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Infants' Visual Preferences in the Presence and Absence of Auditory Stimulation

DAVID S. MOORE

Pitzer College

Two experiments were conducted to explore the hypothesis that altering rate of change of an auditory stimulus will affect infants' fixation of changing visual stimuli. Experiment 1 revealed that average percent time that infants preferred looking at the less stimulating of two meaningless visual displays was highest under conditions of auditory stimulation. Experiment 2 demonstrated a significant inverse linear relation between rate of change of loudness in auditory stimulation and attentiveness to rapidly changing visual stimulation, due largely to decreased looking at the most stimulating display under conditions of auditory stimulation. In addition, the heart rates of a significant number of subjects were found to be accelerated in the presence of auditory stimulation. The results are interpreted as indicating that this type of sensory interaction is mediated, at least in part, by a subject's level of arousal. © 1995 Academic Press, Inc.

Understanding of perceptual processes in infancy has grown tremendously in recent years, largely as a result of empirical study of processes occurring *within* particular senses. However, much less empirical research has been done on the nature of the interactions that exist *between* the senses. While questions regarding intersensory function in adults have long been considered interesting (Welch & Warren, 1986), only in the

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last 20 years have students of perception considered such interactions in immature subjects.

In the 1980's, a small group of researchers demonstrated interaction of polysensory stimulus sources in 4-month-olds (Lewkowicz, 1985) and in neonates (Gardner, Lewkowicz, Rose, & Karmel, 1986; Lawson & Turkewitz, 1980; Lewkowicz & Turkewitz, 1981). Newborns and 4-month-olds attended for a longer time to highly stimulating visual displays when they were exposed to *less* stimulating auditory events; conversely, when they were exposed to more stimulating auditory events they attended to less stimulating visual displays. Similarly, Gardner & Karmel (1984) found that aroused (hungry and unswaddled) neonates looked longer at relatively unstimulating visual displays (lights flashing at 1 and 2 Hz) than at relatively stimulating visual displays (lights flashing at 4 and 8 Hz); less aroused (fed and swaddled) neonates preferred looking at *more* stimulating visual displays. The stimuli used in these studies were either illuminated black and white checkerboards or blank flashing lights; such stimuli allow for a high degree of control over stimulus parameters and are similar to those used successfully in the study of adult perception.

Lewkowicz, Turkewitz, and their colleagues have argued that this form of multimodal interaction is likely a function of the *effective intensity* of the stimuli, effective intensity being a product of both the internal level of arousal of a subject (e.g., an infant's state of organismic arousal) and the physical characteristics of the stimuli (e.g., a sound's loudness, frequency, etc.); they believe this type of interaction is *not* a function of the information implicit in the stimuli (Turkewitz, Gardner, & Lewkowicz, 1984). Specifically, data regarding this phenomenon have been interpreted by these investigators in terms of an absolute level of moderate arousal that is optimal for infants. These researchers argue that stimulation in any sensory modality is arousing and that infants seek to maintain moderate levels of arousal (summed across all sensory modes) through appropriate orientation. For example, Turkewitz et al. (1984) reasoned that if stimulation in sensory modes other than vision affects level of arousal, and if level of arousal affects visual preferences, then visual preferences would be expected to be influenced (at least indirectly) by stimulation in other modalities, all other influences on a subject's organismic state of arousal being held constant. These investigators point out that such influence would reflect a response to the physical characteristics of the stimuli, and not necessarily a recognition of any cross-modal equivalence that might exist between the stimuli.

The first experiment reported below is an attempt to partially replicate the findings reported by Lewkowicz (1985). Experiment 2 extended the findings of Experiment 1 by exploring the effect on visual preferences of varying rates of change of *loudness*. This manipulation was chosen because loudness is an auditory dimension that has not been manipulated in previous studies of sensory/perceptual interaction in 4-month-old infants. Thus, both experiments explored the effect of altering rate of change of an auditory stimulus on fixation of changing visual stimuli. The stimuli used were simple, meaningless, and well controlled.

In addition, Experiment 2 provided an empirical test of the contention that auditory stimulation is arousing to infants. Analysis of infants' heart rates, measured during the procedure, allowed for a preliminary assessment of a critical element of the hypothesis proposed by Lewkowicz, Turkewitz, and their colleagues. While previous studies have often assumed that experimental stimuli are arousing, this assumption has not typically been tested for 4-month-old infants.

