Habituation, Sensitization, and Infants' Responses to Motherese Speech

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Four-month-old infants were tested for their visual responses to infant-directed (ID) speech versus adult-directed (AD) speech in a fixed-trial habituation procedure. In Experiment I, infants looked significantly longer in response to a 4 × 4 checkerboard pattern that was compounded with an ID speech segment than an AD speech segment. Looking times increased significantly between the first and second presentations of the ID speech segment only. In Experiment II, infants looked slightly more during ID than AD trials when the two were alternated from trial to trial. Responding to the first AD speech segment was significantly greater than when it was preceded by ID speech than when it was not, while responding to the first ID speech segment was significantly less when it was preceded by AD speech than when it was not. These findings are discussed in relation to the hypothesized differential arousing properties of ID and AD speech.

According to the dual-process theory of infant attention, an infant's responses to

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the repeated presentations of a nonsignal stimulus reflect the operation of two separate processes, habituation and sensitization (Kaplan, Werner, & Rudy, 1990). The habituation process [analogous to Sokolov's (1963) schema-comparison process] produces a stimulus-specific decline in responding to repeated stimulation, and grows stronger as the number of repetitions increases. The state-mediated sensitization process produces increments in responsiveness on early trials, which decay spontaneously over time. These two processes are thought to sum to determine overt responding, with sensitization serving as a "gain control" on the final response pathway (Groves & Thompson, 1970; Thompson & Glanzman, 1976).

A considerable body of evidence has been collected in support of the hypothesis that sensitization is involved in human infants' responses to repeated presentations of black-and-white checkerboard patterns (Bashinski, Werner, & Rudy, 1985; Kaplan & Werner, 1986, 1987; Kaplan et al., 1990). In this article, the contribution of sensitization elicited by "motherese" or infant-directed (ID) speech to visual responding in a fixed-trial habituation procedure is investigated.

Two main types of evidence are thought to reveal the operation of sensitization in the habituation–dishabituation paradigm (Groves & Thompson, 1970; Kaplan et al., 1990). First, although the precise form of the response function predicted by the dual-process theory depends on the relative activation of the habituation and sensitization processes, the dual-process theory predicts that moderately sensitizing stimuli should elicit nonmonotonic patterns of responding. That is, because the response decremental habituation process is weak on early trials but gradually grows in strength as the number of stimulus presentations increases, while the opposite is true for the response incremental sensitization process, when the two processes sum, responding should increase before it begins to decrease. Research with 4-month-olds has demonstrated significant increases in duration of looking between the first and second presentations of a 12 × 12 or a 20 × 20, but not a 4 × 4, black-and-white checkerboard pattern (Bashinski et al., 1985; Kaplan & Werner, 1986). Initial response increments were eliminated when the interstimulus interval (ISI) between the first and second trial was increased from 10 to 20 or 30 s (Bashinski et al., 1985), as would be expected if they were mediated by a time-dependent sensitization process.

The second type of evidence that supports the dual-process analysis comes from studies on dishabituation, as defined by Thompson and Spencer (1966). In contrast to the definition of dishabituation as renewed responding to a *novel* stimulus, Thompson and Spencer defined dishabituation as the renewed response to the *familiarized* stimulus when it is retested *after* the introduction of the novel stimulus. This form of dishabituation was attributed by Thompson and Spencer to the lingering sensitization generated by the presentation of the novel stimulus (see also Groves & Thompson, 1970; Thompson & Glanzman, 1976).

Thompson–Spencer dishabituation of visual fixation has been demonstrated in 4-month-olds who were first habituated to a 4 × 4 or 12 × 12 checkerboard pattern, then given two presentations of a 20 × 20 pattern, and finally retested with the original pattern. A 12 × 12 checkerboard pattern has also been shown to dishabituate looking in infants who were habituated to a 20 × 20 pattern, but a 4 × 4 pattern failed to elicit novelty responses or dishabituate looking after habituation to either a 12 × 12 or 20 × 20 pattern (Kaplan & Werner, 1986). Dishabituation, like initial response increments, has been shown to occur when the familiarized stimulus is retested 10 s, but not 20 or 30 s, after the termination of the dishabituating visual stimulus (Kaplan & Werner, 1986, 1987). Additional studies have demonstrated Thompson–Spencer dishabituation of responding to a 4 × 4 checkerboard after a single presentation of a 75 or 84 dB (SPL), 1000-Hz square-wave tone, but not after a 55 dB, 1000-Hz square-wave tone, a no-change control, or when the checkerboard pattern was omitted (Kaplan, Fox, Scheuneman, & Jenkins, 1991). As in previous studies, Thompson–Spencer dishabituation by tones has been obtained when the familiarized checkerboard pattern is retested 10 s, but not 30 s, after the termination of the tone (Kaplan et al., 1991).

