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Dichotic Perception and Laterality in Neonates

JOSIANE BERTONCINI

Laboratoire de Sciences Cognitives et Psycholinguistique CNRS and EHESS, Paris

JOSÉ MORAIS

Laboratoire de Psychologie Expérimentale, Université Libre de Bruxelles, Bruxelles

RANKA BIJELJAC-BABIC

Laboratoire de Sciences Cognitives et Psycholinguistique, CNRS and EHESS, Paris

STEPHEN MCADAMS

Institut de Recherche et Coordination Acoustique/Musique (IRCAM), Paris

ISABELLE PERETZ

Laboratoire de Psychologie Expérimentale, Université Libre de Bruxelles, Bruxelles

AND

JACQUES MEHLER

Laboratoire de Sciences Cognitives et Psycholinguistique, CNRS and EHESS, Paris

Groups of 4-day-old neonates were tested for dichotic discrimination and ear differences with the High-Amplitude-Sucking procedure. In the first experiment, dichotic speech discrimination was attested by comparison with a control group. Furthermore, among those subjects who showed a substantial recovery of sucking response at least after one of the two syllable changes, it was observed that significantly more subjects manifested a stronger reaction to a right-ear change

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than to a left-ear change. In the second experiment, 4-day-old neonates were tested on syllable and music timbre discrimination. The significant Stimulus Type × Ear interaction observed suggests perceptual asymmetries indicative of very precocious brain specialization.

I. INTRODUCTION

Perceptual processing asymmetries generally indicate lateralized structures that sustain specialized devices for dealing with particular aspects of the environment. Several views have been proposed as to the origin of lateralization. Lenneberg (1967) proposed that after an initial period of equipotentiality between the hemispheres, asymmetry develops along with the acquisition of language. However, clinical, anatomical, and electrophysiological investigations have also yielded results suggesting that hemispheric asymmetry may be present in early infancy (Dennis & Whitaker, 1976; Witelson & Pallie, 1973; Wada, Clarke, & Hamm, 1975; Chi, Dooling, & Gilles, 1977; Molfese, Freeman, & Palermo, 1975; Gardiner & Walter, 1977).

There have been a number of attempts to investigate hemispheric asymmetries in infants' responses to speech and nonspeech stimuli. Some of these studies have combined paradigms of habituation–recovery of behavioral responses with a dichotic presentation of stimuli. One of the first such studies (Entus, 1977) showed that 1- to 4-month-old infants exhibited greater sucking recovery when a change of syllable occurred in the right ear than in the left. Similarly, a left ear advantage was observed for musical stimuli. However, Vargha-Khadem and Corballis (1979) failed to replicate Entus' study and did not observe a right ear advantage for speech in 2-month-old infants. Other investigations using different techniques have reported a right ear advantage for speech. Glanville, Best, and Levenson (1977), and Best, Hoffman, and Glanville (1982), demonstrated a right ear advantage in groups of 3- to 4-month-old infants, using an orienting cardiac response. A 2-month-old group showed a left ear advantage with musical stimuli, but did not evidence asymmetry with speech stimuli (Best et al., 1982).

There are many possible explanations for the discrepancies among these studies. The methods and the ages of the subjects tested vary greatly. In addition, processing asymmetries may develop during the first few months of life, or alternatively, they may be present at one age, disappear, and then reappear at a later age (Bever, 1982; Lokker & Morais, 1985). Finally, as Best et al. (1982) have pointed out, differences may be induced by the level of development of the perceptual capacities required for the task rather than by hemispheric asymmetry per se.

Given the above mentioned difficulties, it is important to assess the facts once again. It seems reasonable to narrow the age range of subjects tested (and why not test as youngest as possible?). A number of recent studies have investigated the newborn infant's capacities for speech perception with High Amplitude Sucking (HAS). It is now known that neonates are capable of performing simple discrimination tasks with speech contrasts. Bertoncini, Bijeljac-Babic, Blumstein, and Mehler (1987) have shown that 4-day-old neonates can discriminate consonantal place of articulation and vowel quality, in the absence of steady-state information, on the basis of the initial 30 msec of CV syllables. Other studies have demonstrated even more sophisticated abilities in newborns, e.g., detection of phonetic differences between sets of various CV syllables (Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy, & Mehler, 1988) or discrimination of utterances in the native language from those in another language (Mehler, Lambertz, Jusczyk, & Amiel-Tison, 1986; Mehler et al., 1988). Given the speech perception abilities manifested by newborn infants, it seems worthwhile to examine whether there is evidence for lateralization at this age.

