins, the ability to perceive intersensory equivalences was thought until recently to be dependent on, or strongly related to, verbal mediation (Bridger, 1970; Burton & Ettlinger, 1960; O'Connor & Hermelin, 1963). Verbal mediation was invoked primarily because of the apparent increase in intersensory abilities in parallel with language development in children and the failure to find evidence for cross-modal equivalence in nonhuman primates, in conjunction with the greater separation of cortical sensory areas in nonhuman primates. However, since 1970, a number of studies (see Davenport, 1976) have indicated perception of intersensory equivalence, at least for the visual and haptic sensory systems, for apes and monkeys. Once appropriate testing methods were developed, apes and monkeys demonstrated haptic-visual cross-modal matching and apes demonstrated haptic to visual transfer of training. Cross-modal transfer of intensity or pulse pattern discrimination for auditory and visual stimuli has been reported for other mammals (rats, Over & Mackintosh, 1969; prosimian bushbaby, Ward, Yehle, & Doerflein, 1970; rabbits, Yehle & Ward, 1969). Cross-modal tactual to visual transfer has also recently been indicated for infants of 6 to 12 months (Bryant, Jones, Claxton, & Perkins, 1972; Gottfried, Rose, & Bridger, 1977). In addition, more recent studies of cross-modal behavior in children have not supported a correlation between verbal measures and cross-modal behavior (see Freides, 1974). Clearly, language mediation is not necessary for the perception of equivalence, although language could obviously facilitate the establishment of equivalence or other interrelationships between the sense systems.

Several major developmental theorists have been concerned with how infants perceive and respond to objects in their environment, and hence with identifying factors other than language which might contribute to multimodal environmental stimuli being perceived as integral events. For Piaget, attainment of mature object concepts represents a developmental landmark; it is based on parallel increasing differentiation and coordination of schemas (Flavell, 1963). Simultaneous multimodal sensations are not in themselves sufficient to generate awareness of the solidity and exterior nature of objects, although they facilitate the attraction of attention to external stimuli. The infant learns to differentiate and externalize objects through his actions with them and to intercoordinate his perceptions of external things through action; at the same time, "intersensory coordinations contribute to solidifying the universe by organizing actions" (Piaget, 1964).

The theory of sensory integration of Birch and his colleagues proposes that an increasing tendency toward integration of the separate sensory modalities and an increasing differentiation and definition within each of the sense modalities are major developmental patterns (see Birch & Lefford, 1967; 1963). Sensory integration was apparently viewed (see Birch & Bitterman, 1949) as a process in which one stimulus, as a result of contiguous presentation with a second, gradually acquired the functional properties of the second, resulting in an extension or qualitative enlargement of the pattern of stimulation which would elicit particular responses. Essentially, this was a process of afferent organization in which equivalences of different stimulus patterns were established, with the acquisition of cross-modal equivalences representing a more complex and later appearing ability than intramodal ones.

In contrast, other theorists have stressed the unity of the senses in infancy. Bower, for example, maintains that the sensory modalities are inherently integrated; a native or primitive unity of the senses is built into the structure of the human nervous system, such that, for example, visual variables specify tactile consequences from birth (Bower, 1974). The principle theme of development is increasing differentiation of the senses rather than coordination or integration and this differentiation is probably endogenously generated without influence of function.

While concerned with the same issues, Gibson (1969) has suggested that intersensory integration is a misconception since intersensory integration is primarily considered in relation to the pickup of information about amodal or supramodal properties for which the particular sensory system is irrelevant. Amodal properties are not modality specific but are invariant over input from the various modalities; they are not intermodal relationships but higher order relational information. "It is not unreasonable to suppose that, developmentally, the detection of superordinate amodal relations occurs later rather than earlier and that cross-modal transfer as a consequence increases with age" (Gibson, 1969).

There is currently no convincing evidence for the early independence of auditory and vision. McGurk, Turnure, and Creighton (1977) have argued for intersensory independence in the newborn, and have reported that the addition of a sound moving conjointly with a moving visual target does not result in enhanced tracking behavior and the presentation of a spatially incongruent stationary sound does not disrupt visual tracking of the moving target. However, Hammer and Turkewitz (1975) have reported data indicating that brief intense sounds comparable to those used by McGurk and colleagues (op. cit.) do not elicit the eye turning toward the sound source that less intense sounds do and, in fact, may elicit withdrawal in newborns.

The bulk of the evidence suggests that auditory and visual systems interact in infancy. Most studies have focussed on the effects of auditory stimulation on visual behaviors. Concentration on this direction of influence is in part due to the prominence of visual behaviors in the infant's behavioral repertoire and the relative difficulty of identification and detection of auditory behaviors. Therefore, there is little information about the symmetry of interaction of the auditory and visual systems.

A variety of studies have indicated intersensory influences associated with general organismic changes. The evidence suggests that stimulation of one modality can produce general organismic changes such as altered arousal, which can affect the infant's responsivity to sensory input of another modality. For example, Irwin (1930) examined the effect of background conditions on responsiveness to discrete stimuli and reported that continuous light reduced infants' responsiveness to a variety of different types of stimuli. Brackbill (1970) has reported that background continuous auditory stimulation can decrease, and intermittent stimulation increase, arousal level in infants. Alterations in arousal could alter responsiveness to visual stimuli.

A different influence of auditory stimulation on visual attention in 5-to 14-week-old infants has been reported by Horowitz and her colleagues (Horowitz, 1974). A visual stimulus was presented repeatedly until fixation was habituated to a criterion level; for younger infants, fixation of the same visual stimulus could be recovered by addition of an auditory; for older infants, either addition or subtraction of an auditory stimulus resulted in recovery. This influence on visual attending behavior probably reflects a result of alteration of arousal caused by auditory stimulation. Such changes in the timing and duration of attention to particular targets would facilitate the further development of auditory-visual integration.

Reflexive responses to input on one modality may increase the probability of occurrence of response to input in another modality, as illustrated by studies of sound elicited eye turning. Wertheimer (1961) reported that an infant within minutes of birth turned its eyes toward a lateralized auditory sound. A series of studies by Turkewitz and colleagues (Turkewitz, Birch, Moreau, Levy, & Cornwell, 1966; Turkewitz, Moreau, Birch, & Davis, 1970; Turkewitz, Birch, & Cooper, 1972a; Turkewitz, Birch, & Cooper, 1972b) have also indicated that newborns turn their eyes in the direction of the source of sound, if the sound is of appropriate intensity.

The nature and direction of visual scanning (monitored by corneal reflection technques) of young infants can also be influenced by sound. For newborn infants (Mendelson & Haith, 1976), a diffuse light field is scanned in a more centralized and constrained manner in the presence of sound at the midline; a lateralized visual stimulus is scanned initially in the direction of a lateralized sound source; and fixation is more constrained initially following onset of spatially consonant as opposed to dissonant sight-sound combinations. For infants of 7 to 11 weeks, sound constrains scanning of face and facelike stimuli (Hainline, 1978; Haith, Bergman, & Moore, 1977). The design of these studies suggests that the effect of constraint could be explained on the basis of oculomotor reflexive responses to the spatial location of sound. However, at least for older infants, sound can also have a higher level perceptual effect on scanning. For infants of 7 to 11 weeks, talking differentially increased the proportion of scanning of the eye area, relative to that shown for other areas of the face (Haith, Bergman, & Moore, 1977).

These studies indicate that the auditory and visual systems interact in early infancy. Auditory and visual stimulation can alter arousal and hence responsivity. Introduction (or subtraction) of an auditory stimulus can result in recovery of visual fixation to a visual target even after fixation of the same target was previously habituated. Infants turn their eyes in the direction of sound sources and their visual scanning is more constrained in the presence of sound. The latter responses appear to reflect reflexive oculomotor responding rather than higher level auditory-visual integration: Turkewitz and colleagues (Turkewitz, et al., 1966) have demonstrated that eye turning toward the source of auditory stimuli is as readily elicited when the infant's eyes are closed as when they are open. Although oculomotor reflexes, these behaviors may have consequences for auditory-visual integration; for example, they may permit location of sights associated with sounds and increase the probability of simultaneously looking at particular sights while listening to particular sounds. In a similar fashion, the reaching of young infants which is elicited in the light and continues in the dark toward a target (Bower, 1974) may be a reflexive response; although not itself a higher level behavior, it may contribute to the development of higher level auditory-visual integration. Auditory stimuli also have a more specific effect for infants by about two months, since it may result in differential scanning of particular visual stimuli.

Cross-modal transfer has been reported in older infants (infants of 6 months to a year). There is some data to suggest that infants of 7 months may be responsive to the equivalence and nonequivalence of temporal sequences within and across the auditory and visual modalities (Allen, Walker, Symonds, & Marcell, 1977). A standard visual or auditory temporal sequence (the three events of the sequence were regularly or irregularly spaced) was repeatedly presented during a habituation period; then perception of equivalence was assessed by presenting the same or a different temporal sequence in the same or a different modality. Infants presented with a different temporal sequence showed greater response recovery than did infants presented with the standard temporal sequences. That there was greater recovery for infants shifted in both modality than for those shifted simply in modality suggests the perception of equivalent temporal pattern. The design of this study does permit the possibility that the infants were responding to the duration of the interstimulus interval of the first two events in the sequences rather than a more complex temporal pattern. That infants of this age are responsive to equivalences of information detected through the auditory and visual systems is supported by reports of tactual to visual cross-modal transfer of equivalences of shape. In the first report of cross-modal transfer (Bryant, et al., 1972), infants of 6 to 12 months were familiarized with an object either tactually (the object was rotated in their hands out of their sight) or visually (the object was presented visually to the infant out of reach); they subsequently consistently reached for the familiar as opposed to a novel object when these objects were presented visually. Tactual to visual cross-modal transfer has since been reported for infants of one year for a variety of objects (Gottfried, et al., 1977); infants reliably looked more at, and reached more for, a novel as opposed to the familiar object after brief manual or oral tactual experience with that object. That infants in the first study preferred the familiar object and infants in second preferred the novel object may be related to a number of differences between the studies but either response, when consistent, indicates recognition. Direction of preference might be related to the nature or duration of the familiarization experience or the complexity or attractiveness of the objects (in the first study, for example, the objects made a sound during familiarization; the objects were also unlike considerably in size and shape in the two studies). In addition, since this type of cross-modal testing represents a relatively complex task, a familiarity preference may be more likely with younger infants: Ruff and Kohler (1978) have reported results suggesting tactual to visual transfer in 6-month-old infants which was indexed by a familiarity preference.

Investigation of intersensory coordination has concentrated on tactual-visual rather than auditory visual coordination; while coordination of tactual-visual and auditory-visual systems may be established on different bases and have different developmental histories, this literature illustrates issues which are probably relevant to auditory-visual coordination. Infants have been reported to recognize objects following visual-haptic experience with them, and in tact, tactual to visual cross-modal transfer illustrates perception of the coordination of the tactual and visual aspects of an object as well as perception of their equivalence. However, Schaffer and colleagues have reported studies (Schaffer & Parry, 1970, 1969; Schaffer, 1975) indicating a lack of coordination between the tactual-manipulative and the visual response systems in young infants; that is, 6-month-old infants demonstrated recognition of familiar objects if recognition was indexed by visual fixation but not if recognition was indexed by reaching or manipulation. Other investigators have reported data indicating that 6-month-old infants to demonstrate recognition by manipulative as well as visual responses; whether recognition is demonstrated is apparently related to experimental design and particularly to selection of response measures (Rubenstein, 1974; Ruff, 1976) and to use of stimulus dimensions which are relevant and appropriate to the manipulative as well as the visual systems (Steele & Pederson, 1977).

Other investigators (Gottfried, Rose, & Bridger, 1978) have suggested that haptic-manipulatory experience may actually interfere with processing of concurrent visual experience for infants younger than a year. Infants were given brief (20 seconds accumulated visual fixation of the object) familiarization which was visual only; visual-haptic (the infant was permitted to look at and manipulate the object); or "visual-manipulatory" (the infant was permitted to manipulate the clear plexiglass box housing the stimulus object). Infants of one year demonstrated visual recognition following all three types of familiarization. In contrast, infants of 6 to 9 months demonstrated visual recognition following visual but not visual-haptic or visual-manipulatory experience. However, infants of 6 to 12 months do recognize an object following brief haptic experience alone (Bryant, et. al., 1972). They also recognize objects visually following visual-haptic experience of durations longer than those used in this study (10 minutes - Rubenstein, 1972; 1976; 2 minutes - Ruff, 1976; infant controlled durations - Steele & Pederson, 1977). Therefore, the concurrence of haptic-manipulatory experience with visual experience may have hindered the acquisition and/or encoding of visual information about shape, so that younger infants did not learn a sufficient amount in the short familiarizations of this study to subsequently recognize the familiar object. Whether this disruption is attributable to concurrent exercise of response systems or concurrent information processing is not clear.

Investigations of auditory-visual coordination have been concerned with somewhat different issues. This difference is due in part to differences in the information auditory and visual stimuli convey about objects and events, as compared with the isomorphically identical structural information of touch and vision. One set of studies has focussed on whether infants coordinate spatial information provided by auditory and visual stimuli. In most of these studies, the auditory and visual attributes of an object have been presented in either a spatially congruent or spatially incongruent manner; differences in response to these two conditions have been interpreted as indicating that the infant expects spatial integrity of aspects of the same object. Another set of studies has focussed on whether infants consistently relate particular auditory and visual features of people and objects. In most of these studies, the auditory and visual attributes of objects have been presented in spatially congruent combinations which were either "appropriately matched" or "mismatched"; differences in response to these two conditions have been interpreted as indicating that the infant perceives that particular auditory and visual stimuli are attributes of a common person and should appear together.

