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LANGUAGE DISCRIMINATION RESPONSE LATENCIES IN TWO-MONTH-OLD INFANTS

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Abstract

There is increasing evidence that infants can discriminate native and non-native speech from an early age. Prosody may be essential to this ability. In this paper, we assess the amount of linguistic information needed by two-month-old infants to recognize whether or not a sentence belongs to their native language. We conducted a cross-linguistic study of French and American 2-month old infants, measuring the latency of the first ocular saccade toward a loudspeaker playing short French and English utterances. The results indicated a significant interaction between the infants' nationality and the language of the stimuli. Infants oriented faster to their native language, even when the utterances were short (1.2 s mean). However, eliminating the prosodic organization (scrambled words condition) of the sentences, neutralized the effect. The results confirm that prosody plays a predominant role when young infants process continuous speech, and that short utterances are sufficient to recognize a language as long as prosodic information is present and coherent across the utterance.

Language discrimination response latencies in two-moth-old infants

The shaping of language perception by the linguistic environment starts very early, long before infants produce words and sentences. Werker & Tees (1984) showed that infants' ability to discriminate non-native phonemic contrasts decreases between eight and twelve months of age. Kuhl, Williams, Lacerda, Stevens & Lindblom (1992) and Polka & Werker (1994) found that the change in perception of non-native vowel contrasts is evident at an even earlier age, between 4 and 6 months of life. If linguistic environment modifies language representation at an early age, it is important for infants in multilinguistic environments to categorize utterances according to the language in which they are spoken. Mehler (1988) demonstrated that 4-day-old French neonates can discriminate French and Russian sentences as well as two foreign languages, Italian and English. Nazzi, Bertoncini & Mehler (in press) extended the earlier finding by showing that French neonates discriminate between English and Japanese low-pass filtered utterances. However, native language seems to possess a particular status, even at birth. Newborns have a higher sucking activity when they are listening to their native language (Mehler et al, 1988) and they are able to modify their sucking patterns when doing so allows them to hear their native language (Moon, Cooper & Fifer, 1993).

It has been argued that this early discrimination of languages is based on the prosodic characteristics of the native language. Indeed, Mehler et al (1988) showed that 4-day-old French neonates continue to exhibit language discrimination capacities when the sentences are low-pass filtered, that is when almost all the language characteristics are removed except the prosodic features carried by the fundamental frequency. In addition, although 6-month-old American infants discriminate between English and Norwegian words, they can not discriminate between English and Dutch words (Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk, 1993). The prosodic patterns of English words are closer to Dutch than to Norwegian implying that young infants rely more heavily on prosody than phonetic information to recognize their own language. Only around 9 months has it been shown that the phonetic structure can be used to discriminate languages (Jusczyk et al., 1993). Other studies have also shown that prosody is important for processing continuous speech. For example, infants of different ages are more attentive to child-directed speech than to adult-directed speech. Fernald and Kuhl (1987) showed that the exaggeration of the prosodic contour is responsible for babies' preference for child-directed speech. Likewise, while 2-month-old infants can normally distinguish their mother's voice from other voices, they lose this ability when the intonation variations are reduced (Mehler, Bertoncini, Barriere & Jassik-Gerschenfeld, 1978).

All these studies converge to the idea that prosody plays an important role in the early perception of continuous speech and it has been argued that this early attention to the prosodic structure of speech might bootstrap grammatical and lexical learning by helping infants segment the speech stream and by linking together related terms (Gleitman & Wanner, 1982 ; Christophe, 1993). However, we are far from understanding how prosody is processed by infants. Prosody is a complex interaction between pitch and energy developing along time and this structure can be studied at different temporal levels. For example, Nespor & Vogel (1986) describe seven prosodic units, from syllable to phonological utterance. The prosodic structure of a language can differ at all of these levels. For example, an analysis of the smaller prosodic units (i.e. using units like syllables or feet) classifies French as a syllable-timed language and English as a stress-timed language. At the more global level of sentences, it is generally reported that general constraints, such as breathing patterns, are more important and reduce differences between languages (Vaissiere, 1983). Unfortunately, cross-language comparative studies at this global level are almost non existent.

Jusczyk et al (1993) demonstrated that 6-month-old infants are able to discriminate between English and Norwegian lists of words, indicating that they can utilize word-level prosodic information (i.e., lexical stress patterns) by this age. Prior to this age, the prosodic units that infants might use to discriminate languages have not been explored, but it has been suggested that older babies are able to process smaller prosodic units than younger babies (Jusczyk, Hirsh-Pasek, Kemler-Nelson, Kennedy, Woodward, & Piwoz, 1992). In language discrimination studies with neonates, long sentences (e.g. 17 seconds in the Mehler et al (1988) study) are presented to the subjects for several minutes before eliciting a change in behavior related to native language recognition. This does not necessarily mean that language discrimination is a slow process at this age but rather that experimental paradigms using sucking behavior are designed to study discrimination capacities but not discrimination speed. Assessing when in an utterance an infant recognizes his/her native language would provide an indication of how fast language discrimination is and help to identify which prosodic units infants use to characterize their native language.

In order to obtain infants' reaction times, we designed a new experimental paradigm. We measured eye oriention latencies to a loudspeaker which played sentences in the native or in a foreign language. This paradigm could be described as a dual-task paradigm where attention is divided between sound localization processes and speech analysis processes. If speech analysis processes are different for native and foreign languages, then the speed of the sound localization processes might be affected differently for each language. It has been already shown in infants that orientation latency does not depend only on the localization of the stimuli. Expectation or previous knowledge of the stimulus, for example, can modulate orientation latencies: Four-month-old infants' orientation latency to a lateralized stimulus decreases if the nature of the central cue predicts the side of the target (Johnson, Posner & Rothbart, 1991). They also orient faster to the maternal face than to a unfamiliar face (DeSchonen, Deruelle, Mancini & Pascallis, 1993). Since sound localization capacities have been described in newborns (Field, Muir, Pilon, Sinclair & Dodwell, 1980) and speech is usually a very attractive acoustic stimulus for babies (Colombo & Bundy, 1981; Glenn, Cunningham & Joyce, 1981), it was expected that infants would orient towards speech in any language. However, newborns prefer to listen to their native than to a foreign language (Mehler et al., 1988 ; Moon, Cooper & Fifer, 1993) suggesting that familiarity to a language induces different brain processes. By analogy with the results obtained in visual paradigms, we thus expected infants to orient faster upon hearing familiar sentences in their native language relative to an unknown and thus unfamiliar language. Orientation latencies would thus provide an upper bound on language discrimination speed and give indications about the prosodic unit which is processed.

EXPERIMENT 1

The first aim of experiment 1 was to validate the paradigm by examining if two-month-old infants would orient faster towards sentences in their native language than in another language. Several experiments have demonstrated that, at this age, infants are able to discriminate between their native language and a foreign language when they differ in prosodic structure, such as French and Russian, English and Italian (Mehler et al, 1988), English and Spanish (Moon et al, 1993) or English and Japanese (Hesketh, Christophe & Dehaene-Lambertz, in press). Here, French and English were chosen because they belong to two different rhythmic families. In French, contrary to English, all the syllables are fully realized. The accented syllable is always the word's last syllable and the differences in duration, energy and pitch are small between accented and non-accented syllables. Finally, there is a high proportion of open to closed syllables in French (Dauer, 1983; Fletcher, 1991; Fant, Kruckenberg & Nord, 1991) These parameters give a perceptual impression of syllable regularity, that can be opposed to the stress-timed rhythmic pattern of English (Abercrombie, 1967). Mehler, Dupoux, Nazzi & Dehaene-Lambertz (1996) have suggested that young infants may use these broad rhythmic classes to classify speech input. A second reason for this choice is that we had the possibility to test American-English and French babies. If infants' orientation towards the stimuli is affected by the native language, American and French infants should orient differently to the two languages. In this case we predict a significant interaction between the language of the sentences and the nationality of the infants. On the other hand, if infants only react to some intrinsic properties of English or French, French and American babies should orient similarly to identical stimuli.