Dichotic perception has never been studied in neonates. Thus, it is necessary to establish whether neonates can discriminate minimal changes in pairs of dichotically presented syllables. For this reason, in addition to an experimental group, the first experiment included a control group wherein the same dichotic pair was presented throughout the habituation and the test phases. This control group provided the background data against which we could analyze the results of the various test groups. Several preliminaries had to be disposed of in order to assess possible ear differences. First, might an ear difference be reflected in a difference in the level of postshift sucking scores (i.e., after a change to a novel stimulus)? To assess this possibility it was necessary to obtain an estimate of individual discrimination performance. Such an attempt was made by using the control group data to define a criterion that would differentiate dishabituation–recoveries from random fluctuations in the control group performance. Second, it is likely that some subjects may give no evidence of dishabituation after the changes in either ear. Because it is impossible to argue that the less negative of two negative reactions reflects an ear advantage in discrimination capacity, it was decided that such subjects should be dropped from the analysis of ear effect. Finally, it should be noted that two successive measures on the same subject are reliable if, and only if, a constant level of arousal is maintained throughout the experiment. This condition is often difficult to attain with neonates. Therefore, in a second experiment, we used a complementary approach previously employed by Entus (1977) and by Glanville et al. (1977) in their studies. It consists of evaluating the interaction between the ear effect and the effect due to the linguistic or musical nature of the stimuli. If processing of speech and music gives rise to asymmetries in opposite directions then a significant interaction might be observed without the necessity of any performance estimation and subject selection.

II. EXPERIMENT I

Method

A. Stimuli. The stimuli consisted of four consonant–vowel, synthetic syllables (/ba/, /da/, /ta/, and /pa/). Stimuli were generated with a FORTRAN program performing a numerical simulation of a formant speech synthesizer (Jospa, 1979). The total duration of the two syllables, /pa/ and /ta/, was about 300 msec. For the other two syllables, /ba/ and /da/, the total duration was about 400 msec. Each stimulus was synthesized in two pitch forms: one corresponding to the syllable spoken with a high pitched voice (Fo = 240 Hz in the stable portion of the spectrum) and the other with a low pitched voice (Fo = 120 Hz).

The dichotic pairs consisted of two different syllables, simultaneously presented, one with high pitch and one with low pitch to avoid any possible fusion effects. They were paired as can be seen in Table 1. The change in voicing and place of articulation in the initial stop consonants systematically occurred in the higher pitch syllable (/ba/ vs /ta/ and /da/ vs /pa/).

B. Subjects. All subjects were recruited at the Baudelocque Maternity Hospital in Paris, France. They were healthy, full-term newborns free from complications during pregnancy and delivery. Their gestational age ranged from 38 to 41 weeks and was confirmed by a neurological evaluation (Amiel-Tison, 1977) on the first and third day. All subjects weighed more than 2500 g at birth (mean birthweight: 3311.5 g, *SD*: 381.5) and had 5-min APGAR scores of 10. Their two parents were both right-handed. Parental handedness was assessed by means of a questionnaire consisting of 20 items (writing, drawing, throwing, . . .).

All subjects displayed positive reactions on an auditory test on their second day. Each ear was tested with stimuli on two frequency bands (1000–4000 Hz and 4000–8000 Hz) of white noise at 80 dB delivered by a Babimètre Veit-Bizaguet.

One hundred newborns were tested on the fourth, fifth, or sixth day after delivery. Of these, 40 subjects did not complete the experiment: 8 went to sleep, 4 cried during the experiment, 4 failed to maintain appropriate sucking level, and 10 did not habituate within 10 min during the first habituation phase and 14 during the second habituation phase. Of the 60 subjects (28 females and 32 males, mean age: 4.4 days) who completed the experiment, 40 subjects were assigned randomly to the experimental conditions and 20 to the control group.