Studies of spatial coordination have generally explored an infant's integration of the auditory and visual aspects of its mother. This selection is based on the assumption that the infant's mother would be the multimodal object first perceived as an integral event by young infants, both because of her unique affective importance for the infant and because she is the multimodal object with which the infant has had the most experience. Aronson and Rosenbloom (1971) reported that infants of 1 to 2 months responded with signs of distress (as indicated by tongue protrusion) to the spatially incongruent presentation of their mother's face and voice (the mother was seen at a midline front position but heard via a speaker 90° to the left or right). They concluded that infants as young as 30 days perceive auditory and visual stimuli within a common space and form expectancies that bimodal stimulation from an object will be spatially congruent; violation of these expectancies by perceived discrepancies within the common space produce distress.

However, there were serious methodological problems of this study; for example, test condition order and criteria for continuing testing were potentially biased toward their results and tongue protrusion is an unvalidated measure of distress. Investigators using improved designs have been unable to replicate the phenomenon. When McGurk and Lewis (1974), for example, counterbalanced their spatially congruent and incongruent conditions and monitored a number of responses, they did not find any evidence for distress associated with face-voice spatial separation at 1, 4, or 7 months. Condry, Haltom, and Neisser (1977) have also reported failure to replicate, using essentially the same design.

The contradictionsof these results may be related to the conflict model used for investigation. Young infants tend to orient toward salient visual and auditory stimuli. For example, McGurk and Lewis (1974) reported, for 4-and 7-month-old infants, a significant increase in head turning for their spatial incongruity condition, the majority of the head turns being in the direction of the active speaker. Spatial displacement of equally potent auditory and visual stimuli could well produce conflict between the tendencies to oreint to each of the stimuli, and such conflict between orientation responses in itself could result in disturbance, without any implication for intersensory integration. Whether the conflict resulted in "distressed" behavior or simply a lack of clear behavior might depend on the strength of the tendencies to orient to each of the stimuli alone. In addition, the definition of behaviors which clearly indicate "confusion" or "disturbance" in infants of this age is problematic. While Aronson and Rosenbloom (1971) selected tongue protrusion, two other studies have focussed on responses which reflect a type of activation.

Lewis and Hurowitz have reported a study of face-voice coordination (Note 1) which included a spatial incongruity condition. Data for the 1-and 4-month-old infants combined indicated increased head turning for the displacement condition (direction of turning is unspecified), which the investigators interpret as increased exploratory behavior in response to conditions which "violate the infant's expectation of the person schema". However, a significant increase in head turning was also shown for the control conditions of face alone and voice alone, so that the implications for bimodal integration are unclear.

Lyons-Ruth (Note 2) attempted to replicate the investigation of Aronson and Rosenbloom using an inanimate object. A toy oscillating in synchrony with a chime sound was presented in comparable spatially congruent and incongruent conditions. Infants of 3 to 5 months of age showed an increase in limb and body movement during the spatial incongruity condition. In a separate test, a small group of 4-month-old infants showed a tendency to increase movement when the visual stimulus only was presented at the midline while both the visual and auditory stimuli were presented in a spatially co-located position 90° to the right. However, since looking away from the forward object was very infrequent, this condition was effectively a spatially incongruent one and should have produced an increase in movement. This increase in movement is interpreted as agitation or disquiet resulting from violation of expectancy of auditory-visual coordination; infants expect that "sounds which occur in temporal synchrony with movements of a visual object are features of that object and should move in space with that object". While temporal synchrony of visual and auditory stimulation may well be a form of stimulation uniquely potent for coordination for young infants, no analyses of its role have been reported.

The data of this set of studies suggest that infants in the first 6 months are responsive to the spatial congruity and incongruity of auditory and visual aspects of a person or object, but the bases of their response is unclear. Some of the ambiguities may be related to the use of the conflict model, since the responses observed could be attributable to a conflict in the tendencies to orient to each of the competing stimuli. Other ambiguities may be related to the selection of response measures.

Another set of studies has explored the infant's auditory-visual coordination by presenting the auditory and visual attributes of a person or object in a spatially congruent manner, but either "appropriately matched" or "mismatched". For example, in a study reported by Cohen (1974), both mother and a strange female sat in front of the infant, while their voices were presented in matched and mismatched conditions. 8 month infants showed shorter first fixations to the mismatched combinations and more first fixations away from the mismatches; 5 month infants did not respond differently to the two conditions. Lewis and Hurowitz (Note 1) included a "discrepant" condition (face and voice were spatially congruent at front midline position but were mismatched) in their study of face-voice coordination. Data for the 1 and 4 month subjects combined indicated increased head turning for this condition, but, as discussed above, a significant increase (relative to "normal" nondiscrepant, nondisplaced condition) was also shown when each feature was presented alone, so that the implications for bimodal coordination are unclear. It is possible, however, that the observed behaviors were a response to the temporal incongruity of face movement and voice inflection; these investigators did not report the controls for this factor which had been incorporated in the Cohen study.

Lack of clarity of these results may be related to the use of attributes of the mother to explore auditory-visual coordination. Her unique affective importance may decrease the sensitivity or the appropriateness of these investigative methods. In support of this, Lyons-Ruth (1977) has reported a visual attention study in which infants of 15 to 16 weeks were familiarized with a sounding object at the midline front (objects were made to sound by a rocking motion); the same sound was then presented laterally, either "matched" with the familiar object or "mismatched" with a novel object. Infants looked away more often from the mismatched than the matched combination. The data were interpreted as indicating that, after experience with a sounding object, infants anticipate the appearance of the familiar object at a new spatial location of the familiar sound and show conflict behavior to the unanticipated novel object.

One factor has been common to all the studies of the coordination of the auditory and visual attributes of persons and objects which have been discussed so far: they have all relied on observation of behavior which the experimenter could interpret as indicative of conflict or expectancy violation. Definition of behavior which reflects this phenomenon has been problematic and indices selected have generally not been validated. The studies have also relied on a relatively passive response: the target stimuli have been presented in particular locations or particular combinations and the infant was observed for its response to these experimenter-determined relationships. It is possible that a more fruitful approach would explore the infant's active relating or matching of stimuli of different modalities.

Spelke (1976) has recently described a study exploring more active coordination on the part of the infant. Two motion pictures were simultaneously presented, side by side, to the infant, while a sound track appropriate to one of the pictures was presented via a speaker midway between the two screens. 4-month-old infants looked more at the film which went "appropriately" with the particular sound track being presented. The data may suggest that 4-month-old infants associate auditory and visual stimuli on the basis of synchronized temporal characteristics; this might reflect matching on the basis of perception of the equivalence of temporal pattern of the two stimuli. Alternatively, the data may suggest association of the very familiar and important events of a woman's face and voice (which were playing peekaboo) as opposed to an unfamiliar, nonhuman object and sound (percussive instrument and sound). Spelke and Owsley (Note 3) have reported a similar study exploring face-voice coordination. The infant's mother and father sat side by side facing the infant, while their voices were presented in stereo from speakers behind them. The fixations of 5½ and 7½ month infants tended to reflect coordination (they looked first, faster, and more frequently at the parent whose voice was being presented), but the responses of 3 to 4 month infants were equivocal.

In summary, the importance of intersensory integration in the development of perception of integral objects and events has been suggested by major developmental theorists, but very little information is currently available concerning the nature of auditory-visual integration in infants. The evidence indicates that auditory stimulation does influence visual behaviors in a variety of ways. Even for newborns and very young infants, auditory stimulation can alter arousal and therefore responsivity to visual stimulation. Auditory stimulation can elicit reflexive eye turning and direct scanning and therefore alter the probability that a visual event will be detected in relation to the auditory stimulation. Auditory stimulation can interact in a more specific way with visual stimulation: by about 2 months, infants will, in the presence of a particular sound, look differentially at a particular visual stimulus. The evidence further suggest cross-modal transfer in infants of 6 to 12 months. Infants of 7 months respond in a manner which suggests they perceive the equivalence and nonequivalence of temporal frequency or pattern presented in the auditory and visual modality in succession. That infants are capable of auditory-visual transfer is supported by evidence for tactual to visual transfer of information about shape.

There is also some evidence to suggest that infants of 4 to 8 months coordinate auditory and visual stimuli as attributes of a common object or event. The data suggest, for example, that infants respond differently to combinations of auditory (face) and visual (face) combinations which are "appropriately" and "inappropriately" matched. Further, differential response to matched and mismatched object-sound combinations reflective of coordination can be established on the basis of relatively short familiarization.

The literature also suggests that infants in the first 6 months are responsive to the spatial congruity and incongruity of the auditory and visual attributes of a person or object, although the basis of this response is unclear. In addition, infants are responsive to temporal congruity: they may match auditory and visual stimuli on the basis of temporal synchrony and they may associate auditory and visual stimuli on the basis of prior experience in which these stimuli have exhibited temporal synchrony. However, while the importance of spatial and temporal congruity of auditory and visual stimuli for their coordination has been stressed, no analyses of their influence on the formation or establishment of coordination have been reported.

The present research was therefore designed to acquire some preliminary information about the influence of spatial and temporal congruity of auditory and visual stimuli on the establishment of coordination of these stimuli as attributes of a common object. The research explored the influence, for 6-month-old infants, of different types of spatial and temporal congruity of auditory and visual stimuli on subsequent association of these stimuli. In particular, the nature of the spatial and temporal congruity of objects and sounds was different during familiarization in each of a series of studies; subsequent differential fixation of the familiar object in the presence of the familiar sound indexed association based on the familiarization experience. This association is assumed to be basic to, and possibly reflective of, coordination of these stimuli as aspects of a common object.

General Method

Overall Design

The coordination of auditory and visual stimuli was explored using a design based on standard familiarization-test procedures and visual-auditory coordination procedures presented by Spelke (1976). The infant sat on its mother's lap in front of a testing booth. During familiarization, an object and a sound were presented to the infant for a standard amount of time. During tests, the familiar and a novel object were simultaneously presented to the infant and at the same time either the familiar or a novel sound was presented from a speaker midway between the two objects. Differential fixation of the familiar visual stimulus in the presence of the familiar sound but not in the presence of the novel sound was interpreted as indicative of auditory-visual coordination.

The nature of the spatial and temporal relationship of the sound and object was different during familiarization in each of four studies, but the procedures for the studies were otherwise the same. The familiarization procedures in the first study were designed to maximize the likelihood of auditory-visual coordination; subsequent studies were designed to analyze the influence of particular components of the familiarization procedures of the first study on auditory-visual coordination. In the familiarization of the first study, an object and sound were presented in a spatially and temporally congruent manner, since such congruity was likely to increase the probability of their coordination. The object and sound also displayed a synchronous rhythm since such a common temporal pattern was likely to increase the probability of their coordination. Therefore, in the first study, infants were familiarized with an object which moved in synchrony with the rhythmic sound it was producing. In subsequent studies, components of this maximally congruent relationship were removed so that infants were given experience with a sound and object (1) which displayed the same temporal rhythm but which were spatially incongruent; (2) which were spatially congruent, but exhibited a type of temporal incongruity (the object moved continuously while producing a periodic sound); and (3) which were spatially congruent, but exhibited a different type of temporal incongruity (the object moved periodically while producing a continuous sound).

Subjects

Infants born at Albert Einstein College of Medicine Hospital were included if they were 26 weeks of age and met the following criteria: 1) no problems of gestation, delivery or immediate postnatal period were recorded in the baby register of the hospital nursery; 2) the 1 and 5 minute Apgar scores were at least 7 and 9, respectively; 3) the mother reported the infant to have been in good health since birth; 4) the infant lived in an area of the Bronx or Westchester readily accessible by car; 5) an appointment convenient to the mother and experimenter could be scheduled when the infant was an appropriate age. In addition, basic criteria for the testing sessions were that the infant maintained a potentially attentive state (for example, crying was not so disruptive as to prevent some fixation of the experimental stimuli) and that testing proceeded without undue disruption (for example, by extraneous sounds sufficiently loud to mask the experimental sounds). 155 infants were tested; of these, data of 23 were excluded prior to data analysis for one of the above reasons or for experimenter error. There were approximately 20 infants in each study; no infant served as a subject in more than one study. Letters sent to mothers explaining the purpose and procedure of the study and soliciting their participation and the consent forms signed by mothers prior to testing are in Appendix A and B, respectively.

Apparatus

Infants were tested in their homes, while sitting on their mother's laps at a portable testing booth. The booth was, as a rule, set up on an ironing board so that its height could be adjusted to the infant's sitting position. The three sided booth was constructed of thin plywood and painted flat white. It measured 81.3 cm wide, 61.0 cm high, and 40.6 cm deep; the sides extended 21.6 cm beyond the bottom surface to help block the infant's view at the sides. To permit presentation of the experimental stimuli, a white curtain measuring 63.5 cm by 13.6 cm was centered at the base of the back wall. The curtain was divided at the center to permit projection of the single object used for familiarization. The curtain was also divided 9.5 cm to the left and right of the midline division, to permit openings for the presentation of the two objects used for tests. Each opening was 12.1 cm wide and was covered during familiarization by a flap; the flaps were attached to a single curtain rod which could be lifted to permit simultaneous presentation of the two test objects. The curtains also had a small hole 28 cm to the left and right of the midline division to permit observation of fixation. (See Figure)

Fixation of the objects was recorded on a 4 channel Rustrak event recorder (Model 292-4, 60 rpm motor, #15 high speed gear train, power unit 921-8).