With these two types of behavioral evidence in mind, recent research in our laboratory has focused on assessing whether infant-directed (ID) speech is more sensitizing than adult-directed (AD) speech. Research on infant speech perception has shown that parents from a variety of cultures modify their speech when addressing young infants by increasing frequency, exaggerating frequency changes, slowing tempo, increasing amplitude, simplifying vocabulary and syntax, increasing the number of repetitions, and lengthening pauses between words relative to speech directed toward adults (Fernald & Simon, 1984; Fernald et al., 1989; Grieser & Kuhl, 1988; Papousek & Hwang, 1991). A number of studies have shown that ID speech elicits stronger visual responding from infants than does AD speech (Cooper & Aslin, 1990; Fernald & Kuhl, 1987; Pegg, Werker, & McLeod, 1992; Werker & McLeod, 1989). It has been hypothesized that motherese speech functions to engage and maintain attention, modulate affect, and facilitate information processing (Fernald, 1984). Of particular interest here, however, is the suggestion that ID speech more effectively modulates infant state than does AD speech (Fernald, 1984; Papousek, Papousek, & Symmes, 1991).

Consistent with these ideas are studies that demonstrate Thompson–Spencer dishabituation of looking in response to an ID, but not an AD speech segment (Kaplan, Goldstein, Huckeby, Owren, & Cooper, in press), and in response to a train of rising, but not falling, frequency-modulated sweeps (Kaplan & Owren, in press). In those studies, separate groups of 4-month-olds were given twelve 10-s presentations of the 4 × 4 checkerboard pattern, with a single 10-s speech segment or sweep train presented only during the ninth checkerboard pattern presentation. Renewed responding to the 4 × 4 checkerboard was observed following a single presentation of an ID speech segment (Kaplan et al., in press) or a train of rising frequency sweeps (Kaplan & Owren, in press). In contrast, no renewed responding was evident following an AD speech segment or a train of falling frequency sweeps.

The purpose of the current studies was to further assess the sensitizing properties of ID and AD speech by compounding ID or AD speech segments with a checkerboard pattern on every trial, and assessing the effects on visual responding. Three specific predictions were made for Experiment I. First, based on previous habituation studies in which square-wave tones were compounded with checkerboard patterns on every trial (Kaplan & Werner, 1991), it was predicted that either type of speech segment should increase looking at the checkerboard relative to a control group in which no sounds were presented. Second, based on previous studies on infants' responses to ID and AD speech (Cooper & Aslin, 1990; Fernald & Kuhl, 1987), it was anticipated that infants would look longer at the checkerboard in response to ID than AD speech segments. Third, based on the differential Thompson–Spencer dishabituation that is elicited by ID versus AD speech (Kaplan et al., in press; Kaplan & Owren, in press), it was predicted that ID speech would elicit greater initial increments in visual responding than would AD speech.

Experiment I

Method

Subjects

The subjects were 77 healthy, full-term, 4-month-old infants (M = 124 days, range = 110–138 days). Infants were recruited using newspaper birth announcements from the Boulder–Denver metropolitan area. Data from an additional 16 infants were not included in the analysis. Fourteen infants (6 in the ID conditions and 8 in the AD conditions) were excluded due to continuous crying (defined as intense crying for at least 50 s consecutively, i.e., for two or three trials plus the intervening ISIs at any point during the test), and 2 (1 ID and 1 AD) were excluded because they showed no interest in the projection screen (defined as cumulative fixation of 0.0 s over a consecutive span of 50 s). Lack of interest in the projection screen applies to infants who were calm but engrossed in some other detail of the testing situation, usually their own hands or feet, such that failing to fixate on the projection screen can be viewed as a competing response to other stimuli that possessed attributes of color and movement.