C. Apparatus. Infants sucked on a standard nipple connected to a pressure transducer which was part of a specialized nonnutritive sucking device designed by CEMI (Lyon). The output of the pressure transducer was converted to an electric pulse that was fed

TABLE 1

EXPERIMENT I: DICHOTIC PAIRS OF SPEECH STIMULI PRESENTED TO EACH EXPERIMENTAL GROUP IN THE FIRST AND THE SECOND PART OF THE EXPERIMENT

	Group I		Group II	
	RE	LE	RE	LE
Hab	da	**ba**	**ba**	da
Test	da	**ta**	**ta**	da
Break				
Hab	**da**	ta	ta	**da**
Test	**pa**	ta	ta	**pa**

Note. Bold letters indicate the high pitched syllables in which changes occurred.

through a potentiometer circuit that allowed the selection of the high amplitude sucks by threshold adjustment. Impulses exceeding the threshold were cumulated on an electronic counter that provided sucking rates per minute throughout the experimental session. The same impulses were used to trigger two Tandberg TD 20 A tape recorders. These tape recorders presented dichotic stimuli recorded on tape loops. Before the experimental sessions, identical continuous calibration tones were used for equating the intensities of the two channels on the two tape recorders. One tape recorder was used to deliver habituation stimuli and the other for test stimuli. The selection was made through a Scott A 417 stereo amplifier. The dichotic pairs of stimuli were presented through Seenheiser HD 414 headphones.

D. Procedure. Subjects were tested in a quiet, dimly lit experimental room, about 2 hr after feeding. They were awakened by manipulation and by being held in a face-to-face upright position for few minutes in order to obtain a quiet, alert, eye-open state. They were then reinstalled in their cradle, in a semi-inclined position to maximize the chances of their remaining alert. The headphones and the nipple fixed by a rigid mechanical arm restricted major changes in head position. The experimenter was instructed to avoid any intervention during the experimental session and did not know to which group the subject was assigned.

For each subject the pressure transducer's sensitivity was adjusted during the first 2 min to set the baseline sucking rate between 15 and 25 criterion sucks per minute. After the baseline period, the habituation dichotic pair was presented each time the infant produced a criterion suck, with a maximum rate of one stimulus pair per 1.5 sec. A habituation criterion was set at 2/3 of the maximum sucking rate/1 min obtained during the previous 5 min. For the experimental group, the stimulus was changed in one ear when the sucking rate fell below this criterion for 2 consecutive min. The first 3 min of contingent sucking did not count toward recording the maximum rate with respect to which the habituation criterion was calculated. In addition, to reduce the total duration of the experiment, the habituation criterion had to be attained within 10 min.

The experiment included two parts interrupted by a short pause of 1 min. Each part consisted in a habituation phase and a test phase that lasted 5 min. Two experimental groups of 20 subjects each were used to counterbalance the order of stimulus change. As can be seen in Table 1, Group I received the first change in the left ear, while Group II received the first change in the right ear. Half of the subjects in the control group were presented with the same habituation pair as Group I while the other half received the same pair as Group II. When the habituation criterion was attained no change occurred in either ear and sucking rates were scored for the subsequent 5 min. After the break, the control group resumed the experiment with the same second habituation pair as its corresponding experimental group.

Results

Table 2 presents sucking rates during the baseline part of the experiment, the maxima used to calculate the habituation criterion and the mean sucking rate for the last 2 min of habituation, for both parts of the experiment.

Simple analyses of variance revealed no difference between groups on each of these preshift measures ($F(2, 57) = 1.077$ for the baseline, $F < 1$ in the other cases). Thus, the control and the two experimental groups performed similarly in the habituation phases of the first and the second part of the experiment. A split-plot ANOVA shows a significant difference of sucking rate between the baseline and both maxima ($p < .001$).

TABLE 2

EXPERIMENT I: MEAN SUCKING RATES OF THE EXPERIMENTAL AND CONTROL GROUPS ON PRESHIFT MEASURES—BASELINE, MAXIMA USED TO CALCULATE HABITUATION CRITERION, AND MEANS OF LAST TWO PRESHIFT MINUTES

	Group I	Group II	Control
Baseline	18.15	17.45	20.65
Max 1	43.40	45.95	43.10
Preshift 1	20.63	22.28	25.63
Max 2	40.95	46.85	41.60
Preshift 2	22.30	25.63	23.95

Note. Max 1 and Preshift 1 for the first part of the experiment; Max 2 and Preshift 2 for the second part of the experiment.