EXPERIMENT 1

Method

Subjects. The subjects were 30 normal, healthy infants (15 males and 15 females) between 3 months, 20 days and 4 months, 10 days of age (mean age = 124 days). All infants were screened for a family history of epilepsy and seizure disorder. The parents of potential subjects were selected from the entire population of new parents in the Boston area and were contacted as a function of the proximity of their home to the Harvard Infant Study in Cambridge. Each subject was volunteered by a parent who brought the infant to the laboratory and was present with the infant throughout the procedure. Subjects' parents were given $5.00 for participating in the study.

Stimuli. The auditory stimuli were constructed using a Mattel Electronics Synsonics drum machine (Model 5281/0030). The machine was initially set to deliver one combination snare-and-muted-cymbal transient beat (i.e., of very short duration) per second; 30 minutes of beats at this rate were recorded directly from the drum machine onto a standard high-bias cassette tape, using a high-quality tape deck operating at 1⅞ i.p.s. Similar cassette tapes were made of beats delivered at two, three, four, and five beats per second. All auditory stimuli were presented through a speaker with an 8.5-in. woofer and a 5.5-in. tweeter. The speaker was in the same plane as the visual stimuli at midline in front of the infant, and it produced sounds that were 68.5 dB as measured with a Scott (type 451) A-weighted sound level meter at the infant's ears.

The visual stimuli were presented using a paired-comparison/preferential-looking technique. These stimuli were generated by two Realistic wide-angle xenon strobe lights with variable speed controls and large-faceted, semispherical reflectors (catalogue 42-3009A), which were covered by blue and green theatrical gels. The lights generated transient images of blue-green circles, each of which had a peak brightness of approximately 5-foot lamberts as measured with a Tektronix J16 photometer and J6503 luminance probe; these circles subtended 9.4 degrees of visual arc. The centers of the circles were separated by 25 degrees of visual arc. Throughout the procedure, the lights were set to flash twice and four times per second, respectively. Critical flicker fusion (CFF) was assumed to be higher than either of these repetition rates, as Regal (1981, p. 554, Fig. 7) estimated CFF in 4-month-old infants to be similar to that in adults (approximately 45 Hz).

Procedure. Each caretaker first filled out a questionnaire requesting general information about the child (including health information). The subject was then seated in the caretaker's lap in a dimly lighted testing room, 3 feet from a freestanding wall containing the strobe lights. The wall was equipped with a small window through which the entire session could be unobtrusively observed and videotaped.

Each caretaker was given some general information concerning the procedure and then asked to orient the infant toward, and keep the infant centered with respect to, the lights. Caretakers were also told to do whatever was necessary to keep the infant in a quiet, alert state, as long as this action would not interfere with the infant's viewing of the lights. Finally, caretakers were told to keep their eyes closed so that they could not systematically influence the looking behavior of the infants (the left/right positions of the lights could not be ascertained through closed eyelids). This request posed no problem for the caretakers, who were given a chance to see the lights at the conclusion of the test session; caretakers did not peek during the procedure.

Each trial involving an auditory stimulus began with the simultaneous presentation of both auditory and visual stimuli (which were not synchronized and which bore no natural relationship to one another), and lasted for 10 s, at which time all stimuli were terminated. Onset, duration, and offset of stimuli were computer controlled. The next trial began as quickly as it was possible to switch cassette tapes in one playback unit, usually within 5 s. All subjects experienced at least two blocks of six trials each; subjects in a quiet, alert state at the conclusion of the second block experienced a third block of six trials. During the first block, subjects experienced one trial with no auditory stimulation, and five other trials, one trial with each of the five drum repetition rates. The second and third blocks were both identical in structure to the first block; the second block followed the first block after a pause of approximately 3 min, and the third block followed the second block without a break. Trials failing to elicit an infant's attention (i.e., zero fixation of both visual stimuli) were repeated; repeated trials always elicited attention.

The order of presentation of the six auditory conditions (including the no-sound condition) was counterbalanced using a Latin Square design; each order was experienced by five subjects. Fifteen subjects saw the 4-Hz light on the right side during the first block of trials and on the left side thereafter. The remaining 15 subjects saw the lights arranged in the opposite fashion. Boys and girls were equally distributed across experimental conditions.

