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Language Discrimination by Newborns: Toward an Understanding of the Role of Rhythm

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Three experiments investigated the ability of French newborns to discriminate between sets of sentences in different foreign languages. The sentences were low-pass filtered to reduce segmental information while sparing prosodic information. Infants discriminated between stress-timed English and mora-timed Japanese (Experiment 1) but failed to discriminate between stress-timed English and stress-timed Dutch (Experiment 2). In Experiment 3, infants heard different combinations of sentences from English, Dutch, Spanish, and Italian. Discrimination was observed only when English and Dutch sentences were contrasted with Spanish and Italian sentences. These results suggest that newborns use prosodic and, more specifically, rhythmic information to classify utterances into broad language classes defined according to global rhythmic properties. Implications of this for the acquisition of the rhythmic properties of the native language are discussed.

Learning a language requires recognizing the regularities that are linguistically relevant, while discarding irrelevant variations due to differences in amplitude, voice timbre, speech rate, and so on. Moreover, considering that most infants grow up in a multilingual environment (Harris & Nelson, 1992), it is reasonable to think that language acquisition may require the separation of utterances according to the language to which they belong. Investigators of bilingualism view the separation of languages either as a gradually emerging ability or as an innate ability (see Arnberg & Arnberg, 1985, for a review). In the past decade, infant speech perception research has established that infants under 6 months of age react to a change in the language of utterances (Bahrick & Pickens, 1988; Dehaene-Lambertz & Houston, in press; Mehler et al., 1988; Moon, Panneton-Cooper, & Fifer, 1993), supporting the idea that utterances belonging to different languages can be distinguished early in life. However, these results provide only a partial description of this question. The present experiments were conducted to specify the extent of this ability and the nature of the information that is used.

Several hypotheses can be proposed to explain how young infants discriminate between utterances drawn from different languages. The first hypothesis that we consider, the native language recognition hypothesis (N hypothesis), proposes that infants have the ability to recognize sentences that belong to their native language. According to this hypothesis, infants discriminate utterances in their native language from those in any other language. This hypothesis is compatible with all studies that have focused on very young infants' ability to discriminate between sentences from their native language and sentences from a foreign one (Bahrick & Pickens, 1988; Dehaene-Lambertz & Houston, in press; Mehler et al., 1988; Moon et al., 1993). In some of these studies, neonates have demonstrated preference for listening to their native language (Mehler et al., 1988; Moon et al., 1993).

Alternatives to the N hypothesis must be considered given that infants might not only discriminate sentences in their native language from sentences in a foreign one, but might also have the ability to discriminate between sentences belonging to two foreign languages. To our knowledge, this issue has only been examined in one study (Mehler et al., 1988), in which French-born newborns were claimed not to discriminate English utterances from Italian ones. However, in their reanalysis of this experiment, Mehler and Christophe (1995) argued that French newborns discriminated sets of English utterances from Italian utterances. These results, however limited, suggest that newborns might discriminate two foreign languages.

A first alternative to the N hypothesis, which we call the general language discrimination hypothesis (G hypothesis), states that infants are capable of discriminating sentences from any pair of languages. According to the G hypothesis, language discrimination results from the ability to extract a set of properties so that any two languages would differ when these properties are compared. Following the G

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hypothesis, infants would discriminate sentences from any two languages from birth, irrespective of the linguistic distance between these languages.

A second alternative to the N hypothesis that we would like to consider, the rhythm-based language discrimination hypothesis (R hypothesis), stems from evidence that newborns are sensitive to prosody, that is, the overall properties of utterances such as intonation and rhythm. The R hypothesis states that infants extract prosodic, and more specifically, rhythmic properties of sentences and that they sort sentences into a small number of classes or sets based on rhythmic, timing properties. In this, the R hypothesis is in agreement with the classification of languages based on rhythm that has been proposed by phonologists (Abercrombie, 1967; Eling, Marshall, & van Galen, 1980; Ladefoged, 1975; Pike, 1945). These phonologists have claimed that many romance languages are syllable-timed, that many Germanic languages are stress-timed, and that languages like Japanese and Tamil are mora-timed.

The rhythmic classes were first defined in terms of the timing units that define their rhythms. In stressed-timed languages, isochrony is supposedly based on the regular occurrence of stressed syllables, whereas in syllable-timed and mora-timed languages, isochrony is supposed to rely on syllables and morae tending to have equal durations, respectively. Many studies investigated the validity of this initial definition and their results, although sometimes contradictory, suggest the absence of such differences in isochrony (see reviews by Lehiste, 1977, or Bertinetto, 1989). In spite of these results, the notion of rhythmic classes has not been abandoned. As Beckman (1993) wrote,

> This typology is one of the most persistent metaphors in the history of our struggle to understand speech rhythms. It must capture some fundamental fact about rhythmic patterns across languages. Otherwise, it would have been relegated to the dustbin long ago, because taken literally as a statement about constant interval durations, as originally proposed, it was very soon proved false. (p. 458)

Consequently, new definitions of the rhythmic classes were developed. Dauer (1987) proposed a list of phonetic and phonological parameters contributing to the characterization of the different rhythmic types. Among these components, the kind of syllabic structures allowed in one language, the presence or absence of vocalic reduction, and the placement and realization of stress are often considered as the three most important ones (Bertinetto, 1989; Dauer, 1983; den Os, 1988). Recent investigations using this definition of the rhythmic classes to constrain the search of differences between the acoustic properties of the different classes brought partial evidence that these parameters might distinguish the rhythmic classes at the acoustic level (Arvaniti, 1994; den Os, 1988; Fant, Kruckenberg, & Nord, 1991; Nazzi, 1997; Shafer, Shucard, & Jaeger, in press).

From the perspective of the R hypothesis, newborns should only be able to discriminate sets of sentences that belong to languages falling into different rhythmic classes (see Mehler, Dupoux, Nazzi, & Dehaene-Lambertz, 1996, for a similar proposal). Experiments on native language discrimination show that young infants can discriminate utterances belonging to syllable-timed languages from utterances belonging to stress-timed languages, when one language presented is the native language (English–Spanish for Bahrick & Pickens, 1988, and Moon et al., 1993; Russian–French and English–Italian for Mehler et al., 1988; English–French for Dehaene-Lambertz & Houston, in press). So far, however, there have been no reports showing that infants do not react when sentences change from one language to another language belonging to the same rhythmic class.