Stimuli

To increase the generality of results, two stimulus pairs were used, the pairs differing markedly (to an adult) from each other. Pair 1 of the visual stimuli were textured geometric shapes constructed of papier mache; the objects were an orange upside-down heart (90 mm high; 90 mm wide; 30 mm deep) and a purple star (150 mm high; 110 mm wide; 32 mm deep). Pair 2 were smooth rubber animal shapes; the objects were a blue mouse (80 mm high; 50 mm wide; 80 mm deep) and a green frog (50 mm high; 73 mm wide; 62 mm deep). Each pair of auditory stimuli consisted of one rhythmic and one fairly constant sound. Pair 1 consisted of the rhythmic sound of a single note struck on the piano (C two octaves above middle C) at a rate of 1 per 2 seconds and the fairly constant sound of a ratchet wheel noisemaker. Pair 2 consisted of the rhythmic sound of a toy squeaked at a rate of 1 per 2 seconds and the fairly constant sound of a high pitched bell rung continuously. The auditory stimuli were recorded on cassette tape and played on portable GE and Panasonic cassette recorders, channeled through small, independent speakers (3.2 cm).

Procedure

The apparatus was assembled and the infant seated facing the testing booth on its mother's lap; the mother was requested to keep the infant centered in front of the booth and to prevent the infant from touching the experimental stimuli. The experimenter and observer were behind the booth, concealed from sight of the infant. The experimenter scheduled the testing procedures and presented the experimental stimuli. The observer recorded fixation of the experimental stimuli throughout familiarization and test procedures.

The infant was presented with a sound and object for three 30 second familiarization trials. Familiarization was followed by two 10 second tests; the familiar and novel objects were presented simultaneously with the familiar sound in one test and the novel sound in the other test. To control for possible position preferences, the infant was then given an additional 30 second familiarization, followed by another two 10 second tests with the position of the two objects reversed. Trials, including familiarization and tests, were separated by approximately 5 seconds. Duration of trials and intertrial intervals was monitored by a stopwatch. Following testing with the first stimulus pair, there was a break of sufficient duration (generally several minutes) to permit the preparation of the second pair of experimental stimuli during which the infant was removed from the testing situation. The same procedure was then repeated with the second pair of objects and sounds.

For familiarization, the object was attached to a thin dowel rod and projected through the center division of the curtain; the objects were moved throughout familiarization but the type of movement was different in the different studies. To control for possible stimulus preferences, each object in each stimulus pair served as the familiar object for approximately one half the subjects in each study. During familiarization, sound was presented from a small speaker which was attached to the dowel rod just behind the object where it was obscured by the object; the sounds therefore appeared to an adult to come from the object. The exception was Study II, in which the familiarization speaker was attached to the testing booth. Because general background noise level varied from home to home, the intensity of the experimental sounds was adjusted to achieve sounds which were moderately loud and of an approximately uniform ratio to background sound level.

For tests, both the familiar and a novel object were presented simultaneously, in the presence of either the familiar or a novel sound. The objects were attached to a white board 32.4 cm apart from center to center. This board was placed so that the objects were behind the two curtain flaps and so equidistant from the midline to the left and right. For the onset of each test, the two objects were simultaneously exposed by raising the curtain rod to which the two flaps were attached. At the same time that the two objects were exposed, either the familiar or a novel sound was switched on. Sounds during tests were produced from a speaker at the midline of the back wall just above the curtain; since this speaker was midway between the familiar and novel objects, the sounds could not be localized, by an adult, to either object. Each infant was given a total of 4 tests, 2 under each sound condition. To control for possible position bias, the position of the familiar and novel objects was reversed between tests 2 and 3. Two counterbalanced sound orders were used (familiar-novel-novel-familiar; novel-familiar-familiar-novel); approximately half the infants were given each sound order.

The observer monitored the infant's eyes through one of the observation peepholes and recorded, via pushbuttons, the infant's fixation of stimulus objects on an event recorder. Each recording reflected both incidence and duration of fixation. In observing position, the observer faced the infant (but was hidden by the test booth) and was approximately 64 cm removed from the infant and 23 cm to the right of the infant's midline. The stimulus objects were at a 90° angle from the observer's line of vision and were not easily seen by the observer.

Scoring fixation

The Rustrak tapes were scored twice. The nature of the recordings ensured that the scorers would be blind to the experimental conditions of the tapes being scored. The scorer measured the length of each fixation to the nearest 32nd of an inch, a 32nd corresponding to $\frac{1}{4}$ second fixation.

Analysis of results

Because fixation patterns can vary for different infants and in relation to particular experimental stimuli, the data were analyzed in terms of the number of fixations, duration of fixation and proportion of fixation (the ratio of the duration of fixation of the familiar object to the duration of fixation of both objects). These measures have been standardly used in the literature and were all examined here, since the testing methods of this research are unusual to the investigation of auditory-visual behaviors and there was no rationale for selecting out any one of the three measures. Analysis of the data indicated that, in general, the results of the three response measures were essentially the same. However, observer reliability (see below) for number of fixations was relatively low (Appendix C); the data for number of fixations are therefore not presented in the results sections of each study, but are instead presented in a summary table in Appendix D.

Reporting of results

Because the intervening familiarization could have produced differences in learning shown in tests 1 and 2 and tests 3 and 4, data were first analyzed for differences in fixation shown in these two sets of tests. This comparison did not reveal any systematic differences between the two sets of tests (Appendix E) and the data are therefore presented in terms of means based on the 4 tests.

Similarly, data for familiarization are presented as the mean for the four familiarizations, since comparison between the four familiarizations did not reveal any systematic differences between them (Appendix F).

In addition, since no sex differences were suggested in any of the studies for either stimulus pair, the results reported are for male and female subjects combined.

Results were also analyzed for systematic bias in direction of looking. This analysis revealed a trend toward increased looking at the object on the right ($t=2.038$, $p<.10$) for Pair 2 in Study II and a significant increase in looking to the left object ($t=3.364$, $p<.01$) for Pair 1 in Study III. The results in both of these cases were corrected for position bias and reanalyzed (Appendix G), but the corrected data indicated the same pattern of results as the uncorrected data. The results are therefore reported without regard to object position.

Although not directly relevant to the results of the present research, since each object served as the familiar object for one half the subjects, a detailed description of the analysis for stimulus preference is presented in Appendix H.

Observer reliability

Observers were not informed of the experimental conditions; although during familiarization, they could see and hear the object and sound, during tests, their opportunities for locating the left-right position of the two objects were minimal: the objects were very peripheral to the observers (about 90° from their line of sight) and the pace of the experimental procedures did not give the observers opportunity to remove their eyes from the observation peephole once the testing for a particular experimental stimulus pair had begun. The observers reported little awareness of object position or nature of sound while observing.

Ten people served as observers in this study; 2 of these were observers for 59% of the infants included in the data analysis and 4 were observers for 83% of the infants.

Reliability was assessed in two ways. In the first method, each of the 4 people who had observed the largest number of infants scored the same videotape of a 6-month-old infant; because of the particular importance of reliability for tests, the videotape included 4 familiarizations and 8 tests. Although the videotape was made in the laboratory, it was similar in most respects to the actual testing situation (in particular, it was taken from the slight angled position of the observation peephole). This method permitted a standard base on which to compare observations. Reliability was also assessed in the standard testing situation by direct observation of different infants. For this, the two principle observers were paired together twice and each was paired with one other observer; each pair observed an infant simultaneously.

Analysis for reliability was based on Pearson r correlations of the duration of fixation for each observer (reliability for number of fixations is presented in Appendix C). When the 4 observers scored the same videotape of an infant, the mean correlations for duration of fixation were .93 (range .87 to .98) and .91 (range .84 to .97) for fixations of the object on the infant's left and right, respectively, and .94 (range .87 to .99) for familiarization. For the direct observations of different infants, the mean correlations for duration of fixation were .86 (range .71 to .97) and .90 (range .80 to .99) for fixations of the object on the infant's left and right, respectively, and .87 (range .65 to .97) for familiarization.

Study I: Spatial and temporal congruity

This first study explored whether 6-month-old infants would demonstrate coordination of auditory and visual stimuli when they were maximally congruent with respect to both time and space. To stress the relationship of the auditory and visual stimuli as properties of the same object, and so maximize the likelihood of auditory-visual coordination, the object moved in pronounced rhythmic synchrony with the sound it was producing. Spatial congruity was accentuated since the sound came from the object and moved in space with the object. Temporal congruity was accentuated since both the object and sound were presented and removed simultaneously and neither stimulus was presented to the infant without the other. In addition, both object and sound exhibited a periodic synchronized temporal pattern.

Method

Subjects

The subjects for this study were 23 infants, 11 males and 12 females (the 1 and 5 minute Apgar scores of one subject were below the usual criteria, being 6 and 8, respectively). 8 additional infants were tested but excluded prior to data analysis (2 for crying, 1 for sib interference, 2 for extraneous sound, 3 for experimenter error). The mean age of the subjects was 26 weeks, with a range of 25 weeks, 4 days, to 27 weeks, 6 days.

Procedure

At the same time that the object to be familiarized was projected through the center of the curtain, the rhythmic sound was switched on and the object was moved in synchrony with the sound. Since sound was produced through a speaker just behind the object, it appeared to an adult to come from and move with the object. For Pair 1, the object moved in an arc (the end points approximately 20 cm apart) and for Pair 2, the object moved up and down (the end points approximately 15 cm apart). In both cases, the change in direction of movement coincided with the occurrence of a sound.

Results

When performance for the two stimulus pairs was combined (see Table 1), in the presence of the familiar sound, infants spent a significantly greater proportion of their fixation time ($t=3.551$, $p<.01$) looking at the familiar object than at the novel object and they looked at the familiar object significantly longer ($t=3.396$, $p<.01$) than at the novel one. In contrast, in the presence of the novel sound, they did not look differentially at either object.

Analysis of variance was not done for proportion of fixation since the proportion of fixation for the familiar and novel objects are complements (within studies, they add to 100% of the looking time); the required two way ANOVA would be essentially the same as the t tests already reported. For duration of fixation, ANOVA indicated a significant difference in response to the two visual stimuli in relation to the two auditory stimuli (auditory-visual interaction, $F=5.97$, $p=.02$). The main effect for visual condition ($F=6.00$, $p=.02$) reflected increased fixation of the familiar object under both sound conditions.

Analysis of the data for each pair separately (see Table 1) indicated essentially the same pattern of fixation as for the combined data. For Pair 1, in the presence of the familiar sound, the infants spent a significantly greater proportion of their fixation time ($t=2.128$, $p<.05$) looking at the familiar than the novel object; they also looked longer at the familiar than the novel object, but this difference was not significant. In contrast, in the presence of the novel sound, the infants showed no differential fixation of the two objects. For Pair 2, in the presence of the familiar sound, the infants spent a significantly greater proportion of their fixation time ($t=2.800$, $p<.02$) looking at the familiar than the novel object and they looked significantly longer ($t=3.728$, $p<.01$) at the familiar than the novel object. In contrast, in the presence of the novel sound, they did not look differently at either object.

ANOVA for each pair indicated results in the same direction: a trend toward a difference in duration of fixation of the two objects in relation to the two sounds was indicated for each pair (auditory-visual interaction for Pair 1: $F=3.28$, $p<.10$; auditory-visual interaction for Pair 2: $F=3.67$, $p<.10$).

The infants also looked more at the familiar object in the presence of the familiar sound than in the presence of the novel sound (see Table 2). For each pair, they looked significantly longer at the familiar object in the presence of the familiar sound than in the presence of the novel sound (for Pair 1: $t=2.491$, $p<.05$; for Pair 2, $t=2.104$, $p<.05$) and proportion of fixation indicated a trend in the same direction for Pair 1 ($t=1.720$, $p=.10$).

The data were also analyzed for whether infants shifted their fixations between objects more in the presence of the familiar or novel sound, but no differences were indicated.

Infants tended to look at the sounding object for most of each of the familiarization periods. The mean durationof fixation was 28.60 seconds (range 27.61 to 29.32) for Pair 1 and 28.12 (range

26.90 to 29.88) for Pair 2. ANOVA did not indicate any differences between the four familiarization periods in duration of fixation for either pair. The duration of fixation shown by each infant during familiarization was not correlated with fixation of the familiar object in the presence of the familiar sound during test.

Discussion

The results of this study indicate that 6-month-old infants will look differentially at a particular combination of auditory and visual stimuli when they have had experience in which these stimuli have exhibited maximal spatial and temporal congruity. To accentuate the spatial and temporal congruity of the object and sound, infants were familiarized with an object which moved in pronounced rhythmic synchrony with the sound it was producing. They subsequently looked significantly more at the familiar object in the presence of the familiar sound and only in the presence of the familiar sound; they did not look differently at either the familiar or novel object in the presence of a novel sound. This differential pattern of fixation was shown when the data for two stimulus pairs of quite different stimulus characteristics were analyzed separately and when the results for the two pairs were combined.

Infants in this study showed some tendency to look more at the familiar object during both sound conditions, as indicated by the main effect of visual condition in the ANOVA for duration of fixation for the combined pairs data. However, their pattern of fixation of the familiar and novel objects was differentially related to the familiar and novel sound conditions. This was reflected in a significant auditory-visual interaction for duration of fixation for the pairs combined and the trends toward an auditory-visual interaction for each pair separately.

In addition, the infants looked significantly more at the familiar object in the presence of the familiar as opposed to the novel sound.

The results of this study indicated that the spatial and temporal congruity of the object and sound during familiarization was sufficient so that they were coordinated. Subsequent studies were designed to explore the influence of different aspects of the spatial and temporal congruity on coordination.

Study II: Spatial incongruity

This study explored the influence of the spatial congruity exhibited by the auditory and visual stimuli in the first study on the infants' coordination of these stimuli. In this study, the familiarization procedures were the same as in the first study, except that the sound emanated from a different location from that of the object. Therefore, the object moved in a periodic fashion in temporal synchrony with the sound, but the object was presented in front of the infant while the sound was presented from a lateral location.