Duration of looking at each of the lights was recorded on-line during each trial by experimenters trained to record infants' eye movements. The experimenters were unaware of the experimental hypotheses and were unable to determine which of the two lights was on the left and which was on the right. Studies in this laboratory using identical apparatus and procedures achieve inter-rater reliabilities greater than .90. The duration of each fixation was stored in an IBM AT.

Results

Because each subject experienced trials with no auditory stimulation, each served as her/his own control. For each subject, percent of time fixating the faster (4-Hz) light was calculated by dividing amount of time spent looking at the faster light by the total looking time (i.e., the time spent looking at the faster light plus the time spent looking at the slower light) on each trial. Since looking time was to be expressed as a proportion, it was necessary to subject these raw percentage scores to an arc sine transformation before further analyses were undertaken (Snodgrass, 1977). Means of the raw and transformed scores were then calculated for each auditory condition, by averaging across subjects. Raw means, transformed means, and standard deviations are reported in Table 1.

A preliminary statistical examination was undertaken to determine the appropriateness of collapsing the transformed scores across the variables of sex, order of presentation of lights in a particular lateral configuration, block, and side of faster light. A 2 (sex) × 2 (order of sides of 4-Hz light) × 6 (auditory stimulus) × 2 (side of 4-Hz light) repeated measures analysis of variance, in which auditory condition and side of 4-Hz light were considered as within-subjects factors, revealed no significant main effects or interactions. Although the lack of a side of 4-Hz light × order of sides interaction suggests an absence of a block effect operating across blocks 1 and 2, an additional analysis was conducted specifically to test for the possibility of a block effect operating across all three blocks (for those 20 subjects who experienced a third block). A 6 (auditory stimulus) × 3 (block) repeated measures analysis of variance, in which both variables were considered within-subjects factors, revealed no main effects or interactions. Thus, subsequent analyses were conducted on data from all subjects collapsed across all variables except auditory stimulus.

The primary analysis of the transformed scores was a one-way repeated measures analysis of variance in which auditory stimulus was considered as a within-subjects factor. No main effects or interactions were revealed. However, as a test of the hypothesis suggested by Lewkowicz (1985), a planned contrast analysis was conducted to examine the possibility that

TABLE 1
MEAN LOOKING AT THE FASTER LIGHT, MEAN TOTAL LOOKING, AND MEANS OF ARC SINE TRANSFORMED SCORES IN EXPERIMENTS 1 AND 2

	Faster[a]		Total[b]	
Condition	Raw mean (*SD*)	Arc sine transform (*SD*)	Raw mean (*SD*)	Arc sine transform (*SD*)
		Experiment 1		
No sound	.71 (.28)	2.14 (.78)	.72 (.19)	2.06 (.43)
1 Hz	.63 (.29)	1.90 (.76)	.71 (.19)	2.02 (.45)
2 Hz	.65 (.31)	1.96 (.86)	.69 (.21)	1.99 (.51)
3 Hz	.62 (.31)	1.85 (.84)	.71 (.21)	2.02 (.52)
4 Hz	.62 (.31)	1.88 (.89)	.68 (.22)	1.96 (.55)
5 Hz	.61 (.30)	1.87 (.85)	.74 (.21)	2.08 (.54)
		Experiment 2		
Block 1				
No sound	.78 (.28)	2.31 (.82)	.78 (.20)	2.22 (.49)
Slow Δ	.71 (.31)	2.12 (.90)	.80 (.18)	2.25 (.45)
Fast Δ	.69 (.30)	2.06 (.86)	.81 (.16)	2.29 (.40)
Block 2				
No sound	.64 (.29)	1.96 (.81)	.73 (.21)	2.09 (.51)
Slow Δ	.60 (.29)	1.81 (.82)	.75 (.19)	2.13 (.44)
Fast Δ	.57 (.31)	1.74 (.88)	.74 (.20)	2.10 (.50)

[a] Looking at the faster light as a percentage of total looking.