The R hypothesis is consistent with the now widely accepted idea that prosody plays a central role in the acquisition of language (Morgan & Demuth, 1996). Several studies have established that infants have an early sensitivity to the prosodic properties of natural languages. Mehler et al. (1988) have shown that both newborns and 2-month-old infants discriminate between sentences in their native language and sentences in a foreign one even when sentences are low-pass filtered, a modification of the signal that preserves prosody while reducing other linguistic information. But the role of prosody in the discrimination of sentences belonging to two foreign languages has not been investigated so far. Prosody also seems to explain infants' preference for their mother's voice (Mehler, Bertoncini, Barrière, & Jassik-Gerschenfeld, 1978), for infant-directed over adult-directed speech (Fernald & Kuhl, 1987), for native language words over foreign language words (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993), and also the grouping of consecutive syllables into word-like units (Morgan & Saffran, 1995). More specifically, rhythm has been found to play a role in the perception of speech at the word level. Nine-month-old American infants were found to prefer the predominant stress pattern of English words (Jusczyk, Cutler, & Redanz, 1993). Newborns have been shown to be sensitive to the number of syllables in words (Bertoncini, Floccia, Nazzi, & Mehler, 1995; Bijeljac-Babic, Bertoncini, & Mehler, 1993) and to the position of lexical accent (Sansavini, Bertoncini, & Giovannelli, 1997).

To explore the three hypotheses mentioned above, we presented newborns from French-speaking families with sets of filtered sentences in different foreign languages. The rhythmic distance between the languages presented was varied, in that the languages belonged either to two different rhythmic classes (English and Japanese, in Experiment 1) or to the same class (English and Dutch, in Experiment 2). The N hypothesis predicts that infants should fail to discriminate in both of the experiments, as it states that only the utterances in the native language are recognized and therefore discriminated from those in any other language. The G hypothesis predicts discrimination in both cases. Finally, the R hypothesis predicts discrimination only when the sentences belong to languages from two different rhythmic classes (in this study, English and Japanese). In all experiments, infants were presented with sentences that were low-pass filtered with a cutoff frequency of 400 Hz to reduce segmental information while preserving prosody. Several monolingual speakers of each language were used to record the sentences in the present study. This differed from previous studies, in which one bilingual speaker was used to record the sentences in both languages. However, as Cutler, Mehler, Norris, and Segui (1992) have argued that even very proficient bilinguals are dominant in one of their languages, it appeared safer to rely on monolingual speakers, provided that several speakers of each language are used in order to ensure that infants discriminate between languages rather than between speakers' voices or ways of speaking.

Experiment 1

Method

Stimuli. The stimuli consisted of 40 English and 40 Japanese sentences (see lists in the Appendix). Four female native speakers of each language were recorded. Each speaker read 10 sentences of her native language in an adult-directed speech style. In selecting the speakers, efforts were made to minimize voice quality differences (pitch and timbre), both within and between languages.

The sentences were matched across languages on number of syllabic constituents, which varied from 15 to 21, and mean duration, which was of about 3,100 ms. The sentences were low-pass filtered using a filter with a 400-Hz frequency cutoff, a transformation that reduces segmental information while preserving prosody.

Procedure and design. Each infant was tested by the same experimenter in a sound-attenuated room. No other persons were allowed in the booth during the experiment. Infants were awakened about 2.5 hr after nursing and roused until a quiet, active state was obtained. They were then placed in a reclining position in a special chair that reduces head movements. The pacifier was held in place by an adjustable mechanical arm. The experimenter sat on a chair out of sight of the infant and remained quiet until the end of the experimental session. He could intervene during the experimental session to readjust the pacifier in the event that the infant lost it. However, this was allowed only during the first minutes of the experiment (that is, more than 5 min before the end of the familiarization phase) to prevent any possibility of interaction between the infant and the experimenter during the critical minutes of the experiment. If the infant lost the pacifier later then the 5th min before the end of the familiarization phase, the infant's data were discarded from the analyses.

The experiment started with a 1-min silent baseline, during which the infants' spontaneous sucking rate was registered. The criterion for selecting high-amplitude (HA) sucks was fixed at the same value for all of the testing sessions and for all participants (it corresponded to an average of about 80% of sucks being considered as HA sucks; see Floccia, Christophe, & Bertoncini, 1997). After the baseline, a familiarization period started during which the occurrence of HA sucks resulted in the presentation of 1 sentence taken from a list of 20 sentences (i.e., 10 sentences from two different speakers of the same language). The presentation of the stimuli was randomly ordered, and the minimal time interval between the onset of two consecutive stimuli was set to 4 s, resulting in a maximum presentation rate of 15 stimuli per minute. The familiarization period lasted at least 5 min, and was completed when a 25% decrement in sucking rate was registered over 2 consecutive min compared with the rate of the immediately preceding minute. When this criterion was reached, stimuli were changed from one language to the other for infants in the experimental group (change in language), whereas infants in the control group continued to be presented with stimuli of the same language but were changed to the other two speakers (no change in language). Thus infants in all groups first heard a set of sentences from two speakers and, after the change, a new set of sentences from two new speakers. The postshift period lasted 4 min.

The stimuli were stored in digital form on the computer. For both the familiarization and postshift periods, the corresponding 20 stimuli were first presented in a random order, then were randomly reordered and played again, and so on until the end of the period. Within each period, stimuli were then played several times. Participants were randomly assigned to one of the four subgroups resulting from the crossing of the two main variables: language order (English or Japanese sentences first) and condition (control or experimental). There were 10 participants in each subgroup.

Apparatus. A Babisol pacifier was connected to a pressure transducer (Gould 13-461550), which in turn was connected to an IBM 386-compatible personal computer via an analog to digital board (Data Translation 2814). The computer detected each sucking response, and registered its amplitude and the time between its occurrence and that of the preceding suck. When an HA suck was detected, a stimulus was delivered by an Oros AU22 board, via a stereo amplifier (Rotel RA820B*3), and two loudspeakers (Martin Control Monitor DB92), at a normal level of intensity.