Method

Subjects

The subjects were 22 infants, 11 males and 11 females. The number of subjects contributing to data analysis for each stimulus pair was 21, since data was omitted for the first stimulus pair for one male (for experimenter error) and for the second stimulus pair for one female (for interference by a sibling). 2 additional infants were excluded for crying. The mean age of the infants was 26 weeks, ranging from 25 weeks, 2 days, to 27 weeks.

Procedure

The testing procedures used in this study were exactly the same as those for the first study, except that during familiarization sound was produced from a different spatial location than that of the object. The speaker to be used for familiarization was mounted near the upper left corner of the testing booth, 54 cm from the bottom and 51 cm from the back wall. Sound coming from this speaker was clearly spatially dislocated from the object to an adult, since it came from above the head and about 90° to the left of someone sitting in the testing position, while the object was presented in a front midline location. Another speaker identical in appearance to the first was attached to the dowel rod used for object presentation during familiarization, so that all visual characteristics of the familiarization procedure were identical to those of the first study.

Results

Results are presented in Table 3. Analysis for the data for Pair 1 and Pair 2 combined did not provide any indication that the infants looked differently at the familiar or a novel object in the presence of either the familiar or novel sound. ANOVA of the duration of fixation indicated essentially the same results: there was no indication of an auditory-visual interaction. The main effect of auditory condition ($F=5.42$, $p<.05$) reflected longer fixation of both objects during the novel sound.

Analysis of response to each of the two pairs separately indicated essentially the same results: infants did not look differently at either the familiar or novel object in the presence of the familiar or novel sound for either pair. The only suggestion of differential response was a trend ($t=1.828$, $p<.10$) toward looking longer at the familiar object in the presence of the familiar sound for Pair 1 only. ANOVA did not suggest an auditory-visual interaction for either pair. For Pair 1, a trend toward a main effect of visual condition for duration of fixation ($F=2.99$, $p=.10$) suggested that the infants tended to look longer at the familiar object regardless of auditory condition.

Data were also analyzed for whether the infants shifted their fixations between objects more in the presence of the familiar or novel sound. For Pair 1, no differences were indicated. For Pair 2, the infants shifted their fixation significantly more frequently ($t=2.204$, $p<.05$) during the novel sound ($\bar{X} = 7.9$) than during the familiar sound ($\bar{X} = 6.5$).

Infants tended to look at the sounding object for most of each familiarization period. The mean duration of fixation was 26.46 seconds (range 24.11 to 29.52) for Pair 1 and 25.56 seconds (range 24.79 to 26.90) for Pair 2. ANOVA did not indicate any differences between the four familiarization periods in duration of fixation for either pair. The duration of fixation shown by each infant during familiarization was not significantly correlated with fixation of the familiar object in the presence of the familiar sound during test.

Discussion

In this study, infants did not show any differential fixation indicative of coordination following familiarization with auditory and visual stimuli which were spatially incongruent. No differential pattern was indicated when data were analyzed for both stimulus pairs combined or for each pair separately. The familiarization procedures had been designed to maximize the likelihood of coordination, given the absence of spatial congruity: although they were in different spatial locations, the object and sound exhibited synchronized pronounced (periodic) rhythm. Therefore, the lack of differential response suggests that spatial congruity may be necessary for coordination of auditory and visual stimuli to be established in 6-month-old infants.

Study III: Temporal incongruity; continuous movement, periodic sound

This study explored the influence of the temporal congruity of the auditory and visual stimuli in the first study on the infants' coordination of these stimuli; in particular, it explored the influence of temporal congruity of movement of the object and occurrence of the sound. In this study, the familiarization procedures were the same as in the first study, except that, while the object produced the same periodic sound, it moved continuously and slowly toward and away from the infant.

Method

Subjects

The subjects were 21 infants, 8 males and 13 females. An additional 6 infants were tested but excluded from the data analysis (2 for experimenter error, 1 for interruption of testing by visitors, 1 for crying, 2 for history of illness not revealed to the experimenter until after testing). The mean age of the infants was 26 weeks, 1 day, with a range of 25 weeks, 4 days, to 27 weeks, 5 days.

Procedure

The procedures used in this study were exactly the same as those for the first study, except that during familiarization the object moved continuously (approximate rate of 1.25 cm/sec) toward and away from the infant. Although it would have been preferable to present stationary objects, the object was moved in this fashion primarily to facilitate maintenance of the infant's attention, since other experimenters have reported that infants often become fussy during familiarizations of durations comparable to those of this study if they involve stationary stimuli (Ruff, Gottfried, personal communication).

Results

Results are presented in Table 4. Analysis of the data for Pair 1 and Pair 2 combined indicated that, in the presence of the familiar sound, infants looked significantly longer ($t=2.128$, $p<.05$) at the familiar than the novel object; they did not spend a greater proportion of their total fixation time looking at the familiar object. In the presence of the novel sound, they showed no indication of differential fixation of the familiar and novel objects. ANOVA for duration of fixation indicated a significant difference in response to the visual stimuli in relation to the auditory stimuli (auditory-visual interaction, $F=5.21$, $p<.05$).

Analysis of the responses to each pair separately suggested that the results for the combined pairs analysis were attributable primarily to responses to Pair 2. Analysis for Pair 1 alone indicated that infants did not look differentially at the familiar or novel object in the presence of either the familiar or novel sound. For Pair 2, in the presence of the familiar sound, the infants looked longer ($t=2.209$, $p<.05$) at the familiar than the novel object; they did not spend a greater proportion of their total fixation time looking at the familiar object. Although ANOVA did not indicate a differential response pattern for Pair 1, ANOVA for duration of fixation for Pair 2 indicated a highly significant auditory-visual interaction ($F=13.42$, $p<.01$).

When fixation of the familiar object in the presence of the familiar sound was compared with fixation of the familiar object in the presence of the novel sound (see Table 5), no difference was indicated for Pair 1. For Pair 2, infants looked more at the familiar object in the presence of the familiar sound than in the presence of the novel sound, as indicated by a significantly greater proportion of fixation ($t=2.312$, $p<.05$) and by a trend in the same direction for duration of fixation ($t=1.784$, $p<.10$).

During familiarization, the mean duration of fixation was 25.64 seconds (range 25.01 to 26.04) for Pair 1 and 24.20 (range 21.75 to 26.42) for Pair 2. For neither pair were the familiarization periods significantly different from each other, nor was duration of fixation during familiarization correlated with fixation of the familiar object in the presence of the familiar sound.

Discussion

In this study, infants were familiarized with an object which produced a periodic sound while it moved in an incongruent continuous manner. When data were analyzed for the two stimulus pairs combined, proportion of fixation did not indicate a differential fixation indicative of coordination. However, duration of fixation indicated a differential fixation: infants looked longer at the familiar than the novel object in the presence of the familiar sound but they did not look differentially at the two objects in the presence of the novel sound. Analysis of the data for the two stimulus pairs separately suggested that this differential duration of fixation was attributable largely to the second stimulus pair: no differential fixation was indicated for the first stimulus pair but differential fixation was indicated in several ways for the second stimulus pair. Duration of fixation indicated that, in the presence of the familiar sound, infants looked significantly longer at the familiar than the novel object but did not look differently at the two objects in the presence of the novel sound. A significant auditory-visual interaction for the ANOVA of duration indicated a differential response to the objects in relation to the sounds. In addition, although proportion of fixation of the familiar object was not significantly greater than that of the novel object during the familiar sound, proportion of fixation of the familiar object in the presence of the familiar sound was significantly greater than proportion of fixation of the familiar object during the novel sound.

While the results therefore indicate coordination of the object and sound of the second stimulus pair, the generality of the results is brought into question by the absence of differential fixation indicative of coordination for the first stimulus pair.

The results of Study I and Study III together suggest that the characteristics of the object and sound of one of the two stimulus pairs are particularly conducive to coordination: evidence for the coordination of this object and sound was indicated following the familiarization conditions of both studies. However, the familiarization conditions of the two studies do not appear to be equally effective for the establishment of coordination: in the first study, a pattern of fixation indicative of coordination was shown for two stimulus pairs of quite different characteristics but in the present study, this differential fixation was shown for only one of the two stimulus pairs. The familiarization conditions of the two studies differed only on the basis of congruity of temporal pattern; therefore, the difference in effectiveness of the two familiarization conditions must be related to this factor.

Study IV: Temporal incongruity; periodic movement, continuous sound

This study further explored the influence of temporal congruity of movement of the object and occurrence of the sound on infants' coordination of these stimuli. In this study, the familiarization conditions were the same as in the first study, except that the object produced a continuous sound while it moved periodically. The temporal incongruity of this study was therefore different from, but complementary to, the temporal incongruity of the previous study.

Method

Subjects

The subjects were 23 infants, 12 males and 11 females. The number of subjects contributing to data analysis for each stimulus pair was 21, since data was omitted for the first stimulus pair for one male (extraneous noise) and one female (experimenter error) and for the second stimulus pair for one male and one female (both for crying). One additional infant was tested but excluded prior to data analysis (for history of illness not revealed to the experimenter until after testing). The mean age of the infants was 26 weeks, ranging from 25 weeks, 1 day, to 26 weeks, 6 days.

Procedure

The testing procedures used in this study were exactly the same as those for the first study, except that during familiarization the object produced a relatively continuous sound; also, during tests, the novel sound was periodic. (The fairly constant sound of each pair of auditory stimuli was the familiarized sound and the periodic sound of each pair was the novel sound.)

Results

Results are presented in Table 6. Analysis of the data for Pair 1 and Pair 2 combined did not provide any indication that the infants looked differently at the familiar or a novel object in the presence of either the familiar or novel sound. ANOVA of the duration of fixation indicated essentially the same results: there was no indication of an auditory-visual interaction.

Analysis of response to each of the two stimulus pairs separately indicated essentially the same results; infants did not show a pattern of differential fixation indicative of coordination for either pair.

The data were also analyzed for whether infants shifted their fixations between objects more in the presence of the familiar or novel sound, but no differences were indicated.

Infants tended to look at the sounding object for most of each of the familiarization periods. The mean duration of fixation was 25.86 seconds (range 24.37 to 28.67) for Pair 1 and 25.96 seconds (range 24.11 to 29.64) for Pair 2. For Pair 2, ANOVA indicated that the duration of fixation for the four familiarization periods was significantly different ($F=4.882$, $p<.05$); inspection of the data indicated a progressive decline in duration of fixation over the four periods. For Pair 2, the duration of fixation during familiarization was significantly correlated with duration of fixation of the familiar object in the presence of the familiar sound during test ($\underline{r} = .425$, $p<.05$).

Discussion

In this study, infants did not show any differential fixation indicative of coordination following familiarization in which the object had moved periodically while producing a temporally incongruent continuous sound. No differential pattern was indicated when data were analyzed for both stimulus pairs combined or for each pair separately. These results suggest that the conditions of temporal incongruity of the present study (involving periodicity of object movement and constancy of sound) are not supportive of the establishment of coordination although the results of the previous study suggest that the temporal congruity of that study (involving constancy of movement and periodicity of sound) may be supportive of coordination.

Studies III and IV: Temporal incongruity

The data for Studies III and IV combined were analyzed in order to assess the influence of temporal incongruity overall. The results of this analysis are presented in Table 7. No pattern of fixation indicative of coordination was indicated by comparison of fixation of the familiar and novel objects in the presence of the familiar and in the presence of the novel sound, nor by analysis of a pattern of differential fixation of the two objects in relation to the two sounds by ANOVA.

Study V: Visual only control; periodic movement

In the present research, coordination was indicated by greater response to the familiar than a novel object in the presence of the familiar sound and by either no differential response to either object or greater response to the novel object in the presence of the novel sound. Although coordination was therefore indexed by a differential response to a particular combination of auditory and visual stimuli, it was possible that a systematic preference for a novel or the familiar object regardless of auditory condition might have obscured or distorted the results. For example, investigators of visual discrimination using the familiarization-test procedures incorporated into the research design used in this research have almost universally reported that infants look more at a novel visual stimulus than the familiar one during tests. Such a novelty preference did not obscure a differential pattern of fixation under the conditions of maximal spatial and temporal congruity of the first study. However, it might have masked or distorted differential fixation in the subsequent studies, in which the congruity of the object and sound was reduced, if that reduced relationship resulted in weaker coordination. That is, since coordination was indicated particularly by greater response to the familiar object in the presence of the familiar sound, a visual novelty preference would have conflicted with that response and could have masked it. On the other hand, a familiarity preference could in itself have resulted in greater response to the familiar object during the familiar sound.

Two studies were conducted to explore for such visually based preferences. These studies were the same visually as the previous auditory-visual studies, but there were no associated sound conditions.

The present study explored response to the visual components of Studies I, II, and IV. That is, during familiarization, the object moved in the same periodic manner as in those studies; the infants were then tested for their response to the familiar and a novel object in silence.

Method

Subjects

The subjects were 22 infants, 11 males and 11 females. An additional 3 infants were tested but excluded prior to data analysis (2 for crying; 1 for history of illness not revealed to the experimenter until after testing). The mean age of the infants was 26 weeks, 1 day, ranging from 24 weeks, 6 days, to 27 weeks.

Procedure

The testing procedures used in this study were exactly the same as those for the first study, except that no sound was presented during familiarization or during tests. In addition, removal of sound would have meant that the consecutive tests of 1 and 2 and tests 3 and 4 were identical, while there had been a change (in sound) between consecutive tests in the auditory-visual studies; therefore, the position of the objects was reversed between tests 1 and 2 and between tests 3 and 4 in the present study.

Results

The results of this study are presented in Table 8. The data do not indicate differential fixation of the familiar or novel objects, either when the data for the two stimulus pairs was combined or when data for Pair 1 and Pair 2 was analyzed separately.