[b] Total looking at both lights as a percentage of total possible looking.

mean percent looking at the faster light increased as a function of decreased auditory stimulation. This analysis indicated that average percent fixation time of the faster light in the no-sound condition was higher than in the 1-Hz ($F(1, 29) = 6.01$, $p < .03$), 2-Hz ($F(1, 29) = 4.21$, $p < .05$), 3-Hz ($F(1, 29) = 10.33$, $p < .004$), 4-Hz ($F(1, 29) = 4.79$, $p < .04$), and 5-Hz ($F(1, 29) = 4.87$, $p < .04$) conditions. In addition, a contrast analysis was conducted using contrast weights chosen to reveal a linear trend in the transformed scores. This analysis was nonsignificant, $F(1, 29) = 3.42$, $p < .075$).

An analysis of total looking time was also conducted, as follows. Each subject's total looking at both lights in each trial was expressed as a percentage of total possible looking time (10 s). Means of these scores and their arc sine transformations were then calculated for each auditory condition, by averaging across subjects; these means and their associated standard deviations are reported in Table 1. The transformed scores were then analyzed in a one-way repeated measures analysis of variance in which auditory condition was considered as a within-subjects factor. This analysis revealed no significant effects; that is, there was no evidence that auditory stimulation affected the *total* amount of looking directed at the visual displays.

Discussion

These data reveal a relationship between duration of fixation of a visual stimulus and stimulation in the auditory mode. Auditory stimulation produced *decreased* preference for more visual stimulation; thus, these results concur with those reported by Lewkowicz (1985), although the effect in this case is a function of whether or not auditory stimuli are present. Note, however, that since *total* looking was *not* influenced by the presence of auditory stimulation, the sounds were *not* merely preventing the infants from attending to the visual stimuli (if auditory stimulation were merely distracting, one would expect diminished *total* looking in the presence of sounds). Rather, in the presence of auditory stimulation, infants chose to spend *relatively* more of their time fixating the less stimulating visual display.

The results do not directly support the hypothesis that *rate of change* of an auditory stimulus influences visual orientation in a predictable way. However, it is likely that the linear trend reported above would be significant with additional statistical power, since the size of the effect associated with this analysis was not small, Cohen's $f = .325$ (Rosenthal & Rosnow, 1984). Alternatively, it is possible that a broader range of rates of change of either auditory or visual stimuli would produce the expected effect. Lewkowicz (1985) used auditory stimuli as fast as 8 Hz, which is 60% faster than the fastest auditory stimulus used in the current experiment; perhaps the auditory stimuli used in the current study were too similar to each other (with regard to their ability to arouse) to produce differential fixation of the visual stimuli.

Experiment 2 was designed to further explore the hypothesis proposed by Lewkowicz, Turkewitz, and their colleagues. If, as hypothesized, auditory stimulation influences level of arousal (which in turn mediates looking), a rapidly changing (i.e., stimulating) sound should lead to increased preference for a light flashing at a slower repetition rate, *even if the auditory dimension that is changing is not repetition rate, as in Experiment 1,* but loudness. Similarly, looking at a light flashing at a faster rate might be expected to be increased in the presence of a slowly changing sound, or in the absence of sound.

In addition, Experiment 2 considers the effect of auditory stimulation on infants' arousal levels. Each subject's heart rate was recorded during the experimental procedure; if the auditory stimuli were arousing, this should be reflected in heart rates that change as a function of auditory condition. Thus, these data will allow an assessment of the hypothesis that arousal has a role in the mediation of sensory interaction.

EXPERIMENT 2

Method

Subjects. The subjects were 36 infants (18 males and 18 females) between 3 months, 20 days and 4 months, 10 days of age (mean age = 123 days). All infants were screened for family history of epilepsy and seizure disorder. All infants were healthy, and except for 3 infants carried 36 weeks but born over 6 lb, all were full term. Subjects were recruited exactly as described for Experiment 1.