Participants. Ninety-one infants from French families were tested within the first 5 days after delivery. They were healthy, full-term newborns recruited at the Port Royal Maternity Hospital in Paris, France. They had suffered no complications during pregnancy and delivery, and had been classified as normal after neurological evaluation on their 1st or 2nd day of life (Amiel-Tison, 1977). All participants weighed more than 2,700 g at birth and had 1-min Apgar scores of more than 8 and 5-min Apgar scores of 10.

Fifty-one infants were excluded for the following reasons: falling asleep (21), irregular or insufficient sucking (15, 13 of them being excluded for HA sucking rates lower than 10 on 1 of the last 2 min before shift or the 1st min after shift), failing to reach the familiarization criterion within 15 min (7), rejecting the pacifier (6), or crying (2). Forty infants (20 girls and 20 boys) completed the experiment. They had a mean age of 3.0 days ($SD = 1.3$) and a mean gestational age of 39.8 weeks ($SD = 1.1$). Their mean birth weight was 3,406 g ($SD = 388$).

Results

For the 40 infants who completed the test, the mean duration of the familiarization phase was 7.3 min. There was no difference between the experimental group and the control group (7.3 min for both groups). The average sucking rates of experimental and control groups are displayed in Figure 1.

An overall analysis of variance (ANOVA) was performed on HA sucking rates during baseline and the last 5 and 2 preshift min, with the main variables of condition (experimental vs. control) and language order (English first vs. Japanese first). During these three periods, there was no significant effect of condition on the baseline, $F(1, 36) = 3.26, p = .08$, on the last 5 preshift min, $F(1, 36) = 3.60, p = .07$, and on the last 2 preshift min, $F(1, 36) < 1$. The order variable had no effect on the baseline, $F(1, 36) < 1$, and the last 5 preshift min, $F(1, 36) = 2.85, p = .1$, but a significant effect appeared on the last 2 preshift min, $F(1, 36) = 6.40, p = .02$, between participants who had heard English sentences (mean sucking rate: 32.2 per min) and participants who had heard Japanese sentences (mean sucking rate: 25.0 per min). However, order did not interact with the condition variable on any of the three preshift measures, $F(1, 36) < 1$, in all cases.

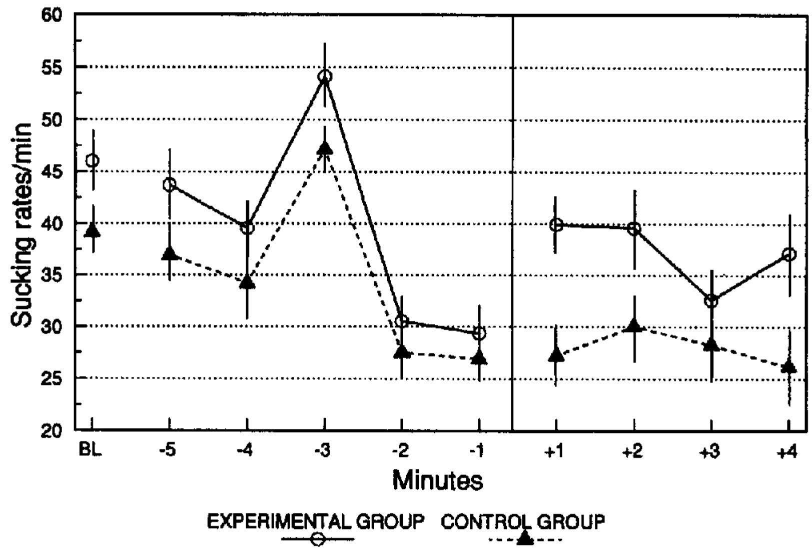

Figure 1. Sucking-rate averages during baseline (BL), last 5 min of familiarization (−5 to −1), and 4 min of test (+1 to +4) for experimental and control groups in Experiment 1. The bars above and below each point indicate the standard error of the mean.

To evaluate the effect of the change of stimuli, we compared the last 2 preshift min with the first 2 postshift min. These comparisons revealed a significant increase in sucking rates in the experimental group, $F(1, 19) = 9.95$, $p < .01$, and no difference in the control group, $F(1, 19) < 1$. There was a significant interaction between shift (2 last preshift min vs. 2 first postshift min) and condition, $F(1, 38) = 4.51$, $p = .04$, indicating that the experimental group's recovery (+9.8 sucks) was significantly larger than that of the control group (+1.4 sucks). Moreover, there was no interaction between order and shift, $F(1, 38) < 1$, even when restricted to either the control or the experimental group, $F(1, 18) < 1$, in both cases. Consequently, the interaction between order, condition, and shift was not significant, $F(1, 36) < 1$, demonstrating that order had not significantly influenced the way infants had reacted to the stimulus change.

Discussion

The present results show that newborns from French-speaking families can discriminate English sentences from Japanese sentences, two languages that are unknown to the newborns tested in this experiment. The fact that we used four monolingual speakers for each language allows us to assert that newborns are sensitive to differences between the two languages and suggests that the interspeaker variability is less salient than the differences between the languages themselves. Newborns thus appear to discriminate between sets of sentences from two foreign languages, one language from a stress-timed class, the other from a mora-timed class. The fact that this result was obtained with filtered stimuli moreover suggests that prosody provides enough information to differentiate sentences from two foreign languages, at least when the languages belong to different rhythmic classes. Thus, newborns can discriminate between sets of sentences on the basis of prosody across two pairs of rhythmic classes: stress-timed versus syllable-timed (Mehler et al., 1988), and stress-timed versus mora-timed (this experiment). It should be noted that discrimination of the sets of sentences only required an average familiarization time with the first set of sentences of about 7 min, followed by a 2-min exposure to the new set of sentences: These relatively short times of exposure suggest that discrimination might be based on the extraction of a very simple parameter or, at least, on a parameter for which the language processing device is specifically tuned.

The results of the present experiment do not fulfill the prediction of the N hypothesis according to which newborns should be unable to detect a change in the language of the sentences when neither language is the native one. Therefore, the N hypothesis fails to explain the newborns' ability to discriminate between two foreign languages. Thus, although the native language may have a special status at birth, as evidenced by preference results (Mehler et al., 1988; Moon et al., 1993), the ability to discriminate languages goes beyond the recognition of the sentences belonging to the native language. This brings us to the remaining G and R hypotheses. These two hypotheses differ on the predictions they make about the discriminability of utterances from languages that belong to the same rhythmic class: The G hypothesis states that newborns should be able to discriminate, whereas the R hypothesis affirms they should not. Experiment 2 was designed to assess the behavior of infants confronted with two stress-timed languages: English and Dutch.