Apparatus

A standard infant car seat was located in front of a 10.8-cm square rear-projection screen mounted in the center of a large black wooden panel. The screen was roughly 42 cm from the infant's head. A video camera (Hitachi Model HV 725U) was positioned on the other side of the wooden panel and provided a full-face view of the infant through a small round aperture cut in the panel, 1.9 cm to the infant's left of the projection screen. The infant's field of view was restricted by a black Plexiglas hood that was moved into position over the infant's head, flush against the wooden panel, immediately before the start of a session. A loudspeaker (Sony Model SS95) was located at midline behind the car seat, angled up slightly toward the infant's back.

One observer viewed the infant on a 16-in. black-and-white video monitor (Panasonic WV-5470) that was located in the experimental room. This observer was not blind to condition and could hear auditory stimuli. Another, independent, observer was located in an adjacent room, watching the infant on an identical video monitor. This observer was blind with respect to condition and could not tell when specific visual or auditory stimuli were presented. This observer's data are reported in this article. Each observer used a hand-held microswitch to signal an infant's visual fixation to a microcomputer. Stimuli were presented using two Kodak Carousel slide projectors (Model 760H) outfitted with Uniblitz shutters. One projector contained a slide of a check pattern and the other a clear slide of the same space-average luminance. The two projectors were situated at right angles to a beam-splitter plate, which allowed one beam to pass directly through to the projection screen, while the other projector's beam was reflected by the mirror side of the plate such that it also fell on the projection screen. Shutters, which provided precise temporal control over visual stimulus presentations, were controlled by a Commodore 128 microcomputer, which also tabulated data concerning microswitch closure.

The visual stimuli were a 4 $\times$ 4 achromatic check pattern and a uniformly illuminated field of equal space-average luminance. Auditory stimuli consisted of four approximately 10-s speech segments that were used previously in studies on Thompson–Spencer

Table 1
Characteristics of ID and AD Speech F_0 Contours: "Round and Around" Stimuli

Phrase	ID/AD	Frequency Range (Hz)	M (Hz)	Duration (ms)	Pause (ms)	Max dB
"Round and around"	ID	317 (217–534)	400	1370	125	66
	AD	50 (210–260)	244	691	0	69
"She goes"	ID	174 (260–434)	306	816	85	66
	AD	120 (184–304)	233	525	0	68
"Where she stops"	ID	250 (271–521)	374	1052	125	68
	AD	54 (206–260)	240	788	25	68
"Nobody knows"	ID	364 (157–521)	357	1439	0	73
	AD	57 (171–228)	199	829	0	69.5

dishabituation (Kaplan, Jung, & Jeffers, 1994). One set of ID and AD stimuli was recorded using a MacRecorder microphone and software (Farallon Computing) and a Macintosh IICX computer while an adult female spontaneously talked to her 4-month-old infant. The MacRecorder has 8-bit resolution and a sampling rate of 22 kHz, with anti-aliasing filtering above 11 kHz.[1] The sentence used as the ID speech segment that was extracted from a 3-min recording was "round and around she goes, and where she stops, nobody knows." This particular sentence was selected because it possessed several key features that are characteristic of ID speech, including high average frequency and exaggerated frequency sweeps. During a session after the ID phrase had been identified, the same woman was invited to record an AD version of the sentence with no infant present. Table 1 summarizes the F_0 range, mean of the F_0, duration of each phrase and pause, and maximum amplitude (in dB, SPL) of each phrase. The ID sentence contained higher mean F_0, greater frequency range, and greater phrase duration than the AD sentence, consistent with past findings (Cooper & Aslin, 1990; Fernald et al., 1989; Fernald & Simon, 1984). In order to make the ID and AD stimuli roughly 10 s in duration, the ID sentence was repeated twice and the AD sentence, because its words were of shorter durations, was repeated three times. Background noise from slide projectors measured near the infant's head was 58 dB (SPL).

