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Categorical perception in bilingual and monolingual adults

Miranda L. Entwistle
School of Communication Sciences and Disorders
McGill University, Montréal

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Abstract

The categorical perception paradigm was used to compare French/English bilinguals' and French and English monolinguals' categorization of code-switched words. A previous study by Burki-Cohen et al. (1987) showed that bilinguals' categorization of a cross-language continuum that varied from a French word to an English word was different when the words were presented in the context of a French or an English carrier phrase. Using the same stimuli the present study examined whether the effects of base language (i.e. the carrier phrase) are due to processing specific to bilinguals or are mediated by general phonetic or auditory processes. Results showed that all three groups were affected by the base language in the same way, suggesting that general processes were involved. These findings indicate that manipulating a carrier phrase does not ensure that a level of language processing is invoked which can reveal categorization processes that are particular to bilinguals.

Résumé

Le paradigme de la perception catégorielle a été utilisé pour comparer la perception des alternances codiques chez les bilingues (Français/Anglais) et chez les unilingues francophones et anglophones. Une étude par Burki-Cohen et al. (1987) utilisant un continuum acoustique dont les extrémités variaient d'un mot Français à un mot Anglais, a démontré que la catégorization chez les bilingues était différent lorsque le mot suivait une phrase porteuse Française ou Anglaise. En utilsant les mêmes stimuli, ce travail examinait si les effets de la langue de base (i.e. phrase porteuse) étaient dû à un traitment spécifique chez les bilingues ou si c'était médié par des processus phonétiques ou auditoires. Les résultats ont démontrés que les 3 groupes étaient influencés de la même manière par la langue de base. Ce qui implique l'utilisation de processus généraux. Ces résultats indiquent qu'en manipulant la phrase porteuse, il ne semble pas y avoir de décodage du langage particulier au bilingues.

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Table of Contents

List of Figures and Tables

Figures

Tables

Introduction

For many years researchers have been conducting cross-language studies to explore the mechanisms of language perception and processing that are universal versus those which develop from specific language exposure. Over the years researchers have also turned to the study of bilinguals in order to further this type of inquiry. Bilingualism presents a unique way to look at these issues since bilinguals have been exposed to two languages. Researchers, therefore, have an opportunity to examine not only how exposure to a specific language affects speech perception and processing, but also how universal processing mechanisms interact with that exposure. For this reason most research on bilinguals seeks to compare them with monolingual speakers of their two languages. More recently however, some researchers have begun to explore bilingualism itself to attempt to both describe and explain bilingual perception and processing of language as distinct from the processing of monolinguals. The present study represents aspects of both of these areas of study.

One of the important areas of research in recent years has centered on bilingual code-switching, that is, when bilinguals switch between their two languages during the same communicative event. Researchers have looked at the many perceptual and productive factors that influence such code-switches. The present study explores how the acoustic/phonetic characteristics of different speech sounds may affect the perception of code-switches by bilinguals as well as monolinguals. This comparison re-introduces the possibility that common perceptual patterns between

monolingual and bilinguals may be found, since comparison with monolinguals has not been carried out in research on code-switching. In particular, this study explores how these two types of groups react when the acoustic/phonetic characteristics of code-switched words can be part of either language versus when the acoustic/phonetic characteristics of code-switched words can only belong to one.

Literature Review

This review is organized in two main sections. The first section outlines categorical perception research from the speech perception tradition. This section begins with a discussion of the theoretical and empirical background of categorical perception, then reviews the studies that have used this paradigm to investigate speech perception in bilinguals. The second section outlines speech processing research that arises from the psycholinguistic tradition. Following this the goals of the present study are outlined.

Speech Perception in Bilinguals

The majority of studies that address bilingual phoneme perception use the categorical perception paradigm, as is true of the present study. For this reason this section begins with an overview of categorical perception both conceptually and empirically. Then an overview of the categorical perception studies concerned with bilingual perceivers is presented.

Categorical Perception

Categorical perception has been an important phenomenon in speech perception research. It is revealed when the results of an identification task (i.e. when subjects are asked to identify a continuum of stimuli as belonging to one of two categories) are compared with the results of a discrimination task (i.e. when subjects are presented two or more stimuli and asked to decide whether they are the same or not). The stimuli used are a set of equally spaced acoustical patterns that are altered gradually on a continuum

between two endpoints. In an identification task (also called a labeling task) adults have been shown to divide such a continuum into categories with an abrupt shift in labeling response between categories, called a category 'boundary'. In a discrimination task, a pair of stimuli that straddle the boundary (i.e. are identified as opposite endpoints) are differentiated easily. However, another pair, although having the same acoustic distance between them as those which cross the boundary, are considerably more difficult to discriminate. The essence of this effect is that speech perception, at least as with regard to consonant sounds, is dominated by categories. This is unlike many other perceptual domains in which stimuli are perceived as continual gradations. For example, colour is perceived continually with discrimination of differences along a hue continuum typically being far better than identification of distinct colour values. Many early studies established that numerous consonant contrasts are perceived categorically (see Repp,1984 for a thorough review). Later research focused on identification of categorically perceived continua and factors that affect the presence or precise location of the category boundaries. A number of bilingual speech perception studies have focused on the identification task, as does the present study.

Categorical perception as an experimental phenomenon was first studied by Liberman, Harris, Hoffman, & Griffith (1957). These researchers used a synthesized speech continuum which they created by altering the onset frequency of the second formant of the stimuli in equally spaced steps so that they spanned the phonemes /b/, /d/, and /g/. English listeners perceived this continuum as three discreet

categories. Liberman et al. claimed that this pattern of perception is evidence for a specialized processor that organizes perception according to phonetic categories. This claim prompted a flurry of research into this perceptual phenomenon.

Work following the initial studies demonstrated that although not specific to speech, categorical perception is a robust finding in perception of many consonant contrasts (see Repp, 1984). Categorical perception has been demonstrated for a variety of manner (e.g. Bastian, Eimas, & Liberman, 1961), place (e.g. Mattingly, Liberman, Syrdal, & Halwes, 1971; Pisoni, 1971), and voicing consonant contrasts (e.g. Liberman, Harris, Kinney, & Lane, 1961), most of which involved stop consonants. By far the bulk of early research on categorical perception focused on voicing contrasts as cued by voice onset time (VOT) (e.g. Lisker, Liberman, Erickson, Dechovitz, & Mandler, 1977; Stevens & Klatt, 1974; Repp, 1984). As will be evident below, studies of bilingual categorical perception have also focused, almost exclusively, on the perception of voicing cued by VOT.

Voice onset time is defined by Abramson & Lisker (1970) as the interval between the release burst of a word initial stop consonant and the onset of laryngeal pulsing . These authors were the first to use the VOT dimension to study voicing (Abramson & Lisker, 1965). In synthetic speech, VOT is simulated using a speech synthesizer that has a sound source which provides energy to a filter that in turn produces formants at various frequencies. The sound source includes both hiss (aperiodic) and buzz (periodic) type sounds. To produce the aperiodic segments (i.e. burst or aspiration) of initial

stop consonants, the hiss type sound is used as the source for the formant filters. To produce the periodic segments (i.e. formant transitions) the buzz type sound is used. To change the VOT, the point at which the aperiodic part of the stop consonant ends and the periodic part begins, is varied.

To create their continuum, Abramson & Lisker (1970) used a low frequency buzz as source for the formant filters to simulate formant transitions into the vowel. To create a voiceless exemplar these authors used the hiss noise to simulate the release burst, coupled