Discussion

The results of this study do not indicate any differential response to the familiar or a novel object following familiarization with an object moving in a periodic manner. The familiarization procedures of the present study were identical to those of Study I (Spatial and temporal congruity), Study II (Spatial incongruity), and Study IV (Temporal incongruity; periodic movement, continuous sound), except that there were no associated sound conditions. Therefore, these results indicate that neither a novelty or familiarity preference are likely to have obscured or distorted the results of these studies. While these results therefore clarify the interpretation of the results of the present research, they diverge from the results usually reported in the visual discrimination literature; this divergence is discussed in connection with the next study.

Study VI: Visual only control; continuous movement

This study explored response to the visual components of Study III. That is, during familiarization, the object moved continuously and slowly toward and away from the infant in the same manner as in that study; the infants were then tested for their response to the familiar and a novel object in silence.

Method

Subjects

The subjects were 24 infants, 13 males and 11 females. Three additional infants were tested but excluded prior to data analysis (2 for experimenter error; 1 for interference by a sibling). The mean age of the infants was 26 weeks, ranging from 24 weeks, 5 days, to 27 weeks, 4 days.

Procedure

The testing procedures used in this study were exactly the same as those for the third study, except that no sound was used either for familiarization or for tests. In addition, as for the previous study, the position of the objects was reversed between tests 1 and 2 and between tests 3 and 4.

Results

Results are presented in Table 8. Analysis of the data for Pair 1 and Pair 2 combined did not indicate a differential response to either the familiar or a novel object. Similarly, no differential response was indicated for Pair 2. However, for Pair 1, although proportion of fixation did not indicate any differential fixation, duration of fixation was significantly greater for the familiar than the novel object ($t=3.211$, $p<.01$).

Discussion

Following familiarization with an object which moved continuously and slowly toward and away from them, infants did not show, overall, a differential response; that is, analysis of the data for Pair 1 and Pair 2 combined did not indicate a differential response to the familiar or novel object. When the data were analyzed for each stimulus pair separately, no differential fixation was indicated for Pair 2. For Pair 1, no differential fixation was indicated by one response measure (proportion) but a familiarity preference was indicated by the other measure (duration). The complete absence of differential fixation for one of the two stimulus pairs suggests that specific stimulus characteristics rather than pattern of movement may be responsible for the difference in results. However, the complete absence of differential response for Pair 2; the fact that a difference was indicated for Pair 1 by only 1 of the 2 response measures; and the complete absence of differential fixation in the previous visual control study suggest that differential fixation for Pair 1 in this study may be due to random factors.

The familiarization procedures of this study were identical to those of Study III, except that there was no associated sound condition. The lack of any indication of a novelty preference in this study indicates that a novelty preference did not obscure or distort the results of Study III. While there was some suggestion of a familiarity preference for Pair 1 in this study, the results in Study III for Pair 1 (see Table 4) gave no indication of increased fixation of the familiar object and suggest that a familiarity preference did not interfere in any obvious way in Study III.

Although not germane to the central concern of this research, the failure to find a differential pattern of fixation, particularly a novelty preference, in this and the previous visual control study is puzzling, since the literature based on visual familiarization-test procedures has generally reported a novelty preference. Factors which control fixation and/or contribute to the appearance of a familiarity or novelty preference are currently poorly understood, but there are a number of differences between the research reported here and much of the visual discrimination literature which may underlie differences in results. One difference is in the nature of the stimuli used: in the present research, the visual stimuli were relatively large, tangible, three dimensional objects; in contrast, much of the literature has been concerned with two dimensional visual displays, or occasionally with free standing cutouts. In the present research, when the objects were visible, they were in relatively close proximity to the infants; close proximity of objects of the nature of those used in this research might make these objects more attractive or even more fearful and either might increase fixation of these objects. Under the conditions of continuous movement, the objects moved in and out of reaching range of the infants and this approach and withdrawal may have had a motivational effect, again increasing the attractiveness or the threatening quality of the objects, and so increasing the tendency to fixate these objects. Increased interest in the familiar object and increased tendency to fixate it could have resulted in lack of a differential pattern of fixation if it conflicted with an attraction to novelty and so each neutralized the other, or it could have resulted in a familiarity preference.

Comparison of studies

The results of the four auditory-visual studies indicate that the familiarization conditions of the four studies had different effects. A post hoc analysis was used to assess whether there was a difference between these effects when they were directly compared. In this analysis, the first study, which involved the condition of maximal spatial and temporal congruity, was considered the standard or control condition. The other studies, which each involved the removal of some aspect of this congruity, were compared against this control, using a common estimate of experimental error, on the basis of the Dunnett $\underline{t}$ statistic.

For duration of fixation, this comparison was based on the difference in duration of fixation of the familiar and novel objects for the familiar and novel sound conditions separately. Duration differences for both stimulus pairs combined indicated that, in the presence of the familiar sound, Study IV differed significantly from Study I (mean difference for Study I = 1.44 secs., for Study IV = -.14 secs., Dunnett $\underline{t}$ = 3.33, $p < .01$) and Study II showed a trend in the same direction (mean difference for Study I = 1.44 secs., for Study II = .34 secs., Dunnett $\underline{t}$ = 2.32, $p < .10$); results for Study III were in the same direction but nonsignificant. The data for Pair 1 alone did not indicate any differences. Duration differences for Pair 2 alone indicated that, in the presence of the familiar sound, Study II and Study IV each differed significantly from Study I (mean difference for Study I = 2.17 secs., and for Study II = -.12 secs., Dunnett $\underline{t}$ = 2.99, $p < .05$; mean difference for Study IV = -.59 secs., Dunnett $\underline{t}$ = 3.60, $p < .01$); again, results for Study III were in the same direction but nonsignificant. In the presence of the novel sound, there were no differences in duration of fixation between the studies. While proportion of fixation indicated differences in the same direction in the familiar sound condition, they were not significant.

Fixation during familiarization was also compared on the basis of the Dunnett t statistic. This comparison indicated that duration of fixation during familiarization in Study III differed from that of Study I on the basis of the combined data (mean duration for Study I = 28.36 secs., for Study III = 24.93 secs., Dunnett $t = 2.89$, $p < .05$) and for Pair 2 (mean duration for Study I = 28.12 secs., for Study III = 24.20 secs., Dunnett $t = 2.78$, $p < .05$); data for Pair 1 showed a trend in the same direction (mean duration for Study I = 28.60 secs., for Study III = 25.64 secs., Dunnett $t = 2.21$, $p < .10$). Duration of fixation during familiarization in Studies II and IV did not differ from that of Study I.

The comparison of test results suggests that the effects of the familiarization conditions of Studies II and IV, which each involved a type of incongruity, were different from the effects of the familiarization conditions of Study I, which involved maximal spatial and temporal congruity; that is, following familiarization conditions which involved either spatial incongruity or one type of temporal incongruity, the pattern of fixation of the familiar and novel object in relation to the familiar sound was significantly different from that shown following familiarization conditions in which the object and sound were spatially and temporally congruent. Differences shown for Study III were in the same direction, but they were not significant.

The comparison of fixation during familiarization indicates that duration of fixation during familiarization of Studies II and IV was not different from that of Study I; this suggests that the differences in test results for Studies II and IV from those of Study I were not due to a reduced duration of fixation during familiarization in these two studies. That Study III differed significantly from Study I in the duration of fixation during familiarization supports the finding reported for the individual studies that duration of fixation during familiarization is not strongly related to differential fixation indicative of coordination during tests: duration of fixation indicated significantly longer fixation of the familiar object than the novel one in the presence of the familiar sound in Study III for the combined data and for Pair 2 and yet these are the only cases which indicated a significant reduction of duration of fixation during familiarization relative to that of Study I.

General discussion

The results of this research indicate that following familiarization with an object which moved in synchrony with a periodic sound which came from the object (Study I), 6-month-old infants subsequently, in the presence of the familiar sound, looked more at the familiar object than a novel one; in contrast, in the presence of a novel sound, they did not look differentially at either object. This pattern of differential fixation was indicated when response to two stimulus pairs of very different characteristics was combined and when response to each pair was analyzed separately.

In contrast, when the spatial and temporal congruity of the object and sound were altered or removed during familiarization, infants did not show a differential pattern of fixation. That is, little or no differential fixation indicative of coordination was shown following familiarization identical to that of the first study except that: 1) the sound source was removed from the object so that the object was presented at front midline while the sound was presented from 90° to the side of the infant (Study II); 2) the object moved continuously while the sound it produced was periodic (Study III); 3) the object moved periodically while the sound it produced was continuous (Study IV). The sole indication of coordination under any of the conditions of reduced congruity was in Study III (continuous movement, periodic sound) in which the infants showed differential fixation suggestive of coordination for one of the two stimulus pairs. Although the absence of any evidence suggestive of coordination for the first stimulus pair could suggest that the differential fixation for the second stimulus pair was due to random factors, it seems more likely that the results reflect the differences between the characteristics of the objects constituting the two pairs and that coordination under this condition of temporal incongruity is strongly related to particular characteristics of the object and sound.

In two visual control studies, the same procedures as for the previous auditory-visual studies were followed except that there were no associated auditory conditions. Infants did not show differential fixation of the familiar or novel objects, suggesting that neither novelty or familiarity preferences were responsible for the results obtained in the auditory-visual studies.

The results of the individual studies indicated that the familiarization conditions of the four studies had different effects. A post hoc analysis, which compared each of the incongruity studies directly with maximal congruity study (Study I), suggested that the results of two of the incongruity studies (Studies II and IV) were each different from the results of the first study; results of the third were in the same direction but were not significantly different.

The data obtained during the familiarization period suggest that differences between the pattern of fixation shown in Study I and Studies II, III, and IV were not related to differences in the amount of visual attention during familiarization. Duration of fixation during familiarization in Studies II and IV was not different from that of Study I; duration of fixation was less than for Study I only in Study III, which was the only incongruity study in which infants showed, in test, a differential pattern of fixation for one stimulus pair which was similar to the differential pattern of fixation of Study I.

Thus far, these results from Study I have been interpreted as indicating intersensory coordination. However, intersensory coordination is a relatively high level form of integration; appeal to this higher level integration would not be desirable if the results could be as readily interpreted in terms of lower level intersensory influences such as facilitation and inhibition. Such an interpretation would seem to require three major components. First, that sound has an activating influence, so as to increase responsiveness to a visual stimulus; that is, that it increases interest in the visual aspects of objects. Second, that the increased visual attention produced by the sound results, during tests, in greater fixation of the familiar object (familiarity preference). Third, that sound also serves a disruptive function, so that introduction of a novel sound during tests disrupts the familiarity preference. According to this interpretation, in Study I, for example, the visual familiarity preference shown in tests in the presence of the familiar sound resulted because sound, when it is spatially and temporally congruent with an object and both exhibit a common rhythm, caused the infants to attend to aspects of the visual stimulus, so producing a familiarity preference; the absence of the familiarity preference in the presence of the novel sound resulted because of the disruptive influence of the novelty of the sound. Similarly, interpretation of the results of other studies would parallel the interpretations already described. For example, the absence of a familiarity preference in the second study would result because sound does not sufficiently enhance interest in an object when it is spatially displaced from the object to produce a familiarity preference.

This interpretation entails two distinctly different functions for sound, its function depending on whether it is a novel sound during familiarization or during test: sound is posited to increase interest and organize looking during familiarization but to disorganize looking during test. Mechanisms by which sound might come to have this differential effect are unclear. One possibility is that habituation to visual and auditory stimuli proceed independently and at very different rates, so that during the familiarization of the present research, the infant becomes auditorily but not visually habituated; subsequently, during test, the infant continues to look at the object in the presence of the habituated familiar sound. Introduction of the novel sound results in recovery of looking, but it is disruptive. This disruption could result from inhibition of the familiarity preference or from competition arising from increased interest in the novel object. Such increased attraction to the novel object would compete with attraction to the familiar object to produce no recognizable preference. Any such competition might be expected to result in an increase in shifts of fixation between the objects during the novel sound. No such difference in shifts during the two sound conditions was observed.

There is little information to support or contradict the major components of this interpretation. The literature does suggest that sound can alter arousal and activate an infant to look at a visual target. In fact, such activation is one potential basis for the establishment of intersensory coordination. In the present research, however, there was no clear indication that the presence of sound during familiarization significantly enhanced visual attention or that differences in results between the studies were related to differences in visual attention during familiarization. Thus, there was no difference between the familiarization conditions of the six studies in the amount of visual attention the infants paid to the object (as indicated by duration of fixation).

No analyses have been reported concerning the relationship of the presence of sound during familiarization and subsequent familiarity or novelty preferences; in the few studies in which sound has been present, it has not been present systematically and the effect of its presence has not been compared with preferences in its absence. One of the bases for suggesting that the addition of sound might produce a familiarity preference was Bryant, et al.'s report (1972) that, following tactual or visual familiarization with anobject that made a sound, 6 to 12 month infants showed a familiarity preference, at least for one of two object pairs. This is different from the novelty preference usually found when familiarization and testing have been strictly visual. This familiarity preference cannot be attributed solely to the addition of sound, since Bryant's stimuli were three-dimensional objects, which differed from the usual two-dimensional objects for which novelty preferences have been standardly reported. A similar familiarity preference has been obtained with 6-month-old infants using silent three-dimensional objects (Ruff and Kohler, 1978). In addition, in a few studies concerned with visual discrimination, infants of comparable ages have been permitted to handle objects which could be made to sound; for example, they could ring a bell or janglekeys or they could bang objects on the test surface or throw them on the floor. Although such self-produced sounds might be expected to be particularly effective in enhancing attention or interest, the results of these studies have shown novelty preferences or no preferences rather than familiarity preferences (Rubenstein, 1974; Gottfried, et al., 1978; Ruff, in preparation). The role of sound in these studies in producing either a novelty or familiarity preference is unclear since all of these studies differed from each other in ways whichmight each influence subsequent responsiveness to the object, but together they do not suggest that a familiarity preference is produced by the presentation of sound in association with an object during familiarization.