Experiment 2

Method

Stimuli. Forty English and 40 Dutch sentences were used (see lists in the Appendix). The English material was the same as that used in Experiment 1. The 40 Dutch sentences were matched with the English ones on their number of syllables, which varied from 15 to 21. Four female speakers of Dutch were recruited, each of whom recorded 10 of the sentences. Construction of the materials was the same as for Experiment 1. Again, efforts were made to minimize voice quality differences between the speakers, both within and between languages.

Procedure, apparatus, and design. The procedure and the apparatus were identical to those described in Experiment 1. Participants were randomly assigned to one of the four subgroups resulting from the crossing of the two main variables: language order (English or Dutch sentences first) and condition (control or experimental). There were 10 participants in each subgroup.

Participants. Ninety-two French-born infants were tested within the first 5 days after delivery. They were healthy, full-term newborns recruited at the Port Royal Maternity Hospital in Paris, France. They were selected according to the same criteria as those used in Experiment 1.

Fifty-two infants were excluded for the following reasons: falling asleep (20), irregular or insufficient sucking (15, 11 of them being excluded for HA sucking rates lower than 10 on 1 of the last 2 min before shift or the 1st min after shift), failing to reach the familiarization criterion within 15 min (6), rejecting the pacifier (6), or crying (5). Forty infants (20 girls and 20 boys) completed the experiment. They had a mean age of 2.9 days ($SD = 1.1$) and a mean gestational age of 39.9 weeks ($SD = 1.0$). Their mean birth weight was 3,383 g ($SD = 391$).

Results

For the 40 infants who completed the test, the mean duration of the familiarization phase was 8.8 min. There was no difference between the experimental and control group (8.7 and 9.0, respectively), $F(1, 38) < 1$. The average sucking rates of experimental and control groups are displayed in Figure 2.

As for Experiment 1, an overall ANOVA was performed on HA sucking rates during baseline and the last 5 and 2 preshift min, with the main variables of condition (experimental vs. control) and language order (English vs. Japanese sentences first). The analysis revealed no difference between groups on these three periods, $F(1, 36) < 1$, in all cases.

The comparisons between the last 2 preshift min and the first 2 postshift min revealed no significant difference in sucking rates for both the experimental group, $F(1, 19) = 2.12$, $p = .16$, and the control group, $F(1, 19) < 1$. Accordingly, there was no interaction between shift (2 min before vs. 2 min after the shift) and condition, $F(1, 38) < 1$. In addition, the interaction among condition, order, and shift did not reach significance, $F(1, 36) < 1$.

Discussion

The results of Experiment 2 indicate that newborns do not discriminate between filtered sentences of English and Dutch. Because English and Dutch belong to the same class (stress-timed), these results support the view that newborns do not distinguish sentences when the languages they belong to fall within the same rhythmic class. Thus, these results conflict with the prediction of the G hypothesis, according to which newborns discriminate utterances from any pair of languages, whereas they are compatible with the R hypothesis, which holds that newborns are able to discriminate utterances only if they belong to languages from two different rhythmic classes.

The experiments conducted up until now suggest that the newborns' ability to discriminate between sentences from individual languages is influenced by rhythmic distance, hence supporting the R hypothesis. Evidence was found that discrimination of sets of sentences by newborns is obtained only when the two languages from which they are extracted belong to different rhythmic classes. The R hypothesis, however, more specifically states that young infants sort

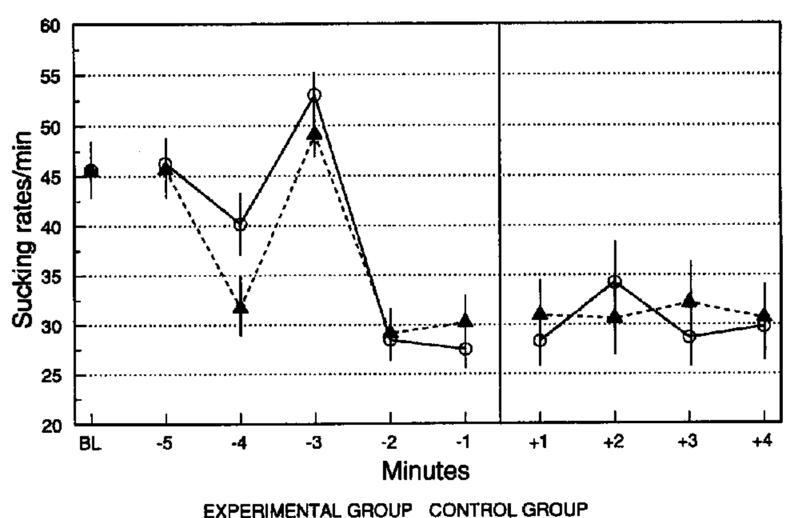

Figure 2. Sucking-rate averages during baseline (BL), last 5 min of familiarization (−5 to −1), and 4 min of test (+1 to +4) for experimental and control groups in Experiment 2. The bars above and below each point indicate the standard error of the mean.

utterances into different classes defined by their global rhythmic properties, independently of the precise identity of the language to which they belong. This statement suggests that, within a rhythmic class, intraclass similarity overrules interlanguage differences for young infants. The following experiment explored this issue, through the study of newborns' ability to discriminate between sentences from two different rhythmic classes when sentences from more than one language for each class are presented.

Experiment 3

Method

Stimuli. Twenty English, 20 Dutch, 20 Italian, and 20 Spanish sentences were used (see lists in the Appendix). The English and Dutch material was a subset of that used in Experiment 2. For each language, two native female speakers recorded 10 sentences. Construction of the materials was the same as for the previous experiments. Efforts to minimize voice quality differences between the speakers were made, both within and between languages.

Procedure, apparatus, and design. The procedure and the apparatus were identical to those described in Experiments 1 and 2.

In each phase of the experiment, each infant was presented with a list of 20 sentences (i.e., 10 sentences from two different speakers of two different languages). During the familiarization phase, infants in the rhythmic group heard two languages belonging to the same rhythmic class, and changed to the two languages from the other rhythmic class in the test phase (English and Dutch, and then Spanish and Italian, or the reversed order). Infants in the nonrhythmic group first heard two languages from two different rhythmic classes, and then the two remaining languages (English and Italian, and then Dutch and Spanish, or the reversed order; English and Spanish, and then Dutch and Italian, or the reversed order). Infants were randomly assigned to one of the two modalities of the condition variable (rhythmic or nonrhythmic). There were 16 infants in each group.