A second set of ID and AD stimuli were obtained from Cooper and Aslin (1990) and had also been used previously in a study on Thompson–Spencer dishabituation (Kaplan et al., 1994). These stimuli were recorded from an adult female actor, and were comprised of four sentences spoken in either ID or AD intonation. The four sentences were: "Good morning. How are you today? What are you doing? Let's go for a walk." The recording was selected by Cooper and Aslin (1990) from among four others based on a test in which 10 adults rated the appropriateness of the segments as speech directed toward either an infant or an adult. Table 2 lists information about the ID and AD sentences' F_0 ranges, mean F_0s, sentence and pause durations, and maximum amplitudes. The ID segment was presented only once, with an 890- to 1100-ms pause between each sentence. The AD segment was presented twice, with a 500- to 790-ms pause between each sentence.

Procedure

Infants were randomly assigned to one of four groups. At the start of the session, the infant was placed in the car seat and the hood was put into place. The test sequence

Table 2
Characteristics of ID and AD Speech F_0 Contours: "Good Morning" Stimuli

Sentence	ID/AD	Frequency Range (Hz)	M (Hz)	Duration (ms)	Pause (ms)	Max dB
"Good morning"	ID	452 (185–637)	336.7	1300	890	79
	AD	162 (163–325)	233.7	500	500	75
"How are you today?"	ID	492 (158–650)	260.9	1000	1020	82
	AD	229 (162–391)	239.0	600	790	76
"What are you doing?"	ID	476 (164–640)	336.7	1200	1100	79
	AD	181 (166–347)	281.9	600	640	75
"Let's go for a walk"	ID	498 (155–653)	266.9	800	0	74
	AD	154 (206–360)	236.2	600	630	70

was initiated by the experimenter when it was judged that the infant was fixating on the projection screen. Thereafter, stimulus presentations were under computer control. Test onset was therefore infant-controlled, but all other stimulus changes were on a fixed-trial schedule. All subjects were given ten 10-s presentations of the 4 × 4 check pattern, with 10-s interstimulus intervals (ISIs) between check pattern presentations. During ISIs the projection screen was uniformly illuminated. Auditory stimuli were presented on every trial, with the check pattern and auditory stimuli occurring simultaneously. In one replication, a group of infants (n = 20) heard the "Round and around" ID speech segment, while a second group of infants (n = 20) heard the AD counterpart. In a second replication, one group of infants (n = 20) was presented the "Good morning" ID speech segment, and another group (n = 17) the corresponding AD speech segment.

The corneal reflection technique was used to estimate visual fixation throughout the test. Each experimenter signaled a look to the computer when the reflection of the visual pattern was judged to be centered on the infant's pupil. The dependent variable was the cumulative amount of fixation on each 10-s trial. Interobserver reliability was calculated for individual tests by correlating total looking time of the two observers on successive 10-s intervals, mean interobserver correlation of + 0.94 (SD = 0.04; range = 0.82–0.99).

Data Analysis

Data were analyzed using analysis of variance (ANOVA). Because changes in responding between Trials 1 and 2 were of central importance, one ANOVA was carried out on the data for all 10 trials, and a separate ANOVA was carried out for Trials 1 and 2 only. This ANOVA was followed by within-subject t tests to assess the a priori prediction that greater initial increments would be observed in response to ID rather than AD speech segments.

In the repeated measures ANOVAs reported here, the *epsilon* (ε) correction factor (Winer, 1971, p. 523) was applied to adjust for the possibility of an asymmetrical covariance matrix. The ε correction factor, which has a maximum value of 1.00 and which decreases as the asymmetry of the covariance matrix increases, is used as a multiplier of degrees of freedom.