For all the groups there is no difference between the maximum sucking rates of the first and the second part, nor between the averages of the 2 preshift min preceding the first and second change of stimuli. Habituation times during the first and the second part appear to be equivalent, i.e., 8.3 min and 7.7 min, respectively.

A. *Stimulus change effect.* An overall analysis of variance was performed on the recovery scores (average of the first 2 min of test minus average of the last 2 min of habituation). Condition (experimental or control) and Order of stimulus change (left ear–right ear or right ear–left ear) were the between-subject factors, and Ear (left and right) was the within-subject factor. The main effect of Condition was significant ($F(1, 56) = 6.899$, $p < .025$) indicating that the recovery scores of the experimental groups were significantly higher than those of control groups (Fig. 1). Neither of the other two main effects, Order of change

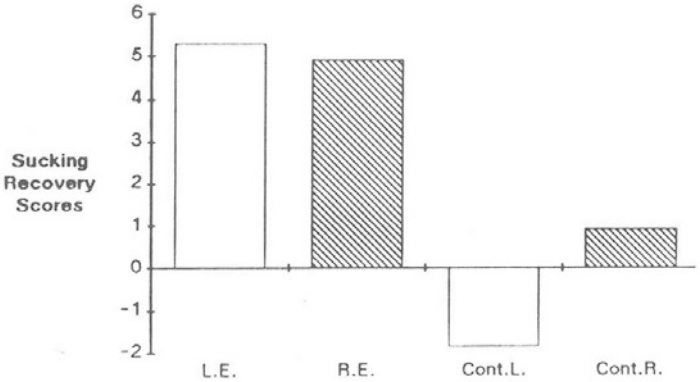

FIG. 1. Sucking recovery scores (average of the first 2 postshift min minus average of the last 2 preshift min) for the experimental subjects as a function of the ear receiving the change (left ear or right ear) and for the corresponding control subjects (Cont. L. or Cont. R.). Experiment I.

and Ear, was significant ($F(1, 56) = 1.998$, and $F(1, 56) < 1$, respectively), nor were any significant interactions observed.

The effect of stimulus change on the 40 experimental subjects is shown by comparing the means of the last 2 min of habituation with the means of the first 2 min of test, regardless of the order in which the stimuli changed. The mean sucking rate after change (27.83 sucks per minute) was significantly higher than that before change (22.71 sucks per minute), $F(1, 39) = 16.376$, $p < .001$. No significant interaction was observed for the ear receiving the change. In fact the increase of sucking was significant for both left and right ear changes ($p < .01$ in each case). Moreover, in the first part of the experiment both experimental groups showed a significant increase of sucking rate compared to the control (Group I, left ear change: $F(1, 38) = 10.04$, $p = .003$; Group II, right ear change: $F(1, 38) = 4.00$, $p = .05$). In the second part of the experiment, differences between the control group and the experimental groups were not significant. The experimental groups seem to be more responsive to the first change than to the second, but this tendency was not significant and did not interact with the ear receiving the change.

B. Ear effect. To compare our results with those of previous studies, we calculated the recovery percentage scores in the same way as did Entus (1977) and Vargha-Khadem and Corballis (1979). For each subject, this score was the number of sucks per minute as a percentage of the infant's maximum preshift sucking rate. An analysis of variance was run on the recovery percentage scores. No significant ear effect on the first postshift minute nor on the 5 postshift min was observed. Nevertheless, comparisons (similar to those conducted by the authors cited above) involving each subject's recovery percentage scores (one for the left ear change and one for the right ear change) showed that 35 out of the 40 experimental subjects had two recovery scores that differed from each other by more than 5%. Twenty-two subjects (55%) obtained a greater percentage recovery score for the right ear, and 13 (32.5%) manifested the opposite trend. Although this distribution went in the predicted direction, it was not different from chance according to a Sign test ($z = 1.352$, $p = .0885$).