Stimuli. The auditory stimuli were generated in a professional recording studio. The loudness of a chorus of adult male voices continuously singing a note (440 Hz) was electronically modulated with an oscillator and a voltage-controlled amplifier. The sound to be loudness-modulated (the chorus) was initially of a constant fundamental frequency and amplitude, being sampled from an E-Mu *Emulator 2* (a sampling keyboard). Two final stimulus sounds were constructed by modulating the loudness of the chorus using two triangle waves with identical frequencies (1 Hz) but different amplitudes. One of the final stimulus sounds varied over a range of 4 Voltage Units (± 2 VU) each half-second; the other varied over a range of 40 Voltage Units (± 20 VU) each half-second. The latter sound was 0 dB at its softest (a transient silence so fast as to be virtually undetectable) and 76 dB at its loudest. The former sound was 75 dB at its softest and 78 dB at its loudest (all dB measurements were made with a Scott (type 451) A-weighted sound level meter at the infant's ears). This will be referred to as the "slow-change" sound, because the loudness of the sound changed over a much smaller range than the range over which the loudness of the "fast-change" sound changed in the same amount of time. These sounds were recorded onto ¼-in. reel-to-reel recording tape, and were replayed on a high-quality 2-track tape deck operating at 15 i.p.s. They were recorded in 10-s continuous sections; five sections of the fast-change sound were followed by five sections of the slow-change sound, which in turn were followed by five more sections of the fast-change sound. The auditory stimuli were presented as in Experiment 1. The visual stimuli were identical in form and in presentation to those used in Experiment 1.

Procedure. The procedure for this experiment was similar to that used in Experiment 1. As in Experiment 1, infants were seated and centered. After instructions were given to caretakers, a 30-s reading of each infant's baseline heart rate was recorded. Six 10-s familiarization trials ensued, in which infants were exposed to two trials each of the fast-change auditory stimulus presented alone, the slow-change auditory stimulus presented alone, and the visual stimuli presented alone (without any other stimulation).

The experimental trials were 10 s long, and the visual stimuli were presented in each trial; heart rate was recorded throughout the procedure. There were three types of trials: no auditory stimulus presented ("silence trials"), fast-change auditory stimulus presented ("fast-change trials"), and slow-change auditory stimulus presented ("slow-change trials"). Auditory and visual stimuli were presented simultaneously (and asynchronously) in all fast-change and slow-change trials, for the entire duration of the trial. Inter-trial intervals were under 5 s. A block consisted of 15 trials; 5 consecutive trials of one type were followed by 5 consecutive trials of another type, which in turn were followed by 5 consecutive trials of the last type. All subjects experienced two blocks of trials. The second block began after a short (approximately 3 min) break, during which the lateral positions of the lights were changed. This block started with a single trial in which all subjects were exposed only to the visual stimuli, so as to orient them to the changed position of the lights. The following 15 trials were then presented exactly as in the first block. Trials failing to elicit an infant's attention were repeated. Finally, baseline heart rate measurements were taken again, exactly as they had been initially.

The order of presentation of the auditory conditions (including the no-sound condition) was counterbalanced using a Latin Square design; each order was experienced by 12 subjects. Eighteen subjects saw the 4-Hz light on the right side during the first block of trials and on the left side during the second block. The remaining 18 subjects saw the lights arranged in the opposite fashion. Boys and girls were equally distributed across conditions.

Duration of looking at each of the lights was recorded on-line during each trial by an experimenter trained to record infants' eye movements. This experimenter was unaware of the experimental hypotheses. The duration of each fixation was stored in an IBM AT.

Results and Discussion

All subjects completed trials with no auditory stimulation; hence, each was able to serve as her/his own control. Looking time scores were calculated as in Experiment 1; means of raw and transformed scores are reported in Table 1, along with standard deviations. Arc sine transformed scores were then analyzed in a 2 (sex) × 3 (order of presentation of auditory stimuli) × 2 (order of sides of 4-Hz light) × 3 (auditory stimulus) × 2 (side of 4-Hz light) repeated measures analysis of variance, in which auditory stimulus and side of 4 Hz light were considered within-subjects factors.

This analysis revealed a main effect of auditory condition, $F(2, 30) = 5.83$, $p < .01$, and a side of 4-Hz light × order of sides interaction (which corresponds to a main effect of block), $F(1, 15) = 15.85$, $p < .005$. Mean percent time looking at the faster light in each auditory condition and each block is plotted in Fig. 1. Subjects looked longer at the faster