As regards the third component of the interpretation, little information is currently available to suggest that sound disrupts visual behavior, and in fact the literature discussed briefly in theintroduction suggests that sound, at least at moderate intensities, has an influence which could be described generally as organizing. The only closely related research is the series of studies reported by Horowitz and colleagues (1974); the results of these studies indicated that repeated presentation of a visual target resulted in a decline of fixation of the target, but fixation of the same target could be recovered by the introduction of a (novel) sound. Although the subjects of these studies were 5 to 14 weeks, such results indicate that novel sounds can have an organizing influence on fixation, and that they may reinstate rather than disrupt fixation of a familiar target. In the present research, there was no evidence for a disruptive effect of the novel sound and in fact the results for one pair in Study III (temporal incongruity, continuous movement and periodic sound) suggest an organizing influence: in this instance, there was an increase in looking at the novel object in the presence of the novel sound. Disruption of looking would be indicated by a consistent reduction in overall amount of looking in the presence of the novel sound, but the effects of auditory condition indicated by

ANOVAs are inconsistent in direction.

Overall, interpretation of the data of the present research in terms of lower level intersensory influences alone appears to require a cumbersome number of component processes, for some of which there is little support in the durrent data or the literature; interpretation in terms of coordination appears to fit the data more directly, so that appeal to this higher level intersensory process is warranted.

The results of the present research suggest that the establishment of coordination of auditory and visual attributes of people and objects which has been suggested in the literature for infants of less than 6 months may have been based on previous experience in which the auditory and visual attributes were maximally congruent. For example, coordination of the mother's features might be in part attributed to their spatial and temporal characteristics; in the experience of the infant, the mother has always generated a variety of auditory and visual stimuli which have been spatially and temporally congruent and have exhibited a common rhythm.

The results suggest that spatial congruity is necessary for the establishment of coordination, although it is not sufficient in itself. Since no behaviors indicative of distress, increased search behaviors, or response conflict were noted during familiarization which involved spatial incongruity, there was no reason to think that the familiarization conditions of that study were disruptive to the infant, only that they were not supportive of coordination.

The results also suggest that temporally congruous rhythm may in general be necessary for the establishment of coordination, although it is not sufficient in itself. The results do not offer information about other types of integration which might rely more exclusively on synchronous temporal pattern. It is conceivable, for example, that in the presence of the rhythmic sound used in the present research, infants would have matched an object moving in synchrony with that sound versus one moving asynchronously with the sound; such matching on the basis of temporal structure has been suggested as the basis for 4-month-old infants' matching of films and sound tracks (Spelke, 1976). However, the type of coordination (and equivalence) based on matching of concurrently presented auditory and visual stimuli is different from that based on memory of past experience with auditory and visual stimuli. It is also conceivable that the infants perceived the equivalence of the temporal rhythm of the auditory and visual stimuli, even when they were spatially incongruent; such perception of equivalence was suggested by the significantly greater response recovery to shifts in both temporal sequence and modality than to either alone reported for 7-month-old infants (Allen, _et al_., 1976). The perception of equivalence or identity of two temporal patterns (or pulse rates) in different modalities apparently does not imply a common source, and this perception may be different from perception of two stimuli as attributes of a common object or categorization of stimuli as attributes of particular objects.

One effect of rhythm or temporal pattern is probably to increase arousal and attention and different types or rates of temporal change would probably have different effects. All of the studies which have incorporated synchronized rhythmic change including the present research utilized change which was periodic and their results may be related to this periodicity. Periodic change is a readily discriminable pattern and the perception of pulse pattern is probably a basic, lower order phenomenon (see Davenport, 1976).

It has been suggested that rates of change which approximate the heart beat, 4±2 Hz, would be differentially effective in recruitment of attention (Salk, 1962; Simner, 1969). Karmel, Lester, McCarvill, Brown, and Hofmann (1977) have reported that a rate of change of visual stimulation of about 6 Hz is optimal for recruitment of visual attention of 13-week-old infants and they related the differential effectiveness of this rate to aspects of neurophysiological functioning. Whether a rate optimal for recruitment of attention is also optimal for other processing, particularly for promoting intersensory integration, is an empirical question.

Rhythm would not necessarily produce equivalent effects in the au auditory and visual modalities. Asymmetric modality effects, such that information is more readily transferred from one modality to another, or even that transfer can be demonstrated only in one direction have been suggested in a variety of intersensory studies (Freides, 1974). In the present research, the two studies of temporal incongruity could be regarded as symmetrical manipulations of temporal pattern in the visual versus the auditorymodality which had asymmetrical effects. That is, familiarization in Study III was with a periodically changing auditory stimulus and a constant visual stimulus; familiarization in Study IV was with a constant auditory stimulus and a periodically changing visual stimulus. The suggestion of differential response in Study III and the absence of differential response in Study IV could reflect an asymmetric modality effect, with the periodic auditory stimulation of Study III more effective than the periodic visual stimulation of Study IV in recruitment of attention and/or processing of bimodal relationships.

It is possible that the establishment of coordination is related to the infants' state of arousal, to their attention levels, to the salience of the auditory and visual stimuli, to the processing time available, etc. The potential importance of specific characteristics of the experimental stimuli wasillustrated by the results of one of the studies of temporal incongruity (constant movement, rhythmic sound) which suggested coordination for one stimulus pair but not the other. Spelke (1976) had similarly reported a stronger association for one of two film-sound track combinations and Lyons-Ruth (1977) had reported coordination for 3 of her 4 sounding objects, with no coordination for the fourth. The long history of negative results and the eventual demonstration of cross-modal matching and transfer in nonhuman mammals has emphasized the importance of differences in the salience of relevant stimulus characteristics. For example, salience of relevant characteristics has been increased through making different shapes edible and nonedible and, in fact, demonstration of cross-modal matching in monkeys was delayed until this method was developed (Cowey & Weiskrantz, 1975). Particular features of sounds or objects may be differentially attractive or excitatory to infants by their nature - for example, rapid changes in intensity are more likely to arouse than gradual changes, particular shapes may be more appealing on the basis of their curvilinearity or complexity. Objects and sounds can also be differntially salient due to uncontrolled influences or prior experience. For example, the stimulus pair differentially effective in the temporal incongruity study was an animal-squeak combination, which belongs to a general class of sounding objects with which 6-month-old infants are likely to have had some pleasant experiences previous to their introduction in the study (and which also included rapid changes in auditory intensity and curvilinear surfaces). The stronger coordination shown for the film-sound track combination of woman-peekaboo as opposed to percussive instrument-percussive sound may also be related to the effects of past experience with these classes of events (Spelke, 1976); differences in past experience might be responsible for the infant having already made the association or for altering arousal orattentiveness and increasing the attractiveness of particular stimuli, so that new associations are more readily formed.

Piaget has emphasized the importance of behavioral interaction with multimodal objects ofr intercoordination of perceptions about objects and development of object concepts. One implication is obviously that auditory-visual coordination might have been potentiated in this research if the infants had been able to manipulate the objects and make them sound. However, at least one study (Gottfried, Rose, & Bridger, 1978) has suggested that the concurrence of haptic-manipulatory experience with visual experience may hinder the acquisition and/or encoding of visual information about shape for 6-month-old infants. Although extrapolation from visual-haptic interaction to auditory-visual interaction may be misleading, this suggests at a minimum that active manipulation of a sounding object might not be facilitative of integration.

One view of perceptual development (Gibson, 1969) would emphasize the importance of detection of information about invariant and distinctive features of objects in the establishment of coordination. In this view, the direct extraction of amodal or supramodal features common to stimuli of different modalities is essential for cross-modal matching and transfer and would certainly facilitate intersensory coordination. The development of coordination and perception of equivalence would not accurately be considered as the development of increasing intersensory relationships but as the development of increasingly sophisticated and veridical detection of invariant features common to more than one sense system. In this approach, the integration exhibited in the first study would probably be considered to be related to the presence in this study of a salient amodal feature - common rhythm. The absence of this prominant amodal feature in the studies of temporal incongruity could explain the failure of coordination in those studies, but the failure of coordination when this prominant feature was present but the auditory and visual stimuli were spatially incongruent is problematic. Of course, other features of the familiarization situation were invariant also and it is compatible with this view that each feature of the relationship of the auditory and visual stimuli could contribute quantitatively to their integration - for example, common spatial location, movement in space together, common onset and offset, common temporal pattern. The probability of integration might then be related to the number of invariant features present and their detectability.

Another view of development would emphasize the role of S-S or classical conditioning processes for the establishment of coordination. This view would emphasize the importance of learning predictive relationships between environmental events or expectancies that represent and correspond to cue-consequence contingencies (Bolles, 1972; Rescorla & Solomon, 1967). Traditional classical conditioning paradigms might be applied to the present research if the responses of momentary orienting and more prolonged visual regard are distinguished. Direct observation of 6-month-old infants suggests that although both auditory and visual stimuli are effective elicitors of momentary visual orienting, visual stimuli - particularly brightly colored, moving objects - canmaintain visual fixation for relatively longer periods of time but auditory stimuli do not in themselves, without associated visual stimuli, maintain visual fixation. (In fact, the present research did not explore the influence of temporal incongruity of the presence and absence of auditory and visual stimuli because 6-month-old infants would generally not tolerate repetitive familiarization with an auditory stimulus in the absence of a visual one.) Familiarization would then be regarded as the contiguous presentation of a sound with a moving object which elicits prolonged visual fixation. During tests, sound would then elicit prolonged visual fixation of the same object, now stationary.

If visual looking is regarded as a more unitary behavior, then the process might be better conceptualized as sensitization, with the presentation of sound during familiarization elevating already existing responsiveness to the visual stimulus. The process might also be considered an interstimulus relationship resulting from pairing the stimuli a number of times without identified elicitation of identified unconditioned responses or identified reinforcement. That this kind of unreinforced pairing can result in the relating of the two stimuli has been indicated by sensory preconditioning.

Failure to establish coordination under conditions of spatial or temporal incongruity is problematic to these learning explanations. Although it could be argued that incongruity obscures the predictive relationship between the auditory and visual stimuli, it is the temporal contiguity of the two stimuli which has generally been stressed for classical conditioning and the temporal contiguity of the two stimuli during familiarization was the same in all the auditory-visual studies.

The results of this research suggest that 6-month-old infants are restricted in their coordination of auditory and visual stimuli as attributes of common objects on the basis of short experience. They require that an object and sound be maximally spatially and temporally congruent - that is, that the object and sound move synchronously in space and time together - for the coordination of this object and sound. If any elements of this spatial and temporal congruity are not present the probability of coordination is markedly decreased. It is possible that these limitations are the result of experience with multimodal objects and events. In this case, younger infants might coordinate stimuli regardless of whether they are congruous or incongruous. It is also possible that such limitations are part of a general buffering of the infant against associating a multitude of stimuli, some of which might co-occur adventitiously. While specific aspects of auditory and visual relationships may be differentially important at different times in early development, it is likely that the features explored in this research are particularly important throughout early development in structuring the infant's auditory and visual experience into coherent objects and events.

Table 1

Fixation of familiar and novel objects in presence of familiar and novel sounds, following familiarization in which object and sound exhibited spatial and temporal congruity (Study I)

	Familiar sound		Novel sound	
	Familiar object	Novel object	Familiar object	Novel object
Pair 1 and 2 combined				
Mean proportion[a]	.566	.434	.512	.488
SD	.089		.111	
_t_ value	3.551***		0.527	
Mean duration, secs.	5.36	3.92	4.28	4.19
SD	1.88	1.50	1.42	1.58
_t_ value	3.396***		0.232	
Pair 1				
Mean proportion[a]	.556	.444	.482	.518
SD	.125		.205	
_t_ value	2.128*		0.427	
Mean duration, secs.	4.89	4.18	3.90	4.39
SD	1.78	2.33	1.95	2.15
_t_ value	1.221		0.712	
Pair 2				
Mean proportion[a]	.575	.425	.542	.458
SD	.131		.170	
_t_ value	2.800**		1.191	
Mean duration, secs.	5.83	3.66	4.67	3.98
SD	2.82	1.27	2.16	2.30
_t_ value	3.728***		0.948	

[a] _n_ = 23

*** $p < .01$

** $p < .02$

* $p < .05$

Table 2

Fixation of familiar object in presence of familiar versus novel sound, following familiarization in which object and sound exhibited spatial and temporal congruity (Study I)

	Familiar sound Familiar object		Novel sound Familiar object
Pair 1			
Mean proportion[a]	.556		.482
SD	.125		.205
t value		1.720+	
Mean duration, seconds	4.89		3.90
SD	1.78		1.95
t value		2.491*	
Pair 2			
Mean proportion[a]	.575		.542
SD	.131		.170
t value		0.857	
Mean duration, seconds	5.83		4.67
SD	2.82		2.16
t value		2.104*	

[a] $n = 23$

* $p < .05$

+ $p < .10$

Table 3

Fixation of familiar and novel objects in presence of familiar and novel sounds, following familiarization in which object and sound were spatially incongruous (Study II)

	Familiar sound		Novel sound	
	Familiar object	Novel object	Familiar object	Novel object
Pair 1 and 2 combined				
Mean proportion[a]	.527	.473	.515	.485
SD	.106		.158	
t value	1.165		0. 442	
Mean duration, secs.	3.18	2.84	3.42	3.18
SD	1.13	1.14	1.89	1.38
t value	1.382		0.460	
Pair 1				
Mean proportion[a]	.541	.459	.570	.430
SD	.169		.198	
t value	1.112		1.621	
Mean duration, secs.	3.21	2.42	3.56	2.54
SD	1.84	0.83	2.70	1.61
t value	1.828+		1.319	
Pair 2				
Mean proportion[a]	.515	.485	.460	.540
SD	.140		.173	
t value	0.500		1.048	
Mean duration, secs.	3.14	3.27	3.28	3.81
SD	1.37	1.96	1.67	1.91
t value	0.250		0.950	