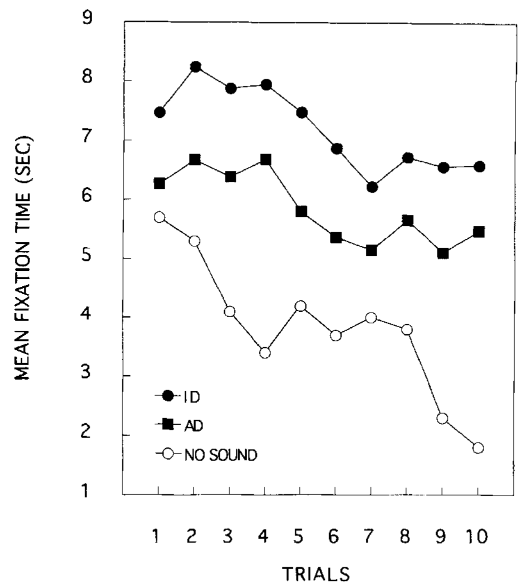

Fig. 1. Mean fixation times in response to the 4 × 4 checkerboard pattern compounded, in separate groups, with ID or AD speech segments. Data are also included from a group that responded to the checkerboard pattern in the absence of sound (from Kaplan & Werner, 1991).

Results

Figure 1 presents the mean looking times for infants in the ID and AD conditions, along with previously published data on responses of 4-month-olds to the checkerboard alone (Kaplan & Werner, 1991).[2] The mean duration of looking was greater in the ID condition than in the AD condition, and both were greater than in the Checkerboard Alone condition. Initial increments in mean looking times were obtained in the ID and AD conditions, but not in the Checkerboard Alone condition. A 2 × 2 × 10 mixed three-factor ANOVA was carried out on these data, with type of speech segment (ID vs. AD) and replication ("Round and around" vs. "Good morning" stimuli) as between factors, and trials as the within factor. That ANOVA yielded a significant effect of speech segment type, $\varepsilon = 0.79$, $F(1,58) = 8.34$, $p < .01$, but no significant effect of replications, $F(1,73) = 0.40$, $p > .50$, and no interaction between these two factors, $F(1,58) = 2.52$, $p > .10$. There was a significant effect of trials, $F(7,519) = 6.67$, $p < .001$, but no two-way or three-way interactions, Fs < 1, ps $> .65$. Orthogonal planned comparisons carried out to follow-up the significant effect of trials revealed significant linear, $F(1,519) = 41.41$, $p < .001$, and cubic, $F(1,519) = 11.37$, $p < .001$, trends only.

A second ANOVA was used to analyze responding for Trials 1 and 2 only. That ANOVA produced a significant effect of speech segment type, $\varepsilon = 1.00$, $F(1,73) = 6.45$, $p < .02$, but not of replications, $F(1,73) = 1.14$, $p > .25$, or of the interaction between the two variables, $F(1,73) = 1.97$, $p > .15$. There was a significant effect of trials, $F(1,73) = 4.24$, $p < .05$, but no interaction between trials and speech segment type, $F(1,73) = 0.39$, trials and replication, $F(1,73) = 0.28$, or these three factors, $F(1,73) = 0.76$, ps $> .50$. In spite of the absence of a reliable Speech Segment Type × Trials Interaction, within-subjects t tests were carried out separately for the ID and AD data because of the a priori prediction that initial increments in visual responding would be greater in the ID condition than in the AD condition. There was a significant increase in responding between Trials 1 and 2 in the ID condition, $t(39) = 2.03$, $p < .05$ (two-tailed), but not in the AD condition, $t(36) = 0.89$, $p > .10$. Initial increments of at least 0.1 s were exhibited by 65% of the infants in the ID condition, $z = 1.74$, $p < .05$, and by 56% of the infants in the AD condition, $z = 0.60$, $p > .25$.

Discussion

Four-month-old infants looked longer at a 4 × 4 checkerboard pattern that was compounded with an ID speech segment than one that was compounded with an AD speech segment. Furthermore, significant initial increments in responding occurred in the ID condition but not in the AD condition. This finding parallels those in the Thompson–Spencer dishabituation paradigm in which the same ID and AD stimuli were employed (Kaplan et al., 1994). The current results suggest that both the ID and the AD speech segments are sensitizing when they are presented beginning on Trial 1, but that the ID speech segment appears to be slightly more sensitizing than the AD speech segment.

One potential explanation of the finding that AD speech elicited significantly less responding than ID speech is that the greater number of repetitions of the AD speech segment led to differences in habituation. Because AD speech is comprised of shorter words and has briefer pauses between words than ID speech (see Tables 1 and 2), each AD speech segment was repeated one more time than the corresponding ID speech segment. Differences in responding may be attributable to differences in the number of speech segment repetitions rather than to differences in attentional effects of ID and AD speech per se.