The second goal of experiment 1 was to determine if performance would remain consistent when only prosodic information was presented. Therefore, the stimuli included both normal sentences and low-pass filtered sentences, in which only the prosody was perceptible.

Method

Subjects.

Fourteen two-month-old subjects were recruited from monolingu al American-English speaking parents living in the Eugene-Springfield area, Oregon, USA. The data from two additional subjects were not recorded due to experimenter error. Nine other subjects were rejected because they listened to less than half of the sentences because of excessive crying and/or sleepiness. The 14 subjects (9 girls, 5 boys) had a mean age of 68 days (56 to 75 days).

A second group of 12 two-month-old French infants (4 girls, 8 boys), living in the Paris area, was constituted. They were from monolingual French speaking families, with a mean age of 66 days (57 to 73 days). Five additional subjects did not pass half of the trials because of excessive crying and/or sleepiness and two were seated on their mother's lap because they started crying as soon as they were seated in the baby chair. They were excluded as well as one other infant for video recording problems.

All subjects were full term, without any medical complications during birth or the first months of life. Full informed consent was obtained from the parents.

Stimuli.

A modified version of the tale "the three little pigs" was written in French and English. All the sentences were adjusted so that they were short and had the same simple grammatical structure in French and English. The number of syllables was equalized as much as possible in each syntactic constituent. Word repetitions across sentences (e.g. pig, wolf, house...) were avoided by using synonyms.

A bilingual woman was recorded reading the two versions in French and English. She was from a bilingual French-American family and a professional translator. She used the two languages daily. She was instructed to read the story as if reading to a child, with a "child-directed speech" intonation. Five native speakers of each language listened to the stimuli in their language. All English speaking adults (four American and one British) thought that she was a native American-English speaker and all French speakers judged that she was a native French speaker. All listeners spontaneously noticed that she was speaking to children because of her child-directed speech intonation.

Sixty-four pairs of sentences were extracted from this recording (appendix A). Each sentence corresponded to a phonological utterance in Nespor & Vogel's classification (1986), i.e. it could have been produced in isolation. The number of syllables per sentence was very close in the two languages: 11.1 in English (9 to 13 syllables) and 11.0 in French (10 to 12 syllables) ($F(1,126) = 1.19$, $p = .28$)[1]. However, the mean duration of the sentences was significantly different ($F(1,126) = 20.21$, $p < .001$). The mean length was 2390 ms in French (1618 to 3875 ms) and 2777 ms in English (2012 to 4043 ms). The syllabic rate was consequently different in French and English (286 vs 246 syll/mn, $F(1,126) = 24.33$, $p < .001$). These differences may either be an idiosyncrasy of the speaker or they may reflect differential properties of the languages under study. For instance, monosyllabic words are more frequent in English than in French (e.g. " pig " for "cochon" ; " home" for "maison"). In order to keep a similar grammatical structure with the same number of syllables within syntactical constituents between the two languages, it was necessary to use more words in English than in French sentences (8.6 vs. 8.1, $F(1,126) = 6.36$, $p = .013$). This difference in word number could explain the slower speech rate in English since the intonation of child-directed speech exaggerates the duration of words.

The 64 pairs of sentences were run through a digitized low-pass filter which removed all frequencies above 400 Hz (Butterworth filter, cutoff frequency = 400 Hz, filter order = 4)[2].

Hence, each sentence was available in four conditions: English, filtered English, French and filtered French.

The sentences were presented in a semi-random order. Each condition appeared twice in a block of eight sentences, and all possible transitions between conditions occurred once within every 16 consecutive sentences. Babies never heard the same sentence twice: i.e. if a baby heard a sentence in the French normal condition, he/she did not hear the matched English sentence nor the filtered French or English version of this sentence. Four sequences of 64 sentences respecting these constraints were constructed.

For the American group, the four sequences of sentences were recorded on four cassettes, with an inter-stimulus interval of nine seconds. The duration of a cassette was about 15 minutes. The French group benefited from a technical improvement: The sentences were recorded on the hard drive of a PC computer and were played directly by the computer.

Procedure.

The infants sat in a baby-chair 80 cm from a computer monitor. Two speakers were at 33 degrees to the left and the right of the baby and were covered with the same colorful picture of a woman. Before the beginning of the experiment, the experimenter showed both pictures to the baby. A video camera placed above and set back from the monitor recorded eye movements. A second camera behind the subject recorded the computer monitor. This image and a timer were superimposed in a corner of the video screen to allow off-line coding. The experimenter and the parents were separated from the baby by a wooden partition and checked the experimental run through a video control monitor.

For each baby of the American group, a cassette was randomly chosen among the four cassettes. During the experiment, the cassette was played without interruption on a cassette recorder. Before each trial, the attention of the infants was first brought to the center using colorful moving dots that formed a spiral on the computer monitor. Just before each sentence began, the computer switched on the sound channel for one of the speakers. The sentences were semi-randomly presented to the right and the left of the infant. Each condition was presented once on the left and once on the right in blocks of eight sentences. When a sentence began, the experimenter pressed a key to turn off the spiral. Then eight seconds elapsed before the next spiral reappeared on the central monitor. The side of presentation of the sound and the reappearance of the spiral after eight seconds were controlled by a computer Apple IIe. Eye-orienting behavior was recorded during the entire session and coded off-line.

For each subject of the French group, a sequence of stimuli was randomly chosen among the four possibilities. The sentences were played by a PC computer through a 16-bit sound card. The procedure was similar to the one described above except that the experimenter now waited until the infant oriented back to the center before pressing a key to begin a new trial. With the previous setting, events were entirely determined by the timing of the cassette recording and hence a number of trials were lost because the infant had not been staring at the central attractor when the sound began[3]. With the new setting, central fixation was ensured on each trial. Another difference was that the computer itself turned off the central spiral just before the beginning of the speech stimulus. With the previous setting, the spiral remained on for a short period while the sound was playing, since its offset was determined by the experimenter's reaction to the sound.

Coding

A timer and the computer monitor image displaying the spiral were superimposed on the video tape in order to code reaction times. Coding the American infants' reaction times required an additional step from the procedure with the French infants because the coder had to first locate the frame where the sound began by playing the video frame by frame with the sound. For the French group, the fading of the central spiral was controlled by the computer and always 60 ms before the beginning of the sound. Therefore, the frame following the disappearance of the spiral was used as the beginning of the trial.

All reaction time coding was performed with the sound track *muted*. The coder was thus blind to the side and condition of each sentence. A trial was rejected if the infant was not front-centered at the beginning of the trial or cried or yawned during the trial or because the eyes were not clearly visible. For the valid trials, the first eye movement during each eight-second trial was coded : The beginning of a look was defined as the first frame on which the eyes moved to one side. Reaction time was therefore measured as the difference in timing between the beginning of the trial and the beginning of the first look.

Trials with reaction times over 8 seconds or under 200 ms were rejected. The lower limit of 200 ms was probably too conservative for two-month-old subjects but was used because it is the standard limit chosen in ocular orientation paradigms with infants in the literature[4].