Participants. Seventy-six French-born infants were tested within the first 5 days after delivery. They were healthy, full-term newborns recruited at the Port Royal Maternity Hospital in Paris, France. They were selected according to the same criteria as those used in Experiments 1 and 2.

Forty-four infants were excluded for the following reasons: falling asleep (16), irregular or insufficient sucking (10, 8 of them being excluded for HA sucking rates lower than 10 on 1 of the last 2 min before shift or the 1st min after shift), failing to reach the familiarization criterion within 15 min (9), rejecting the pacifier (7), or crying (2). Thirty-two infants (12 girls and 20 boys) completed the experiment. They had a mean age of 2.8 days (SD = 0.8) and a mean gestational age of 40.0 weeks (SD = 1.1). Their mean birth weight was 3,631 g (SD = 459).

Results

For the 32 infants who completed the test, the mean duration of the familiarization phase was 8.9 min. There was no difference between the rhythmic and nonrhythmic group (8.7 and 9.1, respectively), $F(1, 30) < 1$. The average sucking rates of the rhythmic and nonrhythmic groups are displayed in Figure 3.

As for Experiment 1, an overall ANOVA was performed on HA sucking rates during baseline and the last 5 and 2 preshift min, with the main variable of condition (rhythmic vs. nonrhythmic). The analysis revealed no difference between groups on these three periods, $F(1, 30) < 1$, in all cases.

The comparisons between the last 2 preshift min and the first 3 postshift min revealed a significant increase in sucking rates in the rhythmic group, $F(1, 15) = 15.97$, $p = .001$, and an absence of increase in the nonrhythmic group, $F(1, 15) < 1$. Moreover, it revealed a significant interaction between shift (2 last preshift min vs. 3 first postshift min) and condition, $F(1, 30) = 5.93$, $p = .02$, indicating that the

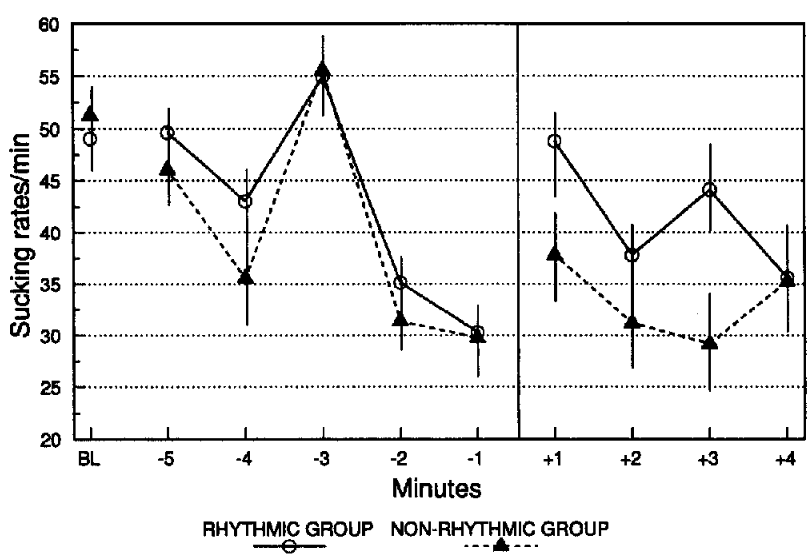

Figure 3. Sucking-rate averages during baseline (BL), last 5 min of familiarization (−5 to −1), and 4 min of test (+1 to +4) for rhythmic and nonrhythmic groups in Experiment 3. The bars above and below each point indicate the standard error of the mean.

rhythmic group's recovery (+10.9 sucks) was significantly larger than that of the nonrhythmic group (+2.2 sucks).

To compare this experiment with the previous experiments, we conducted another analysis including only the first 2 postshift min. The interaction between shift (2 min before vs. 2 min after the shift) and condition showed a tendency toward discrimination but failed to reach significance, $F(1, 30) = 2.75$, $p = .11$. However, the separate analyses of the two groups confirmed the significant increase in sucking rates in the rhythmic group, $F(1, 15) = 15.38$, $p = .001$, and the absence of difference in the nonrhythmic group, $F(1, 15) = 1.76$, $p = .20$. One possible explanation for this merely marginal interaction may be related to the fact that infants in the nonrhythmic group heard the two types of rhythm during the same period. This increased stimulus variability might have made the task more difficult, and might explain why this group presented a slight increase in sucking rates on the first postshift minute, $F(1, 15) = 3.49$, $p = .08$.

Discussion

In this experiment, half of the infants were presented with sentences from combinations of languages belonging to the same rhythmic class (rhythmic group), whereas the other half was presented with sentences from combinations based on two different rhythmic classes (nonrhythmic group). This difference in the way languages were combined was found to affect infants' reaction to the change of sentences, with only infants from the rhythmic group displaying an increase in sucking rates after the change. Because the set of stimuli heard by both groups of newborns was the same throughout the session and across subjects, the difference in behavior cannot be explained by the choice of the languages contrasted, but only by the difference in the way they had been combined. Thus, the present results support the notion that rhythmic distance between languages plays a role in the newborns' ability to discriminate sentences, therefore bringing new evidence in favor of the R hypothesis.

The difference in behavior between the two groups of infants also leads to several inferences concerning newborns' ability to discriminate sentences from individual languages. First, the absence of a reaction in the nonrhythmic group suggests that newborns might not be able to discriminate English sentences from Dutch ones, nor Spanish sentences from Italian ones, thereby going in the same direction as the results found in Experiment 2. Second, the discrimination in the rhythmic group suggests that newborns should be able to discriminate either English or Dutch sentences, from either Spanish or Italian sentences. This in turn predicts that infants can use rhythmic information not only to distinguish between sentences that belong to foreign languages when one is stress-timed and the other mora-timed, as was shown in Experiment 1, but also when one is stress-timed and the other syllable-timed. Whether rhythm is the critical parameter that would account for all these observed results remains to be shown in future research.