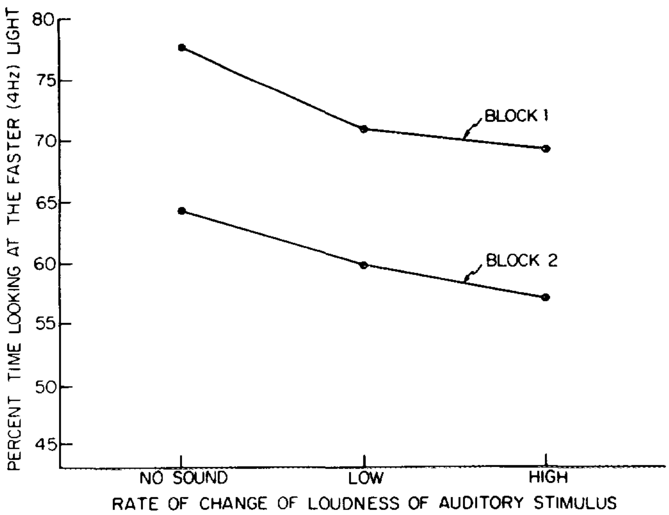

FIG. 1. Mean percent time looking at the faster (4 Hz) light plotted as a function of rate of change of loudness of auditory stimuli.

light in the first block, and during silence trials. There were no other main effects or interactions.

Several planned contrast analyses revealed that the average percent looking at the faster light during silence trials was significantly higher than during fast-change trials, $F(1, 15) = 8.39$, $p < .015$, and slow-change trials, $F(1, 15) = 6.31$, $p < .025$. In addition, a contrast analysis was conducted using orthogonal polynomial-based contrast weights. This analysis revealed a significant linear trend, $F(1, 15) = 8.39$, $p < .015$. Finally, although the average percent looking at the faster light during fast-change trials was significantly lower than the mean of the average looking at the faster light during silence and slow-change trials ($F(1, 15) = 5.45$, $p < .035$), the average percent looking at the faster light during fast-change trials was not significantly lower than during slow-change trials.

An analysis of total looking time was conducted similarly, as in Experiment 1; means of raw and transformed scores are reported in Table 1, along with standard deviations. Arc sine transformed scores were then analyzed first in a 2 (sex) × 3 (order of presentation of auditory stimuli) × 2 (order of sides of 4-Hz light) × 3 (auditory stimulus) × 2 (side of 4-Hz light) repeated measures analysis of variance, in which auditory stimulus and side of 4-Hz light were considered within-subject factors. Because this analysis revealed no main effects or interactions involving sex or order of presentation of auditory stimuli, the data were collapsed across these variables and then subjected to a 2 (order of sides of 4-Hz light) × 3 (auditory stimulus) × 2 (side of 4-Hz light) repeated measures analysis of variance, in which auditory stimulus and side of 4-Hz light were considered within-subjects factors. This analysis revealed only a side of 4-Hz light × order of sides interaction (i.e., a main effect of block), $F(1, 18) = 27.03$, $p < .0001$; average total looking time in the first block (79% of total *possible* looking time) exceeded that in the second block (74% of total possible looking time). The absence or type of auditory stimulation did *not* affect the *total* amount of looking directed at the visual displays.

There are two possible explanations for the fact that infants looked at the faster light less in the second block. First, this effect might be due to habituation. Subjects looked at the faster light from 69.4 to 77.7% of their total looking time during the first block, so it is not surprising that by the second block they might have tired of this stimulus in favor of the slower light. Alternatively, because the main effect of auditory condition in this analysis suggests that infants' visual preferences *are* influenced by overall levels of stimulation, it is possible that reduced visual attention to the faster light in the second block reflects residual arousal produced by exposure to repeated auditory *and* visual stimulation in the first block; if arousal generated in the subjects during the first block remained present during the second block, the hypothesis proposed by Lewkowicz, Turkewitz, and their colleagues would *predict* reduced attention to the faster light in the second block. Thus, this effect might be due to habituation, residual arousal, or some combination of these processes. The change in *total* looking across blocks can be similarly understood.

Heart period data were also analyzed. Subjects were included in the analysis only if a measure of heart period was obtained under each auditory condition. Trials in which more than 66% of the number of inter-beat intervals recorded were excluded were not considered in these analyses; such trials provided data so rarefied as to be considered unstable. Subjects were required to have provided four usable trials across both blocks in each auditory condition (or three in each condition in one block, as these were generally recorded consecutively); these criteria led to the elimination of 17 subjects' data from the following analyses. Each remaining subject's average heart period in each auditory condition was computed and used as the dependent variable in a repeated measures analysis of variance. This analysis revealed no significant effects.