In order to verify the reliability of eye movement coding, babies were double scored. The coders' inter-agreement was .99 on whether a trial was valid or not, .96 on whether a look was present during the trial or not and .93 on the direction of the first look. For orientation latencies scoring, coders' disagreement was defined as a difference of at least three frames in the scoring of the onset of eye movement. The coders inter-agreement was 88.6 % and the cases of disagreement were reexamined until a mutual agreement was found.

Results

The average number of valid trials was 55.5 for American babies and 59.8 for French babies ($t(26) = 1.61$, $p = .12$)

Analyses of hits and errors rates.

For each valid trial, three responses were possible: a correct look toward the speaker playing the sentences (53.9%), a contra-lateral orientation (35.1%) or an absence of orientation (11.1%). An ANOVA performed on the percentage of absence of orientation with Nationality (French vs American) as a between-subjects factor and Language (French and English) and Filtering (filtered vs normal) as within-subject factors showed no main effect nor interaction. On the remaining trials where an orientation response was observed, infants oriented to the correct speaker more often than chance alone would predict (correct orientation: 60.26%; two-tailed t-test for a significant deviation from 50%, $t(25\ d.f.)=6.09$, $p<.001$). An ANOVA was performed on the percentages of incorrect looks with the same factors as above. The only significant effect or interaction was a main effect of filtering ($F(1,24) = 4.52$, $p =.044$) due to an increase in the number of errors for the filtered stimuli. Nevertheless, the percentage of correct looks was significantly greater than chance for both the filtered condition (correct orientation: 56.3%; $t(25\ d.f.)=3.09$, $p=.005$) and the normal condition (correct orientation: 63.7%; $t(25\ d.f.)=5.72$, $p<.001$).

Analyses of reaction time.

In subsequent analyses, only correct responses were considered. The average number of correct responses was 29.6 for American babies and 28.5 for French babies ($t(24) < 1$) For each subject, the average reaction time in each of the four conditions (English, filtered English, French and filtered French) was calculated. Then an analysis of variance was performed with the factors defined as above[5].

There was a main effect of nationality ($F(1,24) = 11.0$, $p = .003$). French infants oriented faster than American infants (1662 ms vs. 2292 ms). There was a non-significant tendency for babies to orient slower toward filtered speech ($F(1,24) = 3.6$, $p = .07$ and there was no effect of language ($F(1,24) = 2.6$, $p = .12$). The main result of interest, the Nationality X Language interaction was significant ($F(1,24) = 4.33$, $p = .048$). As shown by figure 1, American infants oriented faster to English sentences than to French sentences (2096 ms vs 2487 ms, 391 ms effect, $t(13) = 2.66$, $p=.019$) while French infants showed a non-significant trend toward orienting faster to French than to English sentences (1698 vs 1627 ms, 72 ms effect, $t(11) < 1$). Finally, the Nationality X Filtering interaction was significant ($F(1,24) = 4.5$, $p = .045$). French infants oriented slower to filtered than to normal stimuli (1873 ms vs. 1452 ms, $t(11) = 3.1$, $p = .011$) whereas American infants oriented equally fast in the two conditions (2295 ms vs. 2289 ms, $t(13) < 1$). All other 2 or 3-way interactions were non significant.

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Insert Figure 1 about here
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Discussion

In this experiment, two-month-old American and French infants displayed a different behavior toward the same stimuli. American infants oriented faster to English sentences than to French sentences while French infants showed a non-significant trend in the reverse direction. If orienting latencies depended only on acoustical differences, such as length or speech rate, French and American infants would have exhibited the same behavior. The interaction between infants' nationality and the language in which the stimuli were recorded thus indicates that the native or foreign status of the sentences had an influence on orienting behavior. This influence of linguistic environment on babies' behavior fits with the previous results obtained by Mehler et al (1988) on language discrimination using a different method. In their experiment, infants were exposed to several minutes of one language before exhibiting a behavioral change. While confirming these early findings, the results of the present experiment indicate that infants can discriminate languages even with short sentences and that the linguistic information necessary to this task is contained in less than three seconds of continuous speech signal. Furthermore, they suggest that two-month-old infants might not need to hear a complete sentence to recognize their native language. Their mean reaction time was faster than the mean duration of the sentences. On average, babies oriented after hearing about 75 % of the sentences of their native language, suggesting that the useful unit to characterize languages is probably smaller than a sentence.

Mehler et al (1988) argued that language discrimination is based on the prosodic structure of languages because they found the same results when speech stimuli were low-pass filtered. Low-pass filtering preserves prosodic information while eliminating all or almost all of the phonological information. In the present experiment as illustrated by figure 1 and by the non-significant Filtering X Language interaction, subjects behaved similarly for filtered and normal sentences. However, statistical evidence was weaker for filtered speech than for normal speech. Post-hoc analyses showed a significant Nationality X Language interaction (253 ms effect, $F(1,24) = 4.81$, $p = .038$) for normal speech but not for filtered speech (210 ms effect, $F(1,24) < 1$). This can be tentatively related to the acoustical properties of filtered stimuli. Morrongiello & Clifton (1984) observed that young infants experience difficulties in localizing low-frequency sounds. This is confirmed in our experiment by the greater percentage of errors with filtered stimuli. Because of the higher error rates, the average reaction time was calculated on fewer trials in the filtered condition than in the normal condition and this alone could explain the higher variance and weaker statistics in this condition.

The results were complicated by two unexpected effects. First, there was an asymmetry in the results of the two groups. While American infants oriented significantly faster toward their native language, French infants had only a trend toward orienting faster to French sentences. Although the interaction of the babies' nationality with the language of the stimuli is sufficient to demonstrate that linguistic environment influences babies' behavior, we expected a similar size of the language effect in each group. We can tentatively interpret the asymmetry as a combination of two effects. The first one is a language effect, which induced faster reaction time to the native language. The second is a bias toward faster orientation to English sentences. These two effects were in the same direction for American infants but in the opposite direction for French infants. The bias for responding faster to English could be due to the construction of the experimental material. For example, the length and the syllabic rate were different in the two sets of sentences (although the two distributions showed considerable overlap). The child-directed speech intonation pattern might also be more pronounced in English due to cultural influence (Fernald, Taeschner, Dunn, Papousek, Boysson-Bardies (de), Fukui, 1989) or the prosodic structure of the two languages might be responsible for the effect. In the general discussion we will further address the nature of the bias by considering whether it is related to an idiosyncrasy of the speaker or to the structure of these two languages. Despite this bias the main finding is clear -- American and French babies oriented differently toward identical stimuli.

The second complication in the present experiment is the unexpected consequence of the change of procedures between the two groups. For the American infants, the central visual attractor remained on for the first 2 or 3 hundred milliseconds after the onset of the sentences but it was turned off immediately for French infants. As a result, French babies oriented significantly faster than American babies. This effect is compatible with the studies showing that 2-3 month-old infants experience difficulties in disengaging gaze from a central visual stimulus to orient to a lateralized stimulus (Johnson, Posner & Rothbart, 1991). The difference in procedure could also explain the nationality by filtering interaction due to the fact that French infants, but not American infants, were slower in the filtered condition than in the normal condition. Despite equal objective intensity, low-pass filtered stimuli are perceived as being weaker than normal stimuli. Thus the onset of the filtered stimuli was probably less perceptible than the onset of the normal sentences, increasing the subjects' response latencies in that condition. American infants did not exhibit a similar effect perhaps because their orientation time was already slowed by the persistence of the central spiral during the first hundred milliseconds of speech.