A problem in perceptual asymmetry research is that an estimation of individual performance levels is needed before a comparison between scores observed for each ear stimulation becomes possible (and somehow legitimate). In studies with adults, asymmetry is usually estimated with respect to the correctness of responses to stimuli presented in each ear. In the present situation, we have tried to assess the reliability of experimental subjects' recovery behavior. The control group provides a reference point for classifying experimental subjects' recovery scores. For each subject and for each part of the experiment dishabituation ratios (DRs) were calculated as follows: (first postshift minute–last preshift minute)/last preshift minute sucking rate. Then, a criterion DR was established to provide a statistically reliable difference between the control and experimental groups. When the criterion DR was set at 50%, only 3 control subjects in the first part of the session, and 5 in the second part of the session, out of 20 had a higher DR. By contrast, 22 subjects in the first part (10 for left ear change and 12 for right ear change), and 18 subjects in the second part (11 for right ear change and 7 for left ear change), out of the 40 experimental subjects had higher DRs than the 50% level. With this classification, it is possible to distinguish between the experimental subjects who dishabituated and presumably discriminated at least one change from those who did not react to any change. Out of the 40 experimental subjects, 29 reached our criterion level for dishabituation during the first and/or the second stimulus change.[1] For the 29 selected subjects a reexamination of their percentage recovery scores, the same as those used by Entus, indicated that 18 subjects (62%) had a greater recovery for the right ear change, 8 subjects (28%) had a greater recovery for the left ear change, and 3 subjects manifested no difference between their two recovery scores (Fig. 2). According to a Sign test, the distribution of these remaining 26 subjects was significantly different from chance ($z = 1.76$, $p < .05$, one-tailed test).

Discussion

The results of the first experiment clearly show that 4-day-old neonates can discriminate dichotically presented CV syllables. Infants reliably detect a change in one syllable in one ear when the syllable in the other ear remains unchanged. This sensitivity to change in 4-day-olds suggests a refined tuning to language-like stimulation.

Moreover, the present results show that it is difficult to uncover a right ear advantage for speech using a straight-forward analysis of the HAS measure adapted to the dichotic procedure. When all subjects are considered, the effects of the change of syllable are comparable in the two ears. If we perform exactly the same analysis as Entus and Vargha-Khadem and Corballis, we find no significant ear difference, confirming the difficulty in replicating Entus' results. Finally, we took into consideration the responsiveness level of the experimental subjects compared to controls. Considering only the subset of subjects who, according to

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[1] For 11 subjects both DRs were higher than 50%, and for 18 subjects only one DR was above criterion. Seven out of these 18 subjects were in Group I and 11 were in Group II; 11 reacted to the first change and 7 to the second change. Finally, 6 subjects dishabituated after only the change in left ear, while 12 subjects manifested a strong dishabituation reaction for only the change in right ear. The distribution of these 18 subjects was not significantly affected either by the Group factor nor by the position of the change (first or second). Once again the ear effect was in the predicted direction but did not reach the critical level of significance ($p = .119$, binomial test).

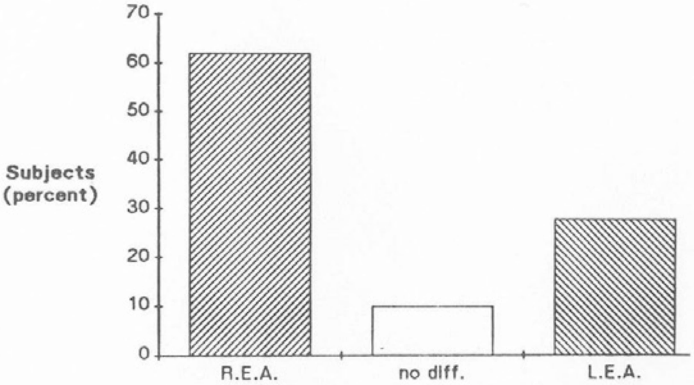

FIG. 2. Proportion of subjects out of the 29 experimental dishabituating subjects displaying differences between their percentage recovery scores. R.E.A., percentage recovery score is higher for the right ear change than for the left ear change; L.E.A., percentage recovery score is higher for the left ear change than for the right ear change. Experiment I.

our criterion, dishabituated at least once, the results indicate that more subjects manifested a stronger reaction to a syllable change in the right ear than in the left. Thus, when performance levels can be assessed in some way, it is possible to find a trend in 4-day-old neonates toward an asymmetric responding to speech stimuli that favors the right ear.