General Discussion

The data presented above show that newborns are able to discriminate between filtered sentences drawn from different foreign languages on the basis of prosodic information. The fact that several speakers of each language were used in all experiments suggests that discrimination was based on languages' rather than speakers' related properties. The present results extend Mehler et al.'s (1988) results, showing that sentences from different languages can be discriminated even when both languages are unfamiliar to the infant.

Experiments 1 and 2 demonstrate that sentences from all language pairs are not equally discriminable: Evidence for sentence discrimination was found for the English–Japanese contrast, but not for the English–Dutch contrast, suggesting that language rhythmic distance is relevant for this discrimination. Experiment 3 showed that newborns discriminate between sentences that differ on their global rhythmic properties, even when combinations of different languages are presented during both the familiarization and the test periods (stress-timed English and Dutch on the one hand, syllable-timed Spanish and Italian on the other hand). This suggests, as we predicted, that the rhythmic information used to discriminate sentences is class-specific rather than language-specific.

Given these results, only one of the three hypotheses presented in the introduction appears to be valid, namely the R hypothesis. The other two hypotheses are not supported by the results obtained: The N hypothesis cannot account for the discrimination of English and Japanese sentences by French-born newborns found in Experiment 1, and the G hypothesis cannot explain the absence of discrimination between English and Dutch sentences found in Experiment 2. Moreover, neither of these hypotheses can explain the results found in Experiment 3. However, the R hypothesis correctly predicted the results of all three experiments: the discrimination of sentences only when infants are presented with a change of rhythmic classes. Thus we now have results showing that newborns discriminate filtered sentences from stress-timed and mora-timed languages (Experiment 1) and from stress-timed and syllable-timed languages (Mehler et al., 1988; Moon et al., 1993; Experiment 3), but not from two different stress-timed languages (Experiments 2 and 3). Moreover, we predict from Experiment 3 that newborns would not discriminate Spanish from Italian, two syllable-timed languages. This indicates that newborns use prosodic information to classify utterances according to broad language classes (although it would now be relevant to know whether the native language is discriminated from another language belonging to its rhythmic class). More important, the present results suggest that the rhythmic distance between languages influences newborns' discrimination performance. Thus, we propose that these classes might be defined in terms of rhythmic, timing properties, and that this classification might reflect the newborns' ability to process rhythmic information.

That infants have an ability to capture rhythmic information from birth might explain that they will acquire the rhythmic regularities of their native language very early in life. Indeed, Jusczyk, Cutler, and Redanz (1993) have shown the emergence, between the age of 6 and 9 months, of a preference for bisyllabic words with a strong–weak (trochaic) pattern over bisyllabic words with a weak–strong (iambic) pattern in American infants. Because the trochaic pattern is the predominant rhythmic pattern of English words (Cutler & Carter, 1987), this result suggests that infants have learned this regularity of their native language by the age of 9 months. The acquisition of this regularity has also been shown to influence the way 7.5- to 9-month-old infants segment speech into word-like constituents (Houston, Jusczyk, & Newsome, 1995; Jusczyk & Aslin, 1995; Morgan & Saffran, 1995). Rhythmic patterns have also been shown to influence speech segmentation (Gerken & McIntosh, 1993) and production (Gerken, 1996) in early childhood.

The newborns' ability to process rhythmic information evidenced by our results is also important for the acquisition of language, as a series of experiments suggest that timing greatly influences the way in which adults process speech. Several studies have shown that the strategies used by adults while segmenting speech are based on the rhythmic properties of their native language (Cutler & Butterfield, 1990, 1992; Cutler, Mehler, Norris, & Segui, 1986; Cutler & Norris, 1988; Mehler, Dommergues, Frauenfelder, & Segui, 1981; Otake, Hatano, Cutler, & Mehler, 1993). Three strategies, one corresponding to each of the three rhythmic classes presented earlier, have been described as follows: French speakers seem to rely on the syllable, English speakers on the alternation of strong and weak syllables, and Japanese speakers on the mora. Moreover, these strategies were found to be used even when listening to foreign-language input, suggesting that they might be deeply embedded in the speakers' language-specific competence, and acquired at a very young age (Cutler et al., 1986; Otake et al., 1993). By showing that newborns classify utterances according to the same rhythmic classes as those found in the study of adults' speech segmentation, the present results support the plausibility of such an early specification.

One way to explain how infants discriminate languages (and will develop the adult rhythmic strategy specific to their native language) is to postulate that they can represent all rhythmic units used by adults, and use the one that corresponds to the language they are hearing. Evidence to support this hypothesis has been sought by studying newborns' ability to discriminate words differing on their number of rhythmic units. Although newborns were found to be sensitive to number of syllables (Bertoncini et al., 1995; Bijeljac-Babic et al., 1993), they were not found to react to a change in number of morae in a context of fixed number of syllables (Bertoncini et al., 1995). Moreover, van Ooijen, Bertoncini, Sansavini, and Mehler (1997) found that newborns do not discriminate a list of strong–strong from a list of weak–strong English bisyllables, then failing to evidence newborns' sensitivity to the difference between strong and weak syllables in a context of bisyllabic words. Taken together, these results might suggest that newborns cannot represent all the rhythmic units used by adults, and might use a universal unit of representation (Bertoncini et al., 1995). However, we propose an alternative to this interpretation. It has been shown that the syllable (or some correlate thereof, such as the vowel) is particularly salient to newborns (Bertoncini & Mehler, 1981; Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy, & Mehler, 1988). It might then be that the use of lists of words having a constant, and small, number of syllables (or vowels) rendered the number of syllables (or vowels) to be the more salient information. This might have resulted in newborns' not reacting to more subtle differences such as number of morae and vowel quality differences between the strong and weak syllables. If so, the absence of discrimination found using bisyllabic words would not necessarily mean that newborns are not sensitive to rhythmic differences between languages.

For the time being, we do not have the possibility to choose between these alternatives. However, the comparison between the studies on newborns' perception of rhythmic units and the present results on language discrimination allows us to conjecture that the newborns' sensitivity to rhythmic information might emerge only at the level of the sentence. On the one hand, no evidence has been found suggesting newborns' sensitivity to the rhythmic units that define the stress-timed and the mora-timed classes when presenting them with bisyllabic words (Bertoncini et al., 1995; van Ooijen et al., 1997). On the other hand, Experiment 1 showed that newborns discriminate sentences that belong to languages from these rhythmic classes (Japanese and English), the sentences having between 15 and 21 syllables. This sensitivity to sentence rhythmic properties is also supported by Experiment 3 (discrimination of sentences from a stress-timed class and sentences from a syllable-timed class). This suggests that newborns already have the sensitivity to differences between the various types of rhythm, provided that they are presented with stimuli larger than words. Although more data will be needed to understand more fully how rhythmic information is used by infants in the process of language acquisition, the experiments reported here provide evidence suggesting that newborns are sensitive to the rhythmic properties of fluent speech.