In summary, experiment 1 indicated that it is possible to obtain temporal measures in young infants and suggested that language discrimination is possible on the basis of hearing a single sentence or less. In order to study the minimal information 2-month-olds need to recognize their native language, we conducted a second experiment in which we reduced the duration of the utterances and the size of the prosodic units in the stimuli. We also corrected some inconsistencies involved in experiment 1. The same procedure was used in both group of subjects. Also gender proportion, which was moderately biased in experiment 1 (36% males in the American group vs 67% in the French group) was better balanced in experiment 2.

EXPERIMENT 2

In the first experiment we found evidence that two-month-olds could discriminate languages using single sentences. The aim of the second experiment was to test two-month-olds' ability to discriminate languages with smaller amounts of speech input than single sentences. Two units have been considered, intonational phrases and words. Intonational phrases are intonation contours to which a pause can be added at the beginning and at the end without modifying the coherence of the contour. Thus the sentences of experiment 1 were cut at a major syntactic boundary that was marked in the prosody. It was expected that infants would discriminate the two languages in this condition confirming that they were able to use a smaller prosodic unit than sentences.

The second condition was the scrambled words condition. Multisyllabic words or phrases were taken from the original stimuli and spliced together in an improper order so that the global prosodic structure was eliminated while maintaining the same word-level information. If the rhythmic structure is the main information used by infants, several successive multi-syllabic words or phrases should provide enough information to discriminate the syllable-timed rhythmic pattern of French and the stress-timed rhythmic pattern of English. Indeed, Jusczyk et al. (1993) have shown that 6-month-old can use the prosodic structure of the words to recognize their native language. However, because in the first months of life, babies are less able to process small prosodic units than later (Jusczyk et al., 1992), 2-month-old babies might have no access to word-level prosodic structure. The aim of experiment 2 was to test if two-month-olds are sensitive to the intrinsic rhythmic properties that distinguish French from English and to test if eliminating the global prosodic structure interferes with processing smaller units. If a global prosodic structure is necessary for processing continuous speech in two-month-old infants, they would discriminate the two languages only in the intonational phrases condition and not in the scrambled words condition. This would result in a significant interaction of Nationality, Language, and Condition.

Method

Subjects.

Eighteen two-month-old subjects were recruited from monolingual American-English speaking parents living in the Eugene-Springfield area, Oregon, USA. Ten additional subjects were rejected because they listened to less than half of the stimuli due to excessive crying and/or sleepiness. Two more were rejected for technical problems during the run. Among the 18 subjects, ten were female, and eight were male with a mean age of 64 days (60 to 72 days).

A second group of 18 two-month-old French infants (11 girls, 7 boys), living in the Paris area, was constituted. They were from monolingual French speaking families, with a mean age of 68 days (61 to 76 days). Eleven more subjects were tested and ten were excluded due to excessive crying and/or sleepiness. The last one was rejected because he had no correct orientation in one of the tested conditions.

All subjects were full term, without any medical complications during birth and the first months of life. Full informed consent was obtained from the parents.

Stimuli.

The sentences from the previous experiment were digitized and manipulated to obtain two experimental conditions for each language. Each condition had the same number of syllables on average. In the "intonational phrase" condition, the sentences were cut at a syntactic boundary that was marked prosodically. Thus, the sentences were cut either between two clauses or before an adverbial phrase. The resulting grammatical structure was very simple, NP-VP or NP-VP-NP for the majority of the stimuli. The prosodic structure consisted of one or two intonational phrases. In the scrambled words condition, multi-syllabic words (e.g. "attention") or phrases (e.g. "old man") were extracted from the original sentences. The words were cut at a zero crossing point in order to avoid any click artifact. Because of the characteristics of child-directed speech, each selected word or phrase was perfectly recognizable in isolation. A new utterance was obtained by pasting 2 or 3 of these multi-syllabic strings, separated by 150 ms of silence, in order to obtain a total of 4 to 7 syllables for each utterance, similar to the intonational phrases. To avoid any global coherence, the words were grouped in such a way that a word extracted from the beginning of a sentence was placed at the end of the new utterance and vice versa. For example, the sentences "and he lay down to digest his dinner" "et il se couche pour digérer son repas" was used to create two intonational phrases (" and he lay down" and "to digest his dinner", "et il se couche" and "pour digérer son repas"), and one scrambled words utterance ("dinner digest lay down", "repas digérer se couche").

64 pairs of utterances were constructed in each condition (appendix B and C). The number of syllables was similar in the two conditions (5.6 syllables) but the duration was different by construction. The mean intonational phrase duration was 1178 ms, shorter than the mean scrambled words duration (1444 ms) ($F(1,252) = 46.27$, $p < .001$). Because the stimuli were extracted from the sentences of the previous experiment, a slight difference in duration between French and English samples persisted. For the intonational phrase condition, the mean duration was 1230 ms in English (783 to 1938 ms) and 1126 ms in French (573 to 2219 ms) (104 ms, $F(1,126) = 4.06$, $p = .046$). For the scrambled words condition, the mean duration was 1494 ms in English (739 to 2376 ms) and 1395 in French (737 to 1975 ms) (99 ms, $F(1,126) = 2.83$, $p=.095$).

Similar differences were found in syllabic rates (intonational phrases : 279 in English vs 312 syll/mn in French : $F(1,126) = 12.4$, $p < .001$ and scrambled words : 230 in English vs 253 syll/mn in French $F(1,126) = 8.88$, $p = .003$).

These utterances were presented in a semi-random order with the same constraints as in experiment 1.

In order to gauge the difficulty of the two conditions of the present experiment, ten French and ten American-English adults were tested in a forced choice language recognition task. The stimuli were low-pass filtered above 400 Hz to force the adults to use only the prosodic information. Adults correctly identified the language of the filtered utterances in 63% of the intonational phrases ($t = 11.1$, $p < .001$) and 62 % of the scrambled words ($t = 12.0$, $p < .001$), indicating that prosodic information in the two conditions was sufficient to discriminate the two languages.

Procedure.

The same experimental and coding procedures were used for the French and the American groups. They were similar to the procedures used in experiment 1 for the French group : For both groups, the stimuli were played by a PC computer through a 16-bit sound card, avoiding the superposition of the spiral and the first hundred milliseconds of speech. The infants sat on a baby chair and had no contact with their parents during the experiment. The coders inter-agreement was similar to the previous experiment : .99 on the valid trials, .95 on the presence of a look during the trial, .93 on the direction of the first look and .85 on the scoring of reaction times.

Results

The average number of valid trials was 54.0 for American babies and 48.8 for French babies (t(34) = 1.17, n.s.).

Analyses of hits and errors rates.

The mean percentage of no looks was of 10.1% and an ANOVA performed on this measure with Nationality (French vs. American) as a between-subjects factor, Language (French or English) and Condition (intonational phrase or scrambled words) as within-subject factors showed no main effect or interaction. On the trials with an orientation response, infants oriented to the correct speaker more often than chance alone would predict (correct orientation: 62.0%; two-tailed t-test for a significant deviation from 50%, t(35 d.f.)=7.13, p<.001). The percentage of correct looks was significantly greater than chance for both the intonational phrases condition (correct orientation: 62.1%; t(35 d.f.)=6.00, p<.001) and the scrambled words condition (correct orientation: 60.0%; t(35 d.f.)=6.46, p<.001). An ANOVA was performed on the percentages of incorrect looks with the same factors as above. No main effect or interaction was significant.

Analyses of reaction time.

The average number of correct orientations was 28.8 for American babies and 28.0 for French babies (t(34) < 1). For each subject, the average reaction time of correct looks in each of the four conditions (English intonational phrases, English scrambled words, French intonational phrases and French scrambled words) was calculated. Then an analysis of variance was performed with the factors defined as above[6].