However, several aspects of the data contradict this hypothesis. First, there were no differences in the speed with which response changes occurred in the ID and AD conditions, as indicated by the absence of a statistical interaction between type of speech segment (ID vs. AD) and trials. Second, if differences in the number of repetitions of the two types of speech segments had an effect on responding, it should have been reflected in a statistically significant interaction between replication condition ("Round and around" vs. "Good morning" stimuli) and trials for both ID and AD conditions, because the former stimulus was repeated one more time per trial than the latter in both ID and AD conditions. No such interaction was obtained. Therefore, an explanation of these findings based on differential habituation due to differences in the number of repetitions of ID versus AD speech segments seems implausible.

Experiment II

Using a between-groups design, Bashinski et al. (1985) showed that 4-month-olds responded more to a 12 × 12 than a 4 × 4 black-and-white checkerboard pattern. However, when individual infants were presented the two types of patterns on alternating trials, differences in visual fixation were eliminated. Bashinski and colleagues suggested that the differences in responding to the 12 × 12 versus the 4 × 4 pattern were attributable to differences in sensitization generated by these two stimuli, and that the within-subject design eliminated the differences in responding because it held constant state variables such as sensitization. The rationale for Experiment II was similar. Experiment I showed that ID speech elicited more looking than did AD speech, and also suggested that ID speech was more sensitizing than AD speech. The question

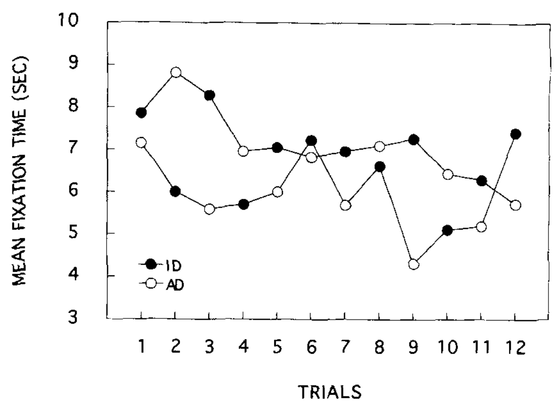

Fig. 2. Mean fixation times in response to the 4 × 4 checkerboard pattern during alternating presentations of ID and AD speech segments for all 12 trials. Data are plotted separately for infants who heard the ID speech segment first versus those who heard the AD speech segment first.

arises as to how much of the differential responding can be attributed to differences in sensitization. Four-month-olds were therefore tested for visual responsiveness to alternating presentations of ID and AD speech.

Method

Subjects

Twenty-six healthy, full-term 4-month-olds (M = 126 days, range = 109–136 days) served as subjects. An additional 9 infants were tested but excluded from the analysis, 4 due to crying (2 each in the ID First and AD First testing orders), 2 due to inattention (both ID First), 1 due to sleeping (AD First), and 2 due to equipment failure (both AD First). Infants were recruited as in Experiment I.

Apparatus

The apparatus from Experiment I was also used in this experiment.

Procedure

Each infant received twelve 10-s presentations of the black-and-white, 4 × 4 checkerboard pattern, with 10-s ISIs between each. On alternating trials, infants heard either the ID or the AD "Good Morning" stimulus that was described in Experiment I. For one group of infants, the ID speech segment was presented first, and for the other group the AD speech segment was presented first. Two observers were present for all tests, with mean interobserver reliability of 0.95 (SD = 0.04; range = 0.84–0.99).

Results and Discussion

Figure 2 presents the mean fixation times of infants in the two testing orders for all 12 trials of the experiment. A 2 × 2 × 6 mixed three-factor ANOVA was performed on these data, with testing order (ID or AD First) as the between factor, speech segment type (ID or AD) as one within factor, and repeated presentations as the other within factor. There was no significant overall effect of testing order, $\varepsilon = 1.00$, $F(1,24) = 2.35$, $p > .10$, and the effect of speech segment type narrowly missed the .05 level of statistical significance, $F(1,24) = 3.99$, $p < .06$. There was no significant interaction between testing order and speech segment type, $F(1,24) = 0.56$, $> .40$. Similarly, there was no significant effect of repeated presentations, $\varepsilon = 0.69$, $F(3,83) = 1.76$, $p > .10$, no significant interaction between testing order and repeated presentations, $F(3,83) = 1.32$, $p > .25$, between speech segment type and repeated measures, $\varepsilon = 0.81$, $F(4,97) = 2.11$, $p > .10$, or between testing order, type of speech segment, and repeated measures, $F(4, 97) = 0.86$, $p > .50$.