Given the difficulty of establishing a right ear advantage for speech syllables in subjects whose state and individual performance can be only indirectly estimated, it seems worthwhile to explore whether differences in processing asymmetries emerge when two different kinds of stimuli were presented. In adults, dichotic presentations involving stop consonant contrasts induce strong right ear advantage, whereas a left ear advantage is typically found for judgments involving timbre (Kallman & Corballis, 1975; Peretz, 1985). Thus, in the following experiment, while using the same syllables pairs as those used in the first experiment in a Speech condition, we add a Music condition involving a timbre discrimination task.

III. EXPERIMENT II

Method

A. Stimuli. The speech stimuli used were identical to those described for the first experiment. The music stimuli consisted of two notes at different pitches. (A: 440 Hz and C: 261 Hz) selected from among four instruments (piano, violin, flute, and oboe), from the bank of sounds of IRCAM, Paris. The recorded instrument sounds were digitized at a sampling rate of 32 kHz on a VAX 11/780. Each sound was adjusted to have the same rms amplitude and overall duration (300 msec) as the other sounds.

The dichotic pairs consisted of two notes played simultaneously by two instruments (Table 3). To make the patterning of stimulus change similar to that used in Experiment I, the change systematically occurred in the higher note. As can be seen in Table 3, the change was related to the timbre and involved a new instrument playing the same note.

TABLE 3
EXPERIMENT II: DICHOTIC PAIRS OF MUSIC STIMULI PRESENTED TO EACH EXPERIMENTAL GROUP IN THE FIRST AND THE SECOND PART OF THE EXPERIMENT

	Group I		Group II	
	RE	LE	RE	LE
Hab	Piano (C)	Flute (A)	Flute (A)	Piano (C)
Test	Piano (C)	Violin (A)	Violin (A)	Piano (C)
Break				
Hab	Piano (A)	Violin (C)	Violin (C)	Piano (A)
Test	Oboe (A)	Violin (C)	Violin (C)	Oboe (A)

Note. Parentheses indicate the pitch of the notes.

The tone pairs were synchronized by ear (informal judgments by three of the authors) to take into account the difference in perceived onset time due to variations in the slope of the attack of each instrument sound. The onset differences varied from 0 to 20 msec.

B. Subjects. All subjects were recruited at the Baudelocque Maternity Hospital (Paris), using the same selection criteria as in Experiment I, except that some subjects were tested on their third day. Forty-one subjects in the Speech condition and 34 in the Music condition did not complete the experiment: 36 went to sleep, 23 cried during the experiment, 6 failed to maintain the appropriate sucking level, 10 did not habituate within 10 min during the first or the second habituation phase. Of the 46 subjects who completed the experiment, 26 subjects (12 females and 14 males, mean birthweight: 3283.2 g, mean age: 3.7 days) were randomly assigned to the Speech condition and 20 (7 females and 13 males, mean birthweight: 3518.2 g, mean age: 4.4 days) to the Music condition.

C. Apparatus and procedure. The apparatus and procedure used were strictly identical to those described in Experiment I. In particular, the duration of the music stimuli (300 msec) was similar to that of the speech stimuli in order to make the reinforcement rate for the two conditions comparable. Within each stimulus condition the subjects were divided into two groups in order to counterbalance order of change (left ear–right ear or right ear–left ear).

Results

Preshift scores (baseline, maxima used to calculate habituation criterion, and means of preshift sucking rate) for the first and second parts of the experiment, for both the Speech and the Music conditions, are given in Table 4. In the Speech condition, analysis of variance reveals no significant difference between the two groups of subjects on these preshift measures ($F < 1$ in each case). In the Music condition, there is one significant difference between the two groups on their maximum sucking rates: The maxima exhibited by Group I were significantly higher than those exhibited by Group II ($F(1, 18) = 5.816$, $p = .025$) but this appears to be the case for both parts of the experiment and does not interact with the ear factor. In fact, this difference does not persist for the last 2 min preceding both shifts ($F(1, 18) = 1.533$).