No main effect was present (all 3 F(1,34) <2). Neither were any of the 2-way interaction (all 3 F(1,34) < 1). However, the triple interaction of Nationality, Language and Condition was in the predicted direction and approached significance ($F(1,34) = 2.95$, $p = .095$). Because we predicted that infants' behavior could be different in the two conditions, the analyses were subsequently restricted to each condition. In the intonational phrase condition, there was a significant Language X Nationality interaction ($F(1,34) = 5.67$, $p = .023$) (figure 2). Post-hoc analyses showed that, as in experiment 1, American infants oriented 410 ms faster to English intonational phrases than to French intonational phrases ($t(17) = 2.22$, $p = .040$). In contrast, French infants had a non-significant tendency to orient faster to French intonational phrases (96 ms, $t(17) < 1$). In the scrambled words condition, the interaction Nationality X Language was not significant ($F(1,34) < 1$). American, as well as French infants, showed the same non-significant tendency to orient faster to English scrambled words (figure 2).

Discussion

This experiment confirmed and extended the results of the previous experiment. A Nationality X Language interaction was again observed in the intonational phrase condition. As in experiment 1, infants tended to orient faster toward their native language. This confirms that short utterances with adequate prosody are sufficient to trigger language discrimination in 2-month-old babies. However, no such behavior was observed in the scrambled words condition. Although phonological information and word prosodic structure were present in the scrambled words condition, the native utterances lacked coherent contour and did not trigger faster reaction times.

One issue, of course, is the extent to which there was enough information in the scrambled words utterances to discriminate the two languages and how the destruction of the prosodic contour across the utterance could prevent any analysis of smaller units. As suggested by the literature, the phonetic and phonotactic differences between English and French were not relevant to discriminate languages at this young age. Specific responses to the phonemes of the native language appear only after 4-6 months of age for vowels (Polka & Werker, 1994 ; Kuhl et al, 1992) and the end of the first year for consonants (Werker et Tees, 1984). Six-month-old American infants are not able to discriminate between a list of words in their native language, English, and a list of words in Dutch, apparently because the two languages have a similar prosodic structure. Only by nine months, do they become able to use the differences in phonetic composition and phonotactic between the two languages. Furthermore, rhythmic differences, present in the scrambled words condition, appear also not sufficient to induce language discrimination. Yet, adults perform at a similar level for filtered scrambled words and for filtered intonational phrases, demonstrating that there was enough prosodic information in the scrambled word condition to discriminate the two languages. Van Ooyen, Bertoncini, Sansavini & Mehler (submitted) have shown that neonates do not discriminate between a list of weak-strong bi-syllabic words and a list of strong-strong bi-syllabic words, suggesting that the word prosodic structure is not initially attended to. Because the disorganization of the global prosodic pattern in scrambled words could affect the analysis of the smaller units, the present experiment is not sufficient to demonstrate that two-month-olds, like neonates, are unable to use the words' rhythmic structure. It does suggest, however, that rhythmic properties are not processed independently of the global structure of the utterance and confirms that infants during the first months of life are more likely to attempt a global analysis of continuous speech than a detailed analysis of small units.

General discussion

The results of the present experiments contribute to our understanding of language discrimination in two important ways. First, they provide a replication of the findings that 2-month-old infants are able to discriminate between their native language and a foreign language. The replication is crucial because it employs another paradigm different from the sucking paradigms. Second, they demonstrate that language discrimination is a fast process, especially considering that reaction times comprise a motor component that is still immature and slow at this age. The mean reaction time was 1672 ms in experiment 2 suggesting that babies need little more than one second to discriminate French from English. The results of experiment 2 also indicate that two-month-olds are able to analyze prosodic units smaller than or equal to an intonational phrase. Jusczyk (1989) showed that 4-1/2-month-old-infants prefer to listen to utterances in which pauses are inserted at syntactical clauses boundaries than utterances in which pauses are inserted within these clauses. The clauses in Jusczyk’s experiment probably correspond to intonational phrases. Thus, these two sets of experiments suggest that young infants listening to continuous speech are able to extract and process prosodic units such as intonational phrases in the speech stream. Further experiments will be necessary to assess whether smaller units, such as phonological phrases, could also support language identification.

An unpredicted result, which was found in experiment 1 and 2, was a bias for infants to orient faster toward English utterances. Such a bias works in combination with the native language effect and contributes to the asymmetry found between the French and the American groups. One possible explanation for this bias is a difference in the experimental material, such as shorter duration of the French stimuli. Note however that the difference in duration between the two languages in experiment 2, while still significant, was minor : around 100 ms.. Because we used natural speech from a single speaker, it is possible that in addition to the language effect, peculiarities of this speaker in one of the two languages could have affected the infants' behavior. The stress-timed nature of English or the cultural behavior toward infants in North-American cultures may have induced our speaker to emphasize the child-directed speech properties of speech when speaking English. In further experiments, several different monolingual speakers could be used in each language to avoid any idiosyncrasy from one speaker and confirm whether or not the asymmetry encountered in the present experiment is related to speaker idiosyncrasy.

Another possibility is that this bias was related to the languages themselves. Jusczyk et al. (1993) tested American-English and Dutch 9-month-old infants on the preference for words in the native language. Their results were highly similar to the present ones : They reported a significant interaction between the infants' nationality and the language preference, but also an asymmetry. American infants listened significantly longer to English words but Dutch infants had only a non-significant tendency to prefer their native language. One explanation of such asymmetries is that English has a world wide diffusion and can be heard on TV and radio, even in countries where it is not the dominant language. Thus, we can not exclude that French infants could have been exposed to English from time to time. If in our experiments, unusual prosodic structures slow down infants' orientation because they are unexpected in the infants' environment, then the behavior differences could be due to French infants being more familiar to English than American infants to French.

A third possibility finally, is that the language structure itself plays a role in the pattern of results. It is for example, possible that the more variable rhythmic pattern of English might better attract infants' attention regardless of the infants' native language. Another explanation is related to the intonation patterns of the two languages. If an intonation pattern is frequent in French intonational phrases but rare in English, American infants might be slowed down when they hear this unexpected pattern. If however, the patterns that are frequent in American-English are also quite frequent in French, then French infants would show little reaction to them. To our knowledge, no studies have compared the frequency of the prosodic patterns of intonational phrases in American English and French. These two languages have generally been compared on segmental characteristics, such as phonemes or, at best, on syllabic structures. However, Delattre (1965) has proposed prosodic patterns for sentences in different languages, among them French and English. He notes that continuation and finality are indicated in English by an intonation fall. In French, a continuation is indicated by a rising intonation and a finality by an intonation fall. Whalen, Levitt & Wang (1991) have studied the multi-syllabic productions of English-American and French infants between 7 and 11 months. For American infants, 50 % of the productions have a falling intonational pattern and the other half is distributed among four other patterns. For French infants, 33 % of the intonation patterns are rising, 33 % are falling and 33 % are other patterns. Thus, French babbling has two frequent patterns while English has only one. These authors relate this fact to the frequency of these patterns in the adults' production. These two studies point to the possibility that the distribution of intonation patterns in French and English is asymmetrical. Such an asymmetry might explain the behavioral asymmetry of our subjects. For American infants, the rising patterns of French utterances would have been unexpected because of their low frequency in English ; whereas for French infants, neither falling nor rising patterns would have been particularly unexpected because both are frequent in French. This hypothesis is clearly very speculative and deserves further exploration.