Although there was no significant interaction between testing order and speech segment type, the mean amount of looking during the first presentation of the AD stimulus was *greater* when it was preceded by the ID stimulus than when it was not, while the mean amount of looking during the first presentation of the ID stimulus was *less* when it was preceded by the AD stimulus than when it was not. An ANOVA comparing responding on Trial 1 to that on Trial 2 for infants in the two testing orders revealed nonsignificant effects of testing order, $F(1,24) = 3.54$, $p > .07$, and trials, $F(1,24) = 0.40$, $p > .70$, but a significant interaction between testing order and trials, $F(1,24) = 4.48$, $p < .05$. Analysis of simple main effects showed a significant difference in looking between the two testing orders on Trial 2, $F(1,24) = 7.05$, $p < .02$, but not on Trial 1, $F(1,24) = 0.45$, $p > .50$, and no significant effect of trials in either the ID-First, $F(1,24) = 2.69$, $p > .10$, or the AD-First, $F(1,24) = 1.84$, $p > .15$, conditions.

For each infant, cumulative looking times during the ID and the AD speech segments were tabulated, and an "ID Preference Score" was calculated by dividing the cumulative looking time during the ID speech segment by the cumulative looking time during the ID plus the AD speech segments. An ID Preference Score near 1.00 indicates a very strong ID preference, a score near 0.00 indicates a very strong AD preference, and a score of 0.50 indicates no preference. The mean preference score was 0.532 ($SE = 0.015$), a value that, although near 0.500, differed significantly from it, $t(24) = 2.07$, $p < .05$ (two-tailed).

These results show that the amount by which 4-month-olds look longer at a checkerboard that is accompanied by ID relative to AD speech is reduced when a within-subject design is employed. The overall effect of type of speech segment narrowly missed the .05 level of significance in this experiment, although the ID Preference Score was significantly, if only slightly, above chance. Furthermore, looking times in response to the first presentation of the AD stimulus was greater when it was preceded by the ID stimulus than when it was not. The AD stimulus, in contrast, did not increase the initial response to the ID stimulus. These findings are consistent with the hypothesis that ID speech is more sensitizing to 4-month-olds than AD speech, and that sensitization contributes to the differences in visual responding that are elicited by ID versus AD speech.

General Discussion

In both between-groups and within-subject fixed-trial habituation tests, 4-month-olds exhibited longer mean looking times when a checkerboard pattern was compounded with an ID speech segment than when the checkerboard was compounded with an AD speech segment, although the magnitude of the effect was reduced in the within-subject design. The finding of greater responding to ID than AD speech in using the fixed-trial habituation procedure is consistent with previous demonstrations of differential responding to ID and AD stimuli that employed operant head-turning (Fernald, 1985; Fernald & Kuhl, 1987), visual-fixation-based auditory preference (Cooper & Aslin, 1990), infant-controlled habituation (Pegg et al., 1992) and fixed-trial dishabituation (Kaplan et al., in press) procedures.

Furthermore, the current findings offer support, within the context of the dual-process analysis of infant attention, for the hypothesis that ID speech increases 4-month-olds' arousal levels more effectively than AD speech. Consistent with the dual-process theory, significant initial increments in visual fixation were obtained only in response to the ID speech segment. Also consistent with the theory, the ID–AD difference in responding was not statistically reliable when a within-subject design was employed, although the ID Preference Score was slightly but significantly above chance. Taken together with a recent study demonstrating Thompson–Spencer dishabituation of visual fixation by ID but not AD speech (Kaplan et al., in press), these findings provide support for the hypothesis that ID speech can more effectively increase an infant's level of arousal than AD speech.