The absence of a significant effect in the heart period data is due to the large variability in measured heart periods. There is the possibility, however, that this variability masks a regular, underlying trend. In fact, a frequency count analysis of change in each subject's heart period across auditory conditions in block 1 did reveal significant differences. Of 17 subjects with heart period data in both silence and slow-change trials, 13 had longer heart periods (lower heart rates) during silence than during slow-change auditory stimulation, $\chi^2(1) = 4.76$, $p < .05$. Similarly, of 22 subjects with heart period data in both silence and fast-change trials, 16 had longer heart periods during silence than during fast-change auditory stimulation, $\chi^2(1) = 4.54$, $p < .05$. Thus, shorter heart periods were associated with auditory stimulation in this analysis.

GENERAL DISCUSSION

Auditory stimulation influenced looking in both experiments. The fact that *total* looking was *not* influenced by the presence of auditory stimulation in either experiment indicates that the infants were not simply distracted from their preferred visual stimulus by the auditory stimuli. Rather, the results suggest that for the types of stimuli used in this study, 4-month-old infants exposed simultaneously to auditory and visual stimulation show a reduced tendency to fixate relatively *more* visually stimulating events.

There were no significant differences between fixation durations in those conditions in which sounds were heard, precluding strong conclusions about the rate-of-change hypothesis. Perhaps this is because, as suggested by Lewkowicz (1986), the *effective* intensity of a stimulus for infants might be the result of "a complex interaction of the duration of the stimulus, . . . its repetition rate," *and* its intensity. Since the visual stimuli used in the current study were of shorter duration than those used by Lewkowicz (1985), they might not have been "intense" enough (in the sense of *effective* intensity) to generate the arousal required to produce statistically significant differences across sound conditions. Because significant and/or marginal linear trends were found in *both* experiments, though, it is quite possible that future research utilizing stimuli with more widely disparate rates of change would lend support to the hypothesis that the rate of change of an auditory stimulus influences visual orientation in the predicted way.

Gardner & Karmel (1984), Gardner et al. (1986), Lawson & Turkewitz (1980), Lewkowicz (1985), and Lewkowicz & Turkewitz (1981) have suggested that the influence on looking of sensory stimulation in any nonvisual modality might be mediated by arousal; however, in contrast to the current study, previous experiments of this type on 4-month-old infants have typically *assumed* that the various stimuli employed were arousing, and have not *measured* arousal in response to stimulation. Regarding the heart period data collected in the current study, it is appropriate to consider the results of the frequency count analysis seriously, because even though the average changes in heart period produced by the auditory stimulation were small (relative to variability), it is unlikely that so many subjects would have experienced increased heart rate in the presence of auditory stimulation by chance alone. Thus, it is likely that the current data indicate that the auditory stimuli were arousing to the subjects (Ciarenello, 1983).

This finding, considered together with the finding that auditory stimulation produced decreased looking at the faster light in *both* Experiments 1 and 2, lends support to the hypothesis that arousal plays a role in the mediation of looking. Our future investigations of sensory/perceptual interaction will begin with the parametric manipulation of critical stimulus variables through a wide range of values. It will also likely be fruitful to explore other measures of arousal. Finally, it would seem that regular collection of heart rate data in future polysensory perception protocols will enhance our understanding of sensory mode interactions in infants.

Although the present data do not permit robust conclusions about the rate-of-change hypothesis, taken together, the results of the two experiments demonstrate that auditory stimulation does influence visual orientation to stimuli that are not themselves producing sounds. Thus, sensory inputs interact to influence infant behavior. The possibility of such interaction is well supported by neuropsychological data that demonstrate the existence of individual subcortical neurons that respond to sensory input from more than one modality. These so-called polysensory neurons have been discovered in such diverse species as macaque monkeys (Benevento, Fallon, Davis, & Rezak, 1977; Jay & Sparks, 1984), mice, rattlesnakes, rabbits, owls, locusts, *Apysia,* and trout (Meredith & Stein, 1985, 1986a, 1986b; see Moore, 1988/1989, for a review); it is quite possible that similar polysensory cells in human infants could play a role in the behaviors observed in the current studies.

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