Conclusion

Short segments of continuous speech (1.2 s on average), are sufficient to induce different behaviors in infants who are exposed to different linguistic environments, as long as the global prosodic organization of this segment is coherent. This emphasizes the importance of the prosodic structure in young infants' language representation. The present experiments also show that language recognition is fast and illustrate, once more, the striking efficiency of linguistic processes in young infants. Finally, they demonstrate that the eye-orienting method can be used to study linguistic processes in young infants. This new method provides temporal data that reflect the on-line processes involved in continuous speech perception. If, as we suppose, orientation is slowed when unexpected auditory stimuli are presented, this method would seem to provide a powerful tool to study the early representations of speech in infants.

Footnotes

[1] In French, all syllables are fully realized but in English there are strong and weak syllables whose perceptive status is different. Therefore, syllable is a questioned notion in English and linguists prefer to describe English rhythmic structure in feet rather than in syllables. In the absence of data on the perceptive status of weak syllables by young infants, each syllable was counted without considering its accentuation status for the purpose of matching sentences across languages.

[2] In order to assure that the language of low-pass filtered sentences was still identifiable, ten French and ten American-English adults were tested in a forced choice language recognition task. They correctly identified the language of the filtered sentences in 65.5 % of the trials. This performance is significantly different from a random choice ($t = 6.9$, $p < .001$) (Dehaene-Lambertz, 1995) and similar to the results of other studies using filtered speech in adults (Maidment, 1983; Ohala & Gilbert, 1979).

[3] In average, 5 trials per subject (0 to 17) were lost because the infant was not front-centered when speech began.

[4] In adults, the fastest reaction times to visual stimuli located at more than 4° of the central fixation are around 180-200 ms (Saslow, 1967). Infants are slower than adults and there is an acceleration during development. In a visual orientation task, the mean reaction time is 760 ms at 2 months and 447 ms at 4 months (Johnson, 1994). Therefore, orientation latencies below 200 ms are usually considered as anticipations in infants.

[5] Because the American-English and French groups were not fully comparable in gender make up (35.7% males in the American group vs 66.7% in the French group), another ANOVA was performed with sex as an additional between-subject factor. There were no significant main effect of sex, nor any interaction between this factor and any other factors in the analysis.

[6] Although the American-English and French groups were comparable in gender make up (44.4 % males in the American group vs 38.9 % in the French group) another ANOVA with sex as an additional between-subject factor was computed as in experiment 1. There were no significant main effect of sex, nor any interaction between this factor and other factors of the analysis.

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Figure Captions

Figure 1: Orientation latency toward normal and filtered sentences in two-month-old French and American infants. Bars represent one standard deviation of the mean.

Figure 2: Orientation latency toward intonational phrases and scrambled words in two-month-old French and American infants. Bars represent one standard deviation of the mean.

Appendix A: Experiment 1 sentences

One day they set off to see the huge world.	Un jour, ils décident de voir le vaste monde.
Their mother kissed them on their little cheeks.	Leur maman les embrasse sur leurs joues replètes.
She told them to pay attention to the big bad wolf.	Elle leur dit de faire bien attention au loup.
The brothers went through the river, which glittered.	Les trois frères traversent la rivière qui serpente.
The eldest met an old man holding some straw.	Le cadet voit un vieil homme portant de l'herbe.
May I have some stubble to build a cottage?	Donnez-moi de la paille pour faire une maison?
The farmer gave him some for eleven coins.	Le fermier lui en donne contre quelque argent.
The fat piglet worked hard to finish his hut.	Le porcelet peine dur pour finir sa hutte.
When he had finished he sat down for a while.	Lorsqu'il a fini il s'asseoit tout rêveur.
Suddenly the horrible beast came along.	Tout à coup surgit le méchant animal.
The flesh-eating gobbled up his podgy victim.	Le carnassier engloutit sa victime dodue.
Then, satisfied, he went on his way to the woods.	Puis, rassasié, il poursuit sa route vers les bois.
The second little pig was walking slowly.	Le second porcelet chemine doucement.
He found a lumberman with a bundle of sticks.	Il trouve un bucheron avec un tas de bois.
He bought wood to construct a fine little shack.	Il en achète pour construire une jolie bicoque.
He painted the door and the windows in purple.	Il peint la porte et les fenêtres en violet.
When he had stopped, he felt dirty and tired.	Quand il termine, il est sale et épuisé.
But it's the hairy monster, who arrived then.	Mais c'est le monstre poilu qui arrive
He barked to the pig to open the front door.	Il crie au cochon d'ouvrir la porte de bois.
Then I will destroy your villa with all my breath.	Je vais donc détruire ta villa avec mon souffle.
Down came the wooden place in a second time.	L'isba cossu s'effondre en un seul instant.
The big dog swallowed the fresh and tasting meat.	Le grand chien avale la viande fraiche et goûtue.
And he lay down to digest his dinner.	Et il se couche pour digérer son repas.
During that time the oldest walked a long way.	Pendant ce temps, l'ainé a marché longtemps.
He crossed a fellow moving a load of bricks.	Il croise un maçon avec un tas de briques.
May I have some bricks to raise my residence	Donnez-moi des briques pour construire ma demeure?
The worker sold his bricks to the brave client	L'ouvrier vend ses briques au brave client.
He fixed a big chimney to light a fire.	Il crée une cheminée pour faire un beau feu.
The country was quiet in the gorgeous sunset.	La campagne est calme dans le soleil couchant.
It was warm and our busy friend was happy	Il fait chaud et notre jeune ami est heureux
Then along came the crual enemy.	Bientôt arrive le féroce ennemi.
My building is like a broad solid castle.	Ma maison est comme un imposant chateau.
The wolf was very angry and starving.	Le loup est très en colère et affamé .
He came each day and tried to trick the piglet.	Il vient chaque jour et tente de prendre le goret.
The wolf told the sweet pig about a field of turnips.	Le loup parle au cochon d'un champ de navets.
They are savory, crunchy and delicious.	Ils sont savoureux, croquants et délicieux.
I will meet you there early in the morning.	Je te verrai là au lever du soleil.
But the little one woke up very early.	Mais le marcassin se lève de très bonne heure.

The voracious robin was still deep asleep.	Le bandit affamé est toujours au lit.
He was disapointed when he indeed woke up.	Il est très déçu quand il se réveille enfin.
Another time he tried an other trick.	Une autre fois il tente une autre ruse.
Once again, our friend got up at sunrise.	De nouveau, notre ami est debout dès l'aube.
He was up in a tree when the hound appeared.	Il est en haut de l'arbre quand l'affreux arrive.
He threw apples at the greedy opponent.	Il lance des pommes à son vorace adversaire.
He chased him away then he ran home safely.	Il le chasse au loin, puis il court sain et sauf.
The circus settled in the nearest village.	Le cirque s'installe dans le village le plus proche.
The young little pig would like to have great fun.	Le jeune cochonnet aimerait s'amuser.
He left for the beautiful fair at sunlight.	Il part à la fête foraine à l'aurore.
But the nasty hoped to catch him over there.	Mais, le vilain espère l'attraper là-bas.
Our fat buddy noticed the gangster.	Notre gros copain aperçoit le bandit.
Quickly he hid in a big barrel which rolled.	Très vite il saute dans un grand tonneau qui roule.
And the barrel nearly knocked the scroundel over!	Et le tonneau rate de justesse le gredin.
He opened the door and gave the key a turn.	Il ouvre la porte et ferme à triple tour.
The wolf was furious and cried out with anger.	Le loup est furieux et rugit avec colère.
But the little pig was quite safe in his house.	Mais le porcelet est à l'abri chez lui.
I am coming to get you, nasty little piglet.	Je viens t'attraper, vilain petit cochon.
I will come down your solid chimney to eat you	Je vais descendre par la cheminée te manger
But the malicious animal had made a big fire.	Mais le malicieux animal a fait un feu.
He had put a huge pot of water to boil.	Il a mis un grand pot d'eau chaude à bouillir.
but he fell into the pot of boiling water.	mais il tombe dans le chaudron plein d'eau bouillante.
And that was the end of the crual beast	Et c'en est fini du sale animal.
He never saw a big bad wolf in the wood.	Il n'a plus vu de méchant loup dans les bois.
He got maried and had a lot of children.	Il s'est marié et a eu beaucoup d'enfants.
He often told the sad story of the wolf.	Il conte souvent la triste histoire du grand loup.