A. Speech results. An analysis of variance was run on the 26 exper-

TABLE 4

EXPERIMENT II: MEAN SUCKING RATES OF THE EXPERIMENTAL GROUPS IN THE SPEECH AND MUSIC CONDITIONS, ON PRESHIFT MEASURE—BASELINE, MAXIMA USED TO CALCULATE HABITUATION CRITERION, AND MEANS OF LAST TWO PRESHIFT MINUTES

	Speech		Music	
	Group I	Group II	Group I	Group II
Baseline	19.85	19.10	20.20	22.00
Max 1	33.85	37.23	45.20	38.70
Preshift 1	19.35	17.88	22.20	21.80
Max 2	34.85	35.85	48.00	37.60
Preshift 2	17.35	20.27	23.45	18.40

Note. Max 1 and Preshift 1 for the first part of the experiment; Max 2 and Preshift 2 for the second part of the experiment.

imental subjects in the Speech condition using the preshift and postshift sucking rate means. The dishabituation effect was significant: postshift sucking rates (on the first 2 min of test) were significantly higher than preshift sucking rates (on the last 2 min of habituation), $F(1, 24) = 8.142$, $p = .008$. The order of change had no major effect and did not interact with any other factor. No significant ear difference was observed ($F < 1$). However, the interaction between ear and pre-/postshift rates approached significance: $F(1, 24) = 3.343$, $p = .076$, indicating that the difference between post- and preshift rates tended to be greater for a change in the right ear than in the left ear. In fact, a separate analysis showed that this difference was significant only for the right ear change ($F(1, 24) = 7.557$, $p = .01$).

B. Music results. An analysis of variance on preshift and postshift rates was run on the 20 subjects in the Music condition. The overall difference between postshift and preshift rates failed to attain significance ($F(1, 18) = 2.63$, $p = .119$). Post hoc comparisons revealed that this difference was significant only for the change in the left ear ($F(1, 18) = 6.103$, $p = .022$). However, no interaction was found between Ear factor and difference in sucking rates ($F(1, 18) = 1.536$).

C. Speech–music interaction. To assess the possibility of a Stimulus Type × Ear interaction, an analysis of variance was computed on recovery scores (average of the first 2 postshift min minus average of the last 2 preshift min) for the 46 subjects, with the Stimulus Type as a between factor. The Ear factor, the Stimulus Type factor and the Order of change failed to produce a significant effect ($F < 1$ in all cases). The only significant interaction was the Stimulus Type × Ear interaction, $F(1, 42) = 4.516$, $p < .05$. As shown in Fig. 3, the recovery scores in the Speech condition tend to be greater for the right ear than for the left ear change; the opposite trend is seen for the Music condition.

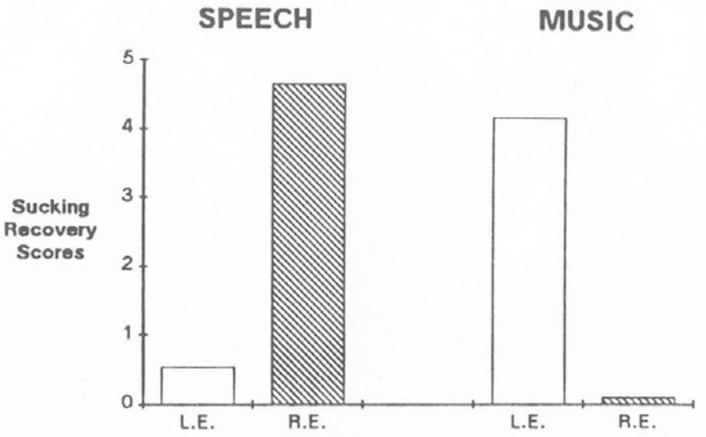

FIG. 3. Sucking recovery scores (average of the first 2 postshift min minus average of the last 2 preshift min) as a function of the ear receiving the change (left ear or right ear) in the speech and music conditions. Experiment II.

Discussion

The results for the Speech condition resemble those observed in the first experiment in that the syllable change induced a reliable recovery of sucking rate. As in Experiment I, the ear difference failed to reach significance, but a trend toward a greater reaction to a right ear change emerged. For the Music condition we did not observe an overall recovery of sucking rate with a change in stimulus.[2] Nevertheless, although an ear difference did not appear clearly, the recovery of sucking reached significance after a left ear change but not after a right ear change.