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Appendix

Stimuli Used in Experiments 1–3

Stimuli are listed according to language (languages appearing in alphabetic order). The superscripted number appearing at the end of each line indicates the number of the experiment in which the sentence was used.

Dutch Stimuli

De jongen stond vroeg op om in zijn nieuwe boek te lezen.[2,3]
De boze demonstranten raakten slaags met de politie.[2,3]
Het omstreden artikel zorgde voor heel wat opschudding.[2]
De prinses had kramp in haar hand van het lintjes doorknippen.[2]
Erwtensoep met worst is nog steeds zijn favoriete gerecht.[2]
De uitgever spande een proces aan tegen de schrijver.[2]
De dader werd helaas bij gebrek aan bewijs vrijgesproken.[2,3]
Het belang van milieubewustheid wordt steeds vaker ingezien.[2,3]
Zij heeft voor alles altijd een psychologische verklaring.[2,3]
De geur van vers gezette koffie verspreidde zich door het huis.[2,3]
Onze laatste aanwinst is een prachtige antieke sofa.[2]
Als je nog eens hier komt zwemmen, neem dan vooral een handdoek mee.[2]
Op het ijs stond een kraampje met chocolademelk en stroopwafels.[2,3]
Nauwelijks was het concert uit of een daverend applaus brak los.[2,3]
Delegaties uit meer dan twintig landen komen naar dit congres.[2]
Het lawaai van de machines maakte elk gesprek onmogelijk.[2]
Een gevoel van enorme opluchting maakte zich van hem meester.[2]
Het draaiorgel is bijna helemaal uit het straatbeeld verdwenen.[2]
In tegenstelling tot zijn broer heeft hij altijd van schaken gehouden.[2,3]
Beeldend kunstenaars doen vaak hun inspiratie op in grote steden.[2,3]
Het economisch klimaat is niet gunstig voor het vinden van een baan.[2,3]
Onder grote spanning vertonen de meeste mensen hun ware aard.[2,3]
In het oude centrum van de stad vind je nog middeleeuwse huizen.[2]
Door het uitvallen van de microfoons was de toespraak onverstaanbaar.[2]
In die dierentuin is voor de eerste maal een pandabeertje geboren.[2,3]
De favoriete werkplek van de schrijfster was een oude villa aan zee.[2,3]
Niemand heeft ooit kunnen achterhalen waar het geld terechtgekomen is.[2,3]
Het was die dag zo heet dat de toeristen spontaan in de fontein sprongen.[2,3]
De jonge architect leverde een verbluffend staaltje van vakmanschap.[2]
Het restaurant werd terstond gesloten om redenen van hygiene.[2]
Volgens oud gebruik wordt in dat dorp ieder jaar een uitbundig oogstfeest gevierd.[2,3]
Honderdveertigduizend soldaten worden in allerijl gemobiliseerd.[2,3]
Plotseling realiseerde ze zich dat ze het zwervende leven moe was.[2]
De reizigers ontdekten tot hun schrik dat de trein op een ander perron stond.[2]
Na maanden van discussie is nu eindelijk een standbeeld geplaatst in het park.[2]
Het nieuwe model fiets werd afgedaan als een vergezocht modeverschijnsel.[2]
Het kind bracht zijn ouders tot schateren met zijn imitatie van de lerares.[2,3]
De nieuwe concertzaal lijkt meer op een ouderwetse fabriekshal dan op iets anders.[2,3]
Dankzij de volle inzet van alle medewerkers is het project een succes.[2]
Ondanks het radiobericht waren de mensen niet voorbereid op de orkaan.[2]

English Stimuli

My grand-parent's neighbour is the most charming person I know.[1,2,3]
The local train left the station more than five minutes ago.[1,2,3]
The next local elections will take place during the winter.[1,2]
Much more money will be needed to make this project succeed.[1,2]
The art gallery in this street was opened only last week.[1,2]
A hurricane was announced this afternoon on the TV.[1,2]
The parents quietly crossed the dark room and approached the boy's bed.[1,2,3]
The first flowers have bloomed due to the exceptional warmth of March.[1,2,3]
In this famous coffee shop you will eat the best doughnuts in town.[1,2]
The young boy got up quite early in order to watch the sunrise.[1,2]
This supermarket had to close due to economic problems.[1,2]
The committee will meet this afternoon for a special debate.[1,2]
Nobody noticed when the children slipped away just after dinner.[1,2,3]
In this case, the easiest solution seems to appeal to the high court.[1,2,3]
The last concert given at the opera was a tremendous success.[1,2,3]
Science has acquired an important place in western society.[1,2]
This rugby season promises to be a very exciting one.[1,2]
Artists have always been attracted by the life in the capital.[1,2]
Finding a job is difficult in the present economic climate.[1,2,3]
Trade unions have lost a lot of their influence during the past ten years.[1,2,3]
The library is opened every day from eight A.M. to six P.M.[1,2,3]
They didn't hear the good news until last week on their visit to their friends.[1,2,3]
Most European banks close extremely early on Friday afternoons.[1,2]
Having a big car is not something I would recommend in this city.[1,2]
This year's Chinese delegation was not nearly as impressive as last year's.[1,2,3]
The city council has decided to renovate the medieval center.[1,2,3]
There is an important market twice a week on the main square of the village.[1,2,3]
The government is planning a reform of the educational program.[1,2]
No welcome speech will be delivered without the press officer's agreement.[1,2]
The recent rainfall has caused very severe damage in the higher valleys.[1,2]
The woman over there is an eminent specialist in plastic surgery.[1,2,3]
Seven paintings of great value have recently been stolen from the museum.[1,2,3]

(Appendix continues)