Appendix B: Experiment 2 intonational phrases

to see the huge world.	de voir le vaste monde.
Their mother kissed them	Leur maman les embrasse
The eldest met an old man	Le cadet voit un vieil homme
holding some straw.	portant de l'herbe.
May I have some stubble	Donnez-moi de la paille
The farmer gave him some	Le fermier lui en donne
The fat piglet worked hard	Le porcelet peine dur
to finish his hut.	pour finir sa hutte.
When he had finished	Lorsqu'il a fini
he sat down for a while.	il s'asseoit tout rêveur.
little pig let me in	petit cochon ouvre-moi
cried the little pig.	hurle le petit cochon.

And the wolf said
will blow your house down
he went on his way
He found a lumberman
He painted the door
When he had stopped
he felt dirty and tired.
But it's the hairy monster
He barked to the pig
to open the front door.
I will destroy your villa
Down came the wooden place
And he lay down
to digest his dinner.
the oldest walked a long way.
He crossed a fellow
the little one woke up
May I have some bricks
to raise my residence
The worker sold his bricks
to light a fire.
The country was quiet
our busy friend was happy.
I won't let you in!
answered our splendid friend
He tried and tried
he could destroy nothing
The wolf was very angry
tried to trick the piglet. .
The wolf told the sweet pig
They are savory,
I will meet you there
He took some turnips
he sprinted quickly back
He was disapointed
when he indeed woke up.
he tried an other trick.
He was up in a tree
when the hound appeared.
He threw apples
He chased him away
he ran home safely.
The circus settled
to catch him over there.
he hid in a big barrel

Le loup répond
ta chaumière tombera
il poursuit sa route
Il trouve un bucheron
Il peint la porte
Quand il termine
il est sale et épuisé.
Mais c'est le monstre poilu
Il crie au cochon
d'ouvrir la porte de bois.
Je vais donc détruire ta villa
L'isba cossu s'effondre
Et il se couche
pour digérer son repas.
l'ainé a marché longtemps.
Il croise un maçon
le marcassin se lève
Donnez-moi des briques
pour construire ma demeure?
L'ouvrier vend ses briques
pour faire un beau feu.
La campagne est calme
notre jeune ami est heureux.
tu n'entreras pas!
répond le fier sanglier.
Il se déchaîne
il ne peut rien détruire.
Le loup est très en colère
tente de prendre le goret.
Le loup parle au cochon
Ils sont savoureux,
Je te verrai là
Il cueille quelques navets
est de retour très vite
Il est très déçu
quand il se réveille enfin.
il tente une autre ruse.
Il est en haut de l'arbre
quand l'affreux arrive.
Il lance des pommes
Il le chasse au loin,
il court sain et sauf.
Un cirque s'installe
l'attraper là-bas.
il saute dans un grand tonneau

He opened the door	Il ouvre la porte
and gave the key a turn.	et ferme à triple tour.
The wolf was furious	Le loup est furieux
cried out with anger.	rugit avec colère.
I'm coming to get you	Je viens t'attraper
He got maried	Il s'est marié
and had a lot of children.	et a eu beaucoup d'enfants.

Appendix C: Experiment 2 scrambled words

little, set off, mother	petits, décident, maman
huge world, attention	vaste monde, attention
holding, old man, eldest	portant, vieil homme, cadet
finish, brothers, painted	finir, trois frères, donnez
glittered, river, cottage?	serpente, rivière, maison?
chinny, fat piglet	porcelet, menton
sat down, second	s'asseoit, second
was walking, horrible beast	animal, méchant, chemine
little shack, slowly	doucement, bicoque
fell down, cabin, flesh-eating	s'écroule, cabane, carnassier
victim, podgy, gobbled up	dodue, victime, engloutit
went on, satisfied	poursuit, rassasié
little pig, construct	porcelet, construire
curly, had stopped, monster	ami, termine, monstre
residence, tired	épuisé, demeure
little tail, open	tire bouchon, d'ouvrir
young wild boar, courageous	marcassin, courageux
dirty, villa	rêveur, villa
second, wooden, down came	instant, s'effondre, cossu
tasting, swallowed, big dog	goûtue, avale, grand chien
dinner, digest, laid down	repas, digérer, se couche
oldest, during	pendant, ainé
cold morning, performed, latter	matin froid, travaille, dernier
fire, chimney, along	beau feu, cheminée, arrive
sunset, gorgeous, country	couchant, soleil, campagne
happy, busy friend	heureux, jeune ami
enemy, crual, enter	animal, féroce, entrer
turnips, answered	navets, repond
trumpet, castle, building	trompette, chateau, maison
piglet, destroy, pretty	goret, détruire, jolie
savory, sweet pig	savoureux, cochon
delicious, crunchy	délicieux, croquants

robin, voracious	affamé, bandit
woke up, huge hound	molosse, réveille
apple trees, spendid friend	pommiers, fier sanglier
appeared, worker	arrive, l'ouvrier
opponent, greedy	adversaire, vorace
little pig, brave client	cochonnet, brave client
solid, beautiful fair	imposant, fête foraine
criminal, nasty	criminel, vilain
scroundel, big barrel, quickly	gredin, grand tonneau, très vite
nearly, barrel	justesse, tonneau
starving, angry, opened	affamé, colère, tempête
anger, cried out, furious	colère, rugit, furieux
angry, disapointed	faché, désappointé
chimney, solid, noticed	méchant, aperçoit, chaudron
huge pot, come down	grand pot, descendre
water, malicious, foolish	eau chaude, malicieux, idiot
huge chimney, animal	cheminée, animal
happily, maried	heureux, marié
children, story, suddenly	enfants, histoire, tout à coup
disapointed, bundle	argent, deçu, embrassent
little cheeks, destroy	joues replètes, détruire
solid, went through, stubble	cochon, traversent, l'isba
asleep, moving, sunrise	repond, déchaine, l'affreux
shouted, castle	construire, chateau
long way, eleven	longtemps, tempêter
sunlight, boiling, ever	aurore, bouillante, depuis
often, big bad wolf, woke up	méchant loup, souvent, se lève
early, nothing, fellow	bonne heure, verrai, maçon
coming, again, would like	l'attraper, aimerait, nouveau
hairy, indeed, nasty	poilu, cochon, vilain
again, safely, sprinted	soufflerai, encore, marché
nearest, never, turnips	navets, chaumière, bientôt