[a] $n = 21$

+ $p < .10$

Table 4

Fixation of familiar and novel objects in presence of familiar and novel sounds, following familiarization in which object and sound were temporally incongruous, the object moving continuously and the sound occurring periodically (Study III)

	Familiar sound		Novel sound	
	Familiar object	Novel object	Familiar object	Novel object
Pair 1 and 2 combined				
Mean proportion[a]	.524	.476	.489	.511
SD	.113		.107	
t value	0.981		0.469	
Mean duration, secs.	3.61	2.93	3.43	3.53
SD	1.28	1.08	1.03	1.13
t value	2.128*		0.355	
Pair 1				
Mean proportion[a]	.511	.489	.504	.496
SD	.210		.157	
t value	0.250		0.125	
Mean duration, secs.	3.18	2.90	3.44	3.15
SD	1.59	1.50	1.53	1.42
t value	0.520		0.643	
Pair 2				
Mean proportion[a]	.540	.460	.473	.527
SD	.154		.169	
t value	1.177		0.724	
Mean duration, secs.	4.05	2.96	3.42	3.91
SD	1.99	1.17	1.45	1.72
t value	2.209*		0.912	

[a] n = 21

* $p < .05$

Table 5

Fixation of familiar object in presence of familiar versus novel sound, following familiarization in which object and sound were temporally incongruous, the object moving continuously and the sound occurring periodically (Study III)

	Familiar sound Familiar object		Novel sound Familiar object
Pair 1			
Mean proportion[a]	.511		.504
SD	.210		.157
_t_ value		0.186	
Mean duration, secs.	3.18		3.44
SD	1.59		1.53
_t_ value		0.603	
Pair 2			
Mean proportion[a]	.540		.473
SD	.154		.169
_t_ value		2.312*	
Mean duration, secs.	4.05		3.42
SD	1.99		1.45
_t_ value		1.784+	

[a] $n = 21$

* $p < .05$

+ $p < .10$

Table 6

Fixation of familiar and novel objects in presence of familiar and novel sounds, following familiarization in which object and sound were temporally incongruous, the object moving periodically and the sound being continuous (Study IV)

	Familiar sound			Novel sound		
	Familiar object		Novel object	Familiar object		Novel object
Pair 1 and 2 combined						
Mean proportion[a]	.504		.496	.506		.494
SD	.102			.095		
t value		0.171			0.298	
Mean duration, secs.	2.97		3.11	2.96		2.91
SD	0.92		1.47	1.16		1.21
t value		0.479			0.181	
Pair 1						
Mean proportion[a]	.539		.461	.519		.481
SD	.165			.080		
t value		1.083			1.060	
Mean duration, secs.	3.11		2.80	2.83		2.69
SD	1.33		1.50	1.36		1.23
t value		0.736			0.581	
Pair 2						
Mean proportion[a]	.473		.527	.496		.504
SD	.165			.167		
t value		0.752			0.105	
Mean duration, secs.	2.82		3.42	3.09		3.13
SD	1.42		2.12	1.58		1.65
t value		1.068			0.090	

[a] $n = 21$

Table 7

Fixation of familiar and novel objects in presence of familiar and novel sounds, following familiarization in which object and sound were temporally incongruous (Studies III and IV)

	Familiar sound		Novel sound	
	Familiar object	Novel object	Familiar object	Novel object
Pair 1 and 2 combined				
Mean proportion[a]	.514	.486	.498	.502
SD	.107		.100	
t value	0.851		0.154	
Mean duration, secs.	3.29	3.02	3.19	3.22
SD	1.15	1.28	1.11	1.20
t value	1.214		0.130	
Pair 1				
Mean proportion[a]	.525	.475	.512	.488
SD	.187		.124	
t value	0.875		0.610	
Mean duration, secs.	3.15	2.85	3.14	2.92
SD	1.45	1.48	1.46	1.33
t value	0.876		0.854	
Pair 2				
Mean proportion[a]	.506	.494	.485	.515
SD	.161		.166	
t value	0.249		0.595	
Mean duration, secs.	3.43	3.19	3.25	3.52
SD	1.82	1.71	1.51	1.71
t value	0.626		0.753	

[a] *n* = 42

Table 8

Fixation of the familiar and novel objects in two visual control studies

	Study V[a] Periodic movement		Study VI[b] Constant movement	
	Familiar object	Novel object	Familiar object	Novel object
Pair 1 and 2 combined				
Mean proportion	.509	.491	.510	.490
SD	.097		.095	
t value	0.439		0.493	
Mean duration, secs.	3.66	3.39	3.28	2.93
SD	1.48	1.02	1.19	.099
t value	0.756		1.587	
Pair 1				
Mean proportion	.513	.487	.540	.460
SD	.146		.115	
t value	0.424		1.698	
Mean duration, secs.	3.75	3.42	3.67	2.81
SD	1.66	1.47	1.54	1.13
t value	0.688		3.211***	
Pair 2				
Mean proportion	.505	.495	.480	.520
SD	.103		.128	
t value	0.228		0.778	
Mean duration, secs.	3.56	3.36	2.89	3.05
SD	1.75	1.15	1.31	1.05
t value	0.555		0.500	

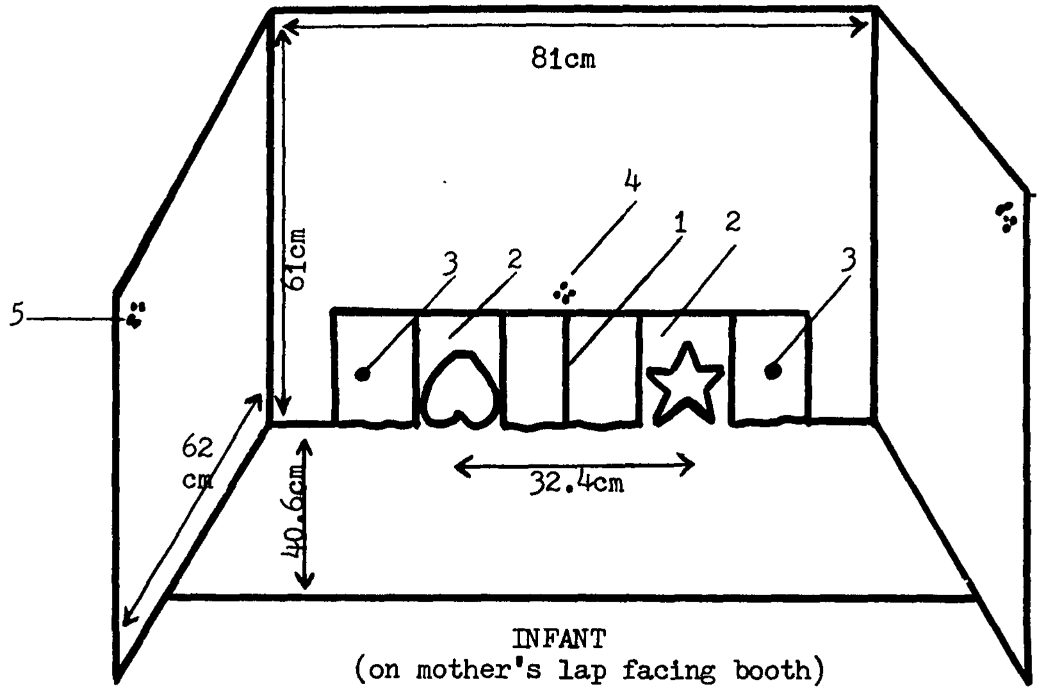
[a] n = 22

[b] n = 24

***p<.01

Figure

Sketch of test booth



1. center division of curtain through which object projected for familiarization
2. flaps removed so that test objects exposed to infant
3. peephole for observation of fixation
4. speaker holes behind which 3.2cm speaker attached for presentation of test sounds in all studies
5. speaker holes used in Study II; 3.2 speaker attached behind holes for spatially incongruent presentation of sounds during familiarization

Appendix A

ALBERT EINSTEIN COLLEGE OF MEDICINE
OF YESHIVA UNIVERSITY
1410 PELHAM PARKWAY SOUTH, BRONX, N.Y. 10461 : EINCOLLMED, N.Y.

ROSE FITZGERALD KENNEDY CENTER
FOR RESEARCH IN MENTAL RETARDATION
AND HUMAN DEVELOPMENT
Room 222

PHONE: (212) 430-2475

Dear Parent,

We are trying to understand how infants respond to their surroundings. In particular, we are looking at how young infants respond to objects around them which they can both see and hear - how they learn that a particular sight and sound go together. For example, babies may put together the faces and voices of their parents - do they also put together other objects with the sounds that go with them? Is the rhythm of things they see and hear important in what they link together? Answers to questions like these will help us understand how babies sort out the many sights and sounds around them. Learning how babies develop an integrated view of their environment is necessary to understanding the early development of infants, so that eventually we may be able to help babies who have problems. We need to see babies who are normal and healthy, and it is our hope that you will give us permission to include your baby in this project.

We will test your baby in your home, at a time which is convenient for you. Nothing will be attached to your baby and the entire procedure will take less than one hour. The baby will sit in your lap. We will present to the baby different combinations of toys and sounds, or lights and sounds, and record how the baby responds. Most babies seem to enjoy this type of procedure.

We will be happy to answer any questions you might have and hope that you will be interested in participating in this project. We will call you in the near future to give you more information and to set up an appointment if you are interested.

Sincerely yours,

Katharine Lawson, M.A.

Gerald Turkewitz, Ph.D.

Appendix B

AUDITORY-VISUAL INTEGRATION IN INFANTS

Informed Consent

I, ____________________, bearing the relationship of ____________________ to the minor ________________, hereby give my consent for the participation of my child in the study of auditory-visual integration in infants. I have read the description of the study given below and have been told that my child may receive the procedures listed below.

Background and Procedure

We are trying to understand how infants respond to the world around them. In particular, we are interested in the ways in which infants put auditory and visual stimuli together. In one study, infants will be presented with a brightly colored toy which makes a sound so that they can become familiar with the toy and its sound. Then we will see whether infants link this particular sound and toy together. In another study, we will look at whether infants link a visual stimulus (a moving toy or a light) with an auditory stimulus which has the same rhythm.

The information we gain from these studies will help us understand how normal healthy infants recognize objects and sounds which go together - how they develop an integrated view of the many types of stimulation coming from their environment, so that eventually we may be able to help infants with problems.

1. Your child was chosen on the basis of being in good health.
2. Testing will take place at your home or at the Kennedy Center and will take less than one hour.
3. Your infant will sit in your lap in front of a screen, while he/she is being observed for one of two studies. In one study, the baby will be repeatedly shown a toy which makes a sound; then different combinations of this toy and sound and a new toy and sound will be presented. In the other study, the baby will be shown different combinations of toys moving, small lights flashing, and sounds. A total of about 30 presentations will be made. We will observe how your baby responds to these different combinations of sights and sounds.
4. The entire session may be videotaped.
5. Results of the testing for your infant will remain anonymous and would be published only as group data. You will be advised of group results if you request it.
6. Although information gained from this study may be beneficial to other infants, there will be no direct benefit to your child.

I have received information explaining this study and have been told the procedures that will be performed, and that I am free to withdraw my consent and discontinue participation in the study at any time without prejudice. I consent to the participation of my child in this study.

____
Signature of Parent

____
Signature of Witness

____
Date

Appendix C

Observer Reliability for Number of Fixations

Analysis for reliability for number of fixations was based on Pearson r correlations for each observer. The mean correlations for number of fixations for the videotape observations were .83 (range .54 to .91) and .58 (range .34 to .92) for fixations of the object on the infant's left and right, respectively, and .56 (range .10 to .97) for familiarization. For the direct observations of different infants, the mean correlations were .83 (range .68 to .93) and .81 (range .50 to .95) for fixations of the object on the infant's left and right, respectively, and .90 (range .82 to .97) for familiarization.

The low reliability for number of fixations makes it a less informative response measure. However, it is possible that assessment by videotape was distorted: although it provided a standardized means of comparing observers, it was not the observation method used for this research and the low reliability may have been related to its novelty to the observers, as well as to the reduced information about direction of fixation provided by videotape which results from 1) poorer resolution and contrast, and 2) decreased information about the position of the visual targets. In fact, all observers reported that scoring the videotape was more difficult than, and different from, observing an infant directly. Although the mean reliability for number of fixations was low for direct observations also, the low correlation appears to be largely attributable to a very small proportion of the observations: two of the 8 (4 left and 4 right) correlations for tests were below .80 and in each case this was due to a discrepancy on a single 1 of the 8 tests.