The Green Party has unexpectedly gained strong support from middle class people.[1,2,3]
This is the first time an international exhibition takes place in this town.[1,2,3]
Mothers usually leave the maternity unit two days after giving birth.[1,2]
The rebuilding of the city started the very first day after the earthquake.[1,2]
Most of the supporters of the football club had to travel for an entire day.[1,2,3]
In spite of technical progress, predicting the weather is still very difficult.[1,2,3]
The latest events have caused an outcry in the international community.[1,2]
It is getting very easy nowadays to find a place in a nursery school.[1,2]

Italian Stimuli

Il mercato si tiene sulla piazza ogni giorno.[3]
La moglie del farmacista sa sempre ciò che vuole.[3]
Le strade che danno sulla piazza sono bloccate.[3]
Le forti piogge della primavera sono dannose.[3]
Il bambino scese prestissimo per vedere l'alba.[3]
Il teatro ha introdotto molte nuove discipline.[3]
La stagione musicale non offrirà grandi novità.[3]
Un quadro molto famoso è stato mal restaurato.[3]
Non ha mai voluto rendersi conto dei suoi gran difetti.[3]
La radio ha comunicato questa mattina la notizia.[3]
La ricostruzione della città dovrà farsi lentamente.[3]
L'ozio non è il solo padre dei gran vizi dell'umanità.[3]
Tutte le deroghe devono recare prova di conformità.[3]
Il vantaggio di poter scrivere liberamente è immenso.[3]
Il venerdì sera le banche chiudono sempre con anticipo.[3]
La situazione della bilancia dei pagamenti non mi lascia mai tranquillo.[3]
I sostenitori della riforma si sono trovati sulla piazza principale.[3]
Credo che riuscirai nei tuoi piani senza farti problemi di sorta.[3]
La statistica permette di comprendere la scienza sperimentale.[3]
Il giunto meccanico è troppo debole per sopportare quel peso.[3]

Japanese Stimuli

Bankokuhakurankai wa sakunen kasaisareeta.[1]
Monku wa shihainin ni iuno ga tettoribayai.[1]
Oono shigo ni machi no saiken ga hajimatta.[1]
Noomin no sonchoo ni taisuru fuman ga tamatta.[1]
Haru no koozui de zuibun ookina higaiga deta.[1]
Shussango sooki ni taiinsuru keekooga tsuyomatta.[1]
Konopanya no keiki wa konokaiwai de hyoobanda.[1]
Konshuu mo terebibangumi o mirujikan ga nai.[1]
Kochira no kata wa keiseigeka no senmonka desu.[1]
Tsugino chihoosenkyo wa kondo no harugoro deshoo.[1]
Saikin no jiken de sekai no yoron wa konranshiteiru.[1]
Kaikakusuishinha ga kenchoomae de demokooshinshita.[1]
Kesa no rajiode taifuukeihoo ga hatsureisareta.[1]
Guusuuno hini wa kono hiroba ni miseya ga deru.[1]
Tsugi no gekijooshiizun wa totemo kyoomibukaidaroo.[1]
Kusuriya no kamisan wa moosugu kaimononi deru.[1]
Tokurei wa kaino sanseinashini wa mitomerarenai.[1]
Moosugu rinjikokkaino kaiki ga hajimaruhazuda.[1]
Kookyooko otsuukikan no seibiwa doomitemo fujuubunda.[1]
Boku wa baiorin no keiko o kazoekirenaikurai yasunda.[1]
Hinode o mirutame ni sonoko wa hayaku kishooshita.[1]
Kokono shokudoo wa eiseijoo no mondai de heisasareta.[1]
Moo gofun ijoo mae ni tokkyuu wa hoomu ni tsukimashitayo.[1]
Jikai no kaikaku no taishoo wa gakkookyooiku no naiyoodesu.[1]
Kokosuunen de roodoodantai no eikyooryoku ga teikashita.[1]
Koocha demo nominagara koko de matasete morauyo.[1]
Keikanwa yoogishano fuuteini nita shooni no mikaketa.[1]
Sobo no sumai no gokinjo wa yoi hitotachi bakaridesu.[1]
Keekaku no jitsugen niwa shikin ga kanari hitsuyoodeshoo.[1]
Chuusankaikyuunaibu de kankyohogoha ga seiryoku o nobashita.[1]
Kotoshi no nihondaihyoodan wa kyonenyori ninzuu ga sukunai.[1]
Doo gijutsu ga shinposhitemo tenkiyohoo wa tekichuushinai.[1]
Daitoshi no seikatsu wa tasuu no geijutsuka o hikitsuketa.[1]
Dokoka tooku de yakiimoya no fuenone ga natteiruyooda.[1]
Oozeino kyakunomae de tabako o suuno wa yametahoo ga yoi.[1]
Ryooshin wa mono oto o tatezu ni kodomo no soba ni chikazuita.[1]
Kodomo o kooritsukoo ni susumaseru nowa muzukashikunai.[1]
Konokeeki no jootainomama dewa shokusagashi wa taihenda.[1]
Shitookyoku ga rekishikuiki no saikaihatsu ni chakushushita.[1]
Amerikajin ga gaikokujin dato kangae tara kookaisuruzo.[1]

Spanish Stimuli

La radio annunció esta noticia el miércoles.[3]
El niño se levantó temprano para ver el sol.[3]
El ladron se fue con el reloj de oro de mi padre.[3]
Esta panadería hace los mejores pasteles.[3]
Los padres se acercaron del niño sin hacer ruido.[3]
Los bancos cierran particularmente temprano el viernes.[3]
Los artistas siempre fueron atraídos por las ciudades.[3]
Los recientos acontecimientos hicieron escandalo.[3]
La reconstrucción de la ciudad empezó el año pasado.[3]
Encontrar un empleo no es facil en el contexto actual.[3]
Las madres salen cada vez mas rápido de la maternidad.[3]
La última exposición universal fue en San Francisco.[3]
La pintura moderna tiene un éxito cada vez más grande.[3]
El presupuesto del ministerio de la cultura bajo mucho.[3]
La Consagración de la Primavera hizo escándalo en París.[3]
Esos leones lo pasaron regio comiéndose a unos cristianos.[3]
La corriente ecológica creció bastante en la clase media.[3]
En verano, las grandes cuidades europeas se llenan de turistas.[3]
Si a los tontos les crecieran alas, no se vería nunca más el sol.[3]
Dios, fijándose que no podía vigilar a todos, creó las madres.[3]

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