Figure 1

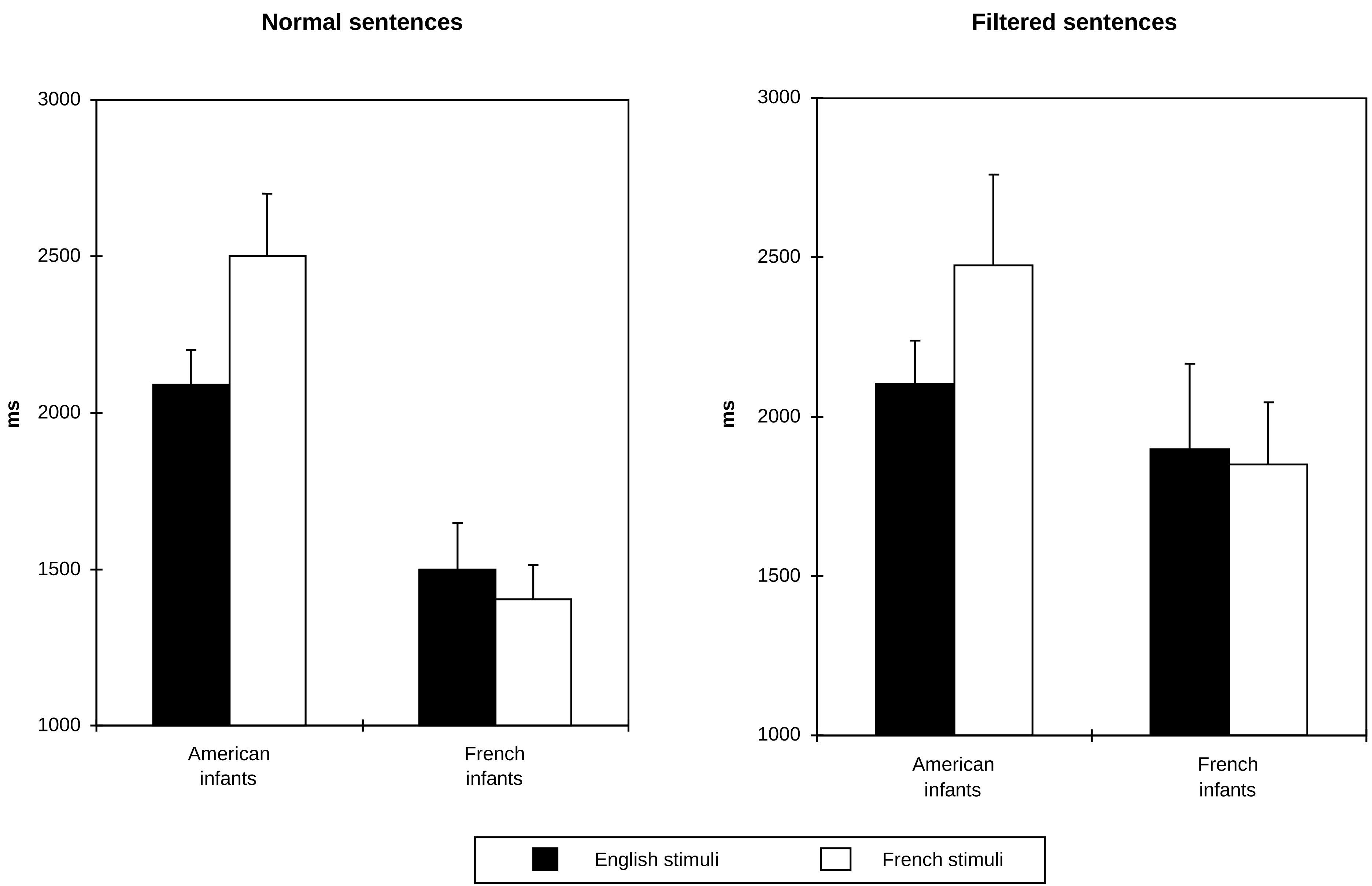
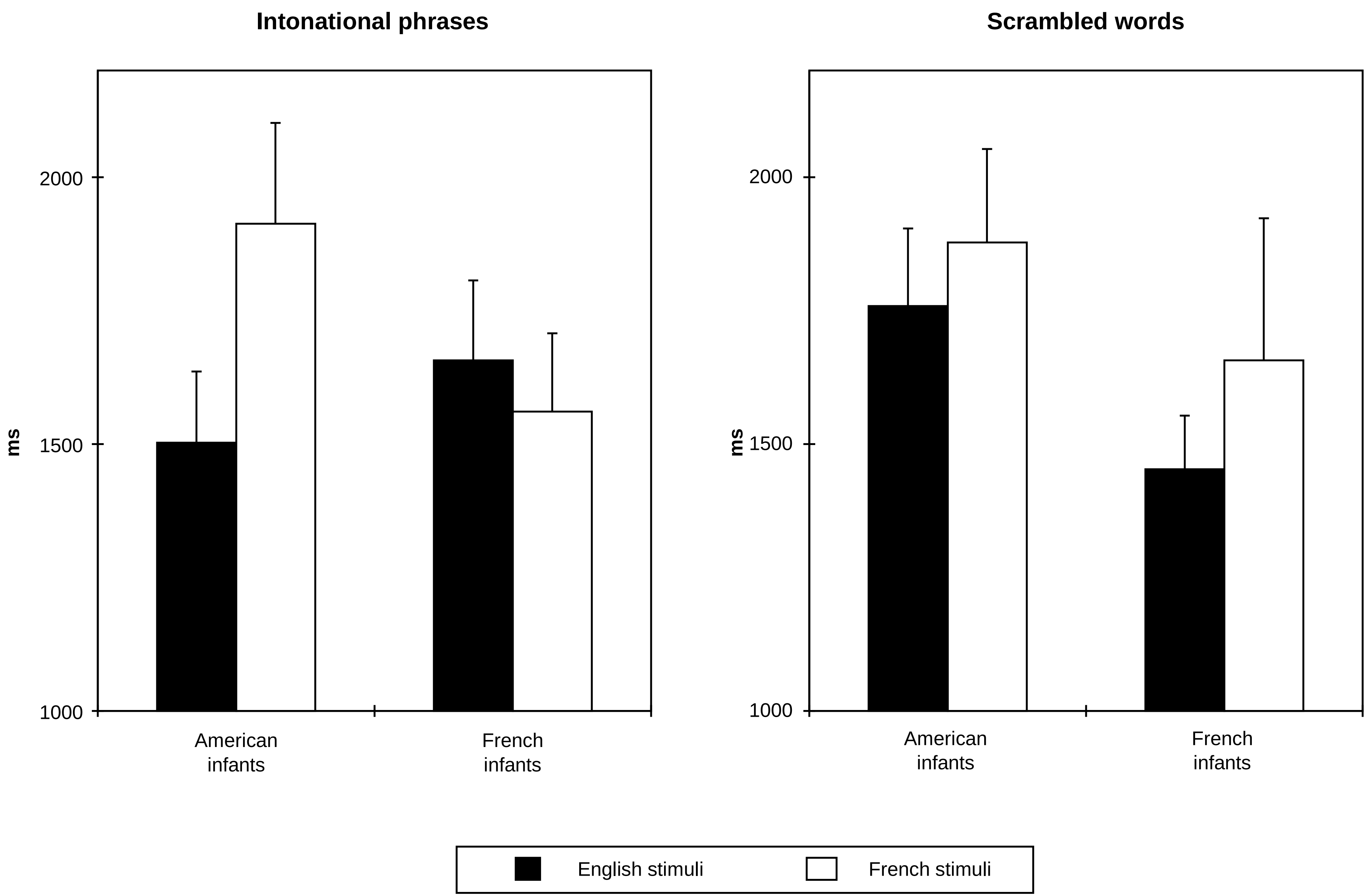

Normal sentences
Filtered sentences
ms
3000
2500
2000
1500
1000
American infants
French infants
English stimuli
French stimuli

Figure 2


Intonational phrases
Scrambled words
ms
2000
1500
1000
American infants
French infants
English stimuli
French stimuli