Given that several other investigators had demonstrated differences in visual responding attributable to ID versus AD speech segments in within-subject operant head-turning or visual-fixation-based auditory "preference" procedures, it is not surprising that a similar effect was obtained here. Nevertheless, as in Experiment 2, the magnitudes of the behavioral "preferences" obtained in past (within-subject) studies have been small. For example, In Fernald's (1985) study, 4-month-old infants turned in the direction of the ID speech contour 8.7 times out of a possible 15 (54%), a value slightly but significantly above chance. In the Cooper and Aslin (1990) study, 1-month-olds looked an average of 33.6 s at a checkerboard during ID playback and 21.6 s during AD playback (61% ID preference). In a follow-up study with 2-day-olds, there was also a significant difference in overall looking in response to ID versus AD speech segments but, again, the preference was small (18.3 ID vs. 13.9 AD, a 56% ID preference). The current findings suggest that within-subject designs, because they reduce any differences in infant state while the infant hears ID or AD speech segments, may lead to an underestimation of the magnitude of differential responding that would be observed in a between-groups design when stimulus-specific *and* general state effects are different for ID and AD stimuli.

In conclusion, the current experiments extended demonstrations of differential visual responding elicited by ID versus AD speech to a fixed-trial habituation procedure, and offered additional support for the hypothesis that one effect of ID speech on 4-month-old infants is to modulate arousal levels.

Notes

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Footnote

[1] An anonymous reviewer raised the concern that the 8-bit resolution of the MacRecorder system may be inadequate due to a relatively low signal-to-noise ratio. The concern is that there may be too few quantizing intervals to separate low amplitude aspects of the signal from background noise. Given that AD speech typically has a smaller dynamic range than ID speech, and the 58-dB background noise levels, the possibility exists that infants may respond more to ID than to AD speech because the ID speech stimulus is at or near

its peak loudness for a greater proportion of the total stimulus duration than was the AD speech stimulus. The implication is that any observed ID–AD differences in responding might be artifactual.

Differences in signal-to-noise ratio and dynamic range between ID and AD speech will always be present due to the greater frequency modulation, amplitude modulation, and dynamic range of ID stimuli (Fernald, 1984). Furthermore, infants must frequently experience adults' ID speech against a background of moderately high ambient noise levels. To a certain extent, then, this reviewer's concerns relate to the broader issue of the relative salience of ID versus AD speech for young infants. Moreover, 4-month-olds have, in prior studies, exhibited equal visual responding during presentations of the specific ID and AD stimuli employed here. For example, although differential Thompson–Spencer dishabituation of looking at a 4 × 4 checkerboard pattern has been demonstrated *following* a single presentation of ID versus AD speech, both speech segments were shown to elicit significant recovery of looking *during* the compound trial with the checkerboard, and there were no differences in the magnitudes of response recovery (Kaplan et al., in press). Prior research in this paradigm had shown that the magnitude of the novelty response elicited during compound presentations of a 4 × 4 checkerboard plus a 1000-Hz square-wave tone was directly related to tone intensity over a range of 55 to 75 dB (Kaplan et al., 1991). It would therefore be expected that if the AD speech segment was perceived to be less intense or less discriminable from background noise than the ID speech segment, infants should have responded less to it during the compound trial. Furthermore, in experiments in which ID or AD speech segments served as conditioned stimuli for adult-face unconditioned stimuli (Kaplan et al., 1994), equivalent levels of visual responding were observed during presentations of ID and AD speech segments in the pairing phase (although differences emerged on a summation test). These data indicate that greater responding to ID than to AD speech segments recorded using an audio system with 8-bit resolution and a sampling rate of 22 kHz is not the inevitable consequence of differential quantizing limitations.

[2] These data were collected from 4-month-olds in the same apparatus under identical conditions, but at a different time. Several other habituation functions have been published that describe 4-month-olds' responses to a 4 × 4 checkerboard pattern under the conditions described in the current experiment (Kaplan et al., 1991; Kaplan et al., in press; Kaplan & Owren, in press; Kaplan & Werner, 1986, 1987). The response levels in all cases were comparable. The data from Kaplan and Werner (1991) are employed here because 10 instead of eight 10-s presentations of the checkerboard pattern were given, as was true in the ID and AD conditions reported here.

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