The most important finding is that when reactions to changes in both kinds of stimulus are contrasted a reliable Stimulus Type × Ear interaction was observed. A change in speech stimulus tends to induce a stronger reaction when it occurs in the right ear, a change in music stimulus tends to induce stronger reaction when it occurs in the left ear.

IV. CONCLUDING REMARKS

The results of the present study suggest that 4-day-old neonates can discriminate dichotically presented CV syllables. We assessed the infants' ability to detect an initial consonant change in one ear only by contrasting experimental and control subjects' scores in the first experiment. This method puts us in a situation similar to that of classical discrimination studies using recovery of sucking as an index of discrimination. In the experimental group the sucking recovery was significant and significantly different from that of the control group. The results of the second experiment were roughly similar to those in the first exper-

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[2] The absence of a control group precludes the interpretation of sucking recovery as a reliable indication of discrimination.

iment when speech is considered, even if the change in the left ear did not produce a significant sucking recovery. However, the sucking recovery scores in Experiment I were not significantly different from those for speech changes in Experiment II ($F(1, 64) = 2.104, p = 0.148$). HAS studies have not stipulated how many discriminative responses a baby must make in order to be considered as discriminating. Thus, since the second experiment did not have a control condition, it can only be stated that the tendency to react to dichotic speech changes was similar in both experiments.

The results for the music condition indicated a tendency similar to that obtained with speech stimuli, when the timbre change was presented to the left ear. Nevertheless, the increase of the postshift sucking rates was not significant; thus, this experiment does not demonstrate discrimination "stricto sensu" of dichotic timbre changes in 4-day-olds.

Ear differences in 4-day-old neonates are also very difficult to evaluate. Indeed, overall, we failed to observe robust ear differences for either speech or music stimuli. In Experiment II, the sucking recovery tended to be greater for speech change in the right ear than in the left, but no such trend was observed in the first experiment. Likewise, there was a trend toward a stronger reaction after a timbre change in the left ear, but the ear factor produced no reliable effect and did not interact with the preshift–postshift difference.

While the individual performance has to be scored when the question of perceptual asymmetry is addressed in speech perception, it is difficult to evaluate using HAS with 4-day-old subjects. In the first experiment, however, we attempted to do just that and we found that in those subjects who can be said to dishabituate for at least one change, 62% showed a greater recovery score after a right ear change, while 28% manifested the opposite trend. In Experiment II no such individual estimation was necessary since we chose to compare asymmetries across different Stimulus Type conditions. Under such conditions a reliable interaction was observed between the ear receiving the change and the nature—speech or music—of the stimulus received. This interaction suggests a precocious dissociation of the cerebral structures involved in the perceptual processing of syllables and tones. The present study, like those mentioned earlier, suggests that although asymmetries may exist, they are difficult to observe, given the methods used with very young subjects. Indeed, on balance, the data seem to indicate that hemisphere specialization is present from birth (Witelson, 1987) and does not result from a long process accompanying the acquisition of language.

Some recent studies show that perceptual asymmetries may arise in tasks where the measure is not taken just after a stimulus change in the left or right ear. For instance, premature infants whose gestational ages at birth were 26–33 weeks were exposed daily to either speech or music.

Exposure started on the fifth day and continued until the infants had attained the gestational age of 36 weeks. Under these conditions, Segalowitz and Chapman (1980) found a greater reduction of tremor movements in right limbs than in the left following exposure to speech stimulation. MacKain, Studdert-Kennedy, Spieker, and Stern (1983) showed that 5- and 6-month-old infants were sensitive to intermodal aspects of speech. When subjects listened to naturally spoken disyllables, they tended to look longer at video display of a face that actually articulated the speech sounds that were heard than at an alternative display where articulation did not match with what they were hearing. This sensitivity however was present asymmetrically. The infants were sensitive to correspondences in the acoustic and optic properties of speech only when watching displays that were placed to the right of a midline. In a similar vein, Colombo and Bundy (1981) observed that 4.5-month-old infants showed a significant preference for a female voice producing continuous speech as compared to white noise. The preference was stronger when the presentation of the voice was associated with a right-side visual target. Thus these studies using different paradigms suggest that certain aspects of speech processing are mediated by the left hemisphere very early in life. It is hoped that more sophisticated methods may help clarify somewhat further the vexing issue of functional asymmetries in infancy.

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