Appendix D

Number of fixations of familiar and novel objects in presence of familiar and novel sounds, Pairs 1 and 2 combined

	Familiar sound		Novel sound	
	Familiar object	Novel object	Familiar object	Novel object
Study I[a]				
Mean	3.41	2.94	3.11	2.96
SD	0.94	0.98	1.02	1.06
_t_ value	5.124***		0.837	
Study II[b]				
Mean	2.80	2.63	3.05	2.87
SD	0.89	0.78	1.05	1.07
_t_ value	1.072		0.984	
Study III[b]				
Mean	2.46	2.53	2.61	2.76
SD	0.80	0.77	0.93	0,80
_t_ value	0.516		1.304	
Study IV[b]				
Mean	3.14	3.05	2.78	2.70
SD	0.94	0.85	0.81	0.95
_t_ value	0.670		0.537	

[a] $n = 23$
[b] $n = 21$
*** $p < .001$

Appendix D continued

Number of fixations offamiliar and novel objects in presence of familiar and novel sounds, Pairs 1 and 2

		Familiar sound		Novel sound	
		Familiar object	Novel object	Familiar object	Novel object
Study I[a]					
Pair 1	Mean	3.59	3.15	3.30	3.30
	SD	0.95	1.12	1.23	1.35
	_t_ value	2.297**		0.000	
Pair 2	Mean	3.24	2.74	2.91	2.63
	SD	1.26	1.17	1.09	1.12
	_t_ value	3.557***		1.274	
Study II[b]					
Pair 1	Mean	2.86	2.50	3.14	2.76
	SD	1.12	0.81	1.32	1.12
	_t_ value	1.540		1.290	
Pair 2	Mean	2.74	2.76	2.98	2.98
	SD	1.16	1.27	1.36	1.41
	_t_ value	0.134		0.000	
Study III[b]					
Pair 1	Mean	2.52	2.76	2.74	2.74
	SD	1.18	0.98	1.20	0.93
	_t_ value	0.886		0.000	
Pair 2	Mean	2.40	2.33	2.50	2.76
	SD	0.86	0.76	1.05	1.01
	_t_ value	0.389		1.759+	
Study IV[b]					
Pair 1	Mean	3.40	3.21	3.14	2.88
	SD	1.42	1.27	1.20	0.99
	_t_ value	0.984		1.372	
Pair 2	Mean	2.86	2.90	2.45	2.50
	SD	0.96	0.80	0.96	1.10
	_t_ value	0.213		0.192	

[a]_n_ = 23　　*** p<.01　　+ p<.10
[b]_n_ = 21　　** p<.02

Appendix E

Comparison between first two tests (tests 1 and 2) and second two tests (tests 3 and 4) of fixation of familiar and novel object in presence of familiar and novel sounds

A. Proportion of fixation of familiar object in presence of familiar and novel sounds

		Familiar sound, Familiar object		Novel sound, Familiar object	
		Tests 1 & 2	Tests 3 & 4	Tests 1 & 2	Tests 3 & 4
Study I					
Pair 1	Mean	.550	.560	.496	.468
	SD	.199	.214	.245	.297
	t value	0.146		0.372	
Pair 2	Mean	.569	.571	.536	.547
	SD	.240	.284	.298	.279
	t value	0.023		0.111	
Study II					
Pair 1	Mean	.537	.545	.570	.571
	SD	.284	.242	.312	.281
	t value	0.092		0.015	
Pair 2	Mean	.540	.490	.490	.433
	SD	.271	.286	.263	.291
	t value	0.473		0.608	
Study III					
Pair 1	Mean	.480	.543	.480	.528
	SD	.302	.249	.239	.318
	t value	0.789		0.468	
Pair 2	Mean	.467	.611	.455	.494
	SD	.217	.245	.284	.199
	t value	1.919+		0.502	
Study IV					
Pair 1	Mean	.523	.555	.421	.617
	SD	.192	.235	.196	.234
	t value	0.531		2.322*	
Pair 2	Mean	.454	.492	.527	.467
	SD	.239	.250	.249	.289
	t value	0.485		0.639	

* $p < .05$
\+ $p < .10$

Appendix E continued

Comparison between first two tests (tests 1 and 2) and second two tests (tests 3 and 4) of fixation of familiar and novel object in presence of familiar and novel sounds

B. Duration of fixation of familiar and novel objects in presence of familiar sound

			Familiar sound, Familiar object		Familiar sound, Novel object	
			Tests 1 & 2	Tests 3 & 4	Tests 1 & 2	Tests 3 & 4
Study I						
	Pair 1	Mean	5.11	4.66	4.64	3.72
		SD	2.84	2.28	3.78	2.49
		t value	0.574		1.011	
	Pair 2	Mean	5.24	6.09	3.73	3.61
		SD	3.26	4.24	2.42	2.31
		t value	0.776		0.135	
Study II						
	Pair 1	Mean	3.69	2.72	2.57	2.26
		SD	2.69	1.94	1.46	1.55
		t value	1.493		0.563	
	Pair 2	Mean	3.55	2.74	3.26	3.27
		SD	2.32	1.70	2.72	2.28
		t value	1.238		0.017	
Study III						
	Pair 1	Mean	3.32	3.04	3.18	2.62
		SD	2.47	2.07	1.87	2.00
		t value	0.401		1.039	
	Pair 2	Mean	3.67	4.43	3.69	2.24
		SD	2.37	2.90	1.46	1.64
		t value	0.997		3.255***	
Study IV						
	Pair 1	Mean	3.11	3.12	2.99	2.62
		SD	1.69	1.53	1.85	1.94
			0.030		0.722	
	Pair 2	Mean	2.98	2.71	3.48	3.36
		SD	2.37	1.97	2.10	2.62
		t value	0.362		0.256	

*** $p < .01$

Appendix E continued

Comparison between first two tests (tests 1 and 2) and second two tests (tests 3 and 4) of fixation of familiar and novel object in presence of familiar and novel sounds

C. Duration of fixation of familiar and novel objects in presence of novel sound

			Novel sound, Familiar object		Novel sound, Novel object	
			Tests 1 & 2	Tests 3 & 4	Tests 1 & 2	Tests 3 & 4
Study I						
	Pair 1	Mean	4.03	3.76	4.29	4.49
		SD	2.27	2.69	2.73	3.02
		t value	0.422		0.246	
	Pair 2	Mean	4.43	4.90	3.93	4.03
		SD	2.90	3.31	3.20	3.21
		t value	0.499		0.105	
Study II						
	Pair 1	Mean	3.64	3.48	2.54	2.55
		SD	3.26	2.62	2.28	2.46
		t value	0.317		0.016	
	Pair 2	Mean	3.64	2.92	3.52	4.10
		SD	2.53	2.12	2.41	2.32
		t value	1.019		0.937	
Study III						
	Pair 1	Mean	3.15	3.73	3.32	2.99
		SD	1.76	2.78	2.06	2.41
		t value	0.749		0.439	
	Pair 2	Mean	3.38	3.45	4.50	3.31
		SD	2.21	2.16	2.88	1.54
		t value	0.100		1.765	
Study IV						
	Pair 1	Mean	2.40	3.26	3.27	2.11
		SD	1.77	1.53	1.95	1.40
		t value	2.067+		2.283*	
	Pair 2	Mean	3.26	2.92	2.76	3.50
		SD	2.57	2.23	1.73	2.62
		t value	0.436		1.144	

* p .05
\+ p .10

Appendix F

Duration of fixation during each of four familiarization periods

A. Duration of fixation during familiarization periods for Pair 1

		Familiarization period			
		1	2	3	4
Study I[a]	Mean, seconds	28.42	29.05	29.32	27.61
	SD	4.37	3.88	4.85	6.71
	F value		0.517		
Study II[b]	Mean	29.52	26.63	25.56	24.11
	SD	4.65	5.29	6.91	7.07
	F value		2.996		
Study III[b]	Mean	25.74	25.01	25.80	26.02
	SD	5.09	4.49	6.60	6.23
	F value		0.126		
Study IV[b]	Mean	28.67	25.35	24.37	25.06
	SD	5.45	5.92	5.84	6.33
	F value		2.216		
Study V[c]	Mean	27.94	25.90	26.86	28.39
	SD	5.06	5.73	6.24	8.30
	F value		0.653		
Study VI[d]	Mean	23.00	21.88	23.59	24.51
	SD	7.02	6.26	6.11	5.78
	F value		0.730		

[a] $n = 23$
[b] $n = 21$
[c] $n = 22$
[d] $n = 24$

Appendix F continued

B. Duration of fixation during familiarization periods for Pair 2

		Familiarization period			
		1	2	3	4
Study I[a]	Mean, seconds	29.88	28.34	26.90	27.70
	SD	3.49	4.71	6.20	7.08
	F value		1.149		
Study II[b]	Mean	26.90	25.29	25.26	24.79
	SD	5.54	7.03	6.95	6.58
	F value		0.419		
Study III[b]	Mean	26.42	23.24	21.75	25.39
	SD	6.19	6.60	6.19	5.22
	F value		2.520		
Study IV[b]	Mean	29.64	25.21	24.87	24.11
	SD	5.17	4.81	5.59	5.14
	F value		4.882*		
Study V[c]	Mean	28.60	26.14	25.53	25.42
	SD	4.56	5.46	7.60	6.37
	F value		1.287		
Study VI[d]	Mean	21.88	21.98	19.94	21.80
	SD	4.69	6.55	7.89	6.24
	F value		0.551		

* p .05

[a] *n* = 23
[b] *n* = 21
[c] *n* = 22
[d] *n* = 24

Appendix G

Correction of results for position preference

Position preference was indicated in two cases. For Pair 2 in Study II, infants showed a trend toward increased looking at the object on the right ($t=2.038$, p .10). For Pair 1 in Study III, infants showed a significant increase in looking at the object on the left ($t=3.364$, p .01). In both these cases, data were corrected in the following manner. Proportion of fixation was corrected by subtracting the mean proportion of fixation to the left (and right) for all tests from the mean proportion of fixation to the left (and right) for each test. Duration was corrected by dividing the duration of fixation to the left (and right) for each test by the total duration of fixation to the left (and right) for all tests. In both cases, the corrected data indicated the same pattern of results as the uncorrected data; that is, no differential pattern of fixation was suggested which was indicative of coordination.

Appendix H

Analysis for stimulus preferences

Analysis for whether either object in each of the two stimulus pairs was preferred regardless of sound conditions was based on response to the familiar object in the presence of the familiar sound. For the visual studies, the analysis was based on the comparable measure of response to the familiar object. Results for this analysis are presented in the following two tables (Appendix H, A. and Appendix H, B.).

The consistent stimulus preference shown for one object (the blue mouse) over the other stimulus (the green frog) in Pair 2 did not account for the coordination observed for that pair in Study I and Study III. As noted before, each object in the pair served as the familiar object for one half the subjects. In addition, the results for this pair in Studies I and III indicated that the response to the two objects was related to the sound conditions: the infants showed 1) significantly greater response to the familiar object in the presence of the familiar sound and not in the presence of the novel sound; and 2) significantly greater fixation of the familiar object during the familiar sound than during the novel sound. Further, the data for duration of fixation (the only measure which indicated significant results in Study III) for the two objects separately indicate that, in the two relevant studies, fixation of each object when it was familiar was influenced by sound condition (see Appendix H, C.).

Appendix H continued

A. Fixation of each object of Pair 1 when familiar and in presence of familiar sound (Studies I-IV) and when familiar (Studies V & VI)

		Proportion		Duration, secs.	
		star	heart	star	heart
Study I	Mean	.585[a]	.517[b]	4.35	5.59
	SD	0.97	.151	1.85	1.48
	t value	1.317		1.728+	
Study II	Mean	.499[b]	.579[c]	3.14	3.29
	SD	.146	.185	1.44	2.20
	t value	1.091		0.184	
Study III	Mean	.436[b]	.580[c]	2.48	3.82
	SD	.250	.145	1.68	1.27
	t value	1.635		2.084+	
Study IV	Mean	.528[b]	.549[c]	3.50	2.76
	SD	.146	.188	1.57	1.02
	t value	0.285		1.286	
Study V	Mean	.481[c]	.545[c]	2.99	4.51
	SD	.133	.157	1.34	1.66
	t value	1.040		2.365*	
Study VI	Mean	.545[d]	.535[d]	3.87	3.48
	SD	.100	.133	1.66	1.46
	t value	0.207		0.612	

[a] *n* = 13
[b] *n* = 10
[c] *n* = 11
[d] *n* = 12

* p .05
\+ p .10

Appendix H continued

B. Fixation of each object of Pair 2 when familiar and in presence of familiar sound (Studies I-IV) and when familiar (Studies V & VI)

		Proportion		Duration, secs.	
		frog	mouse	frog	mouse
Study I	Mean	.525[a]	.635[b]	4.53	7.86
	SD	.113	.123	2.13	2.62
	_t_ value	2.562***		3.346***	
Study II	Mean	.463[c]	.563[d]	2.83	3.43
	SD	.120	.145	1.40	1.35
	_t_ value	1.706		1.009	
Study III	Mean	.456[c]	.615[d]	3.32	4.70
	SD	.163	.100	1.78	2.02
	_t_ value	2.727***		1.653	
Study IV	Mean	.394[d]	.560[c]	2.56	3.11
	SD	.149	.142	1.13	1.70
	_t_ value	2.616**		0.894	
Study V	Mean	.482[d]	.528[d]	2.87	4.24
	SD	.102	.103	1.21	1.98
	_t_ value	1.059		1.960+	
Study VI	Mean	.429[e]	.530[e]	2.38	3.39
	SD	.136	.102	0.99	1.43
	_t_ value	2.052+		2.006+	

[a] _n_ = 14
[b] _n_ = 9
[c] _n_ = 10
[d] _n_ = 11
[e] _n_ = 12

*** p .01
** p .02
* p .05
+ p .10

Appendix H continued

C. Duration of fixation of each object of Pair 2 for studies in which results were significant for this pair (Studies I & III)

		Familiar sound		Novel sound	
		Familiar	Novel	Familiar	Novel
Study I					
mouse (9)[a]	Mean, secs.	7.86	4.04	6.08	3.86
	SD	2.62	1.56	2.34	2.08
	_t_ value	3.718***		1.875+	
frog (14)	Mean	4.53	3.42	3.76	4.06
	SD	1.85	1.29	2.30	1.84
	_t_ value	2.016+		0.360	
Study III					
mouse (11)	Mean	4.70	2.59	3.70	2.96
	SD	2.02	0.51	1.10	1.08
	_t_ value	3.793***		1.618	
frog (10)	Mean	3.32	3.38	3.10	4.95
	SD	1.78	1.55	1.77	1.72
	_t_ value	0.074		2.224+	

[a] Numbers in parentheses are the number of subjects represented by the data for that stimulus

*** p .01

+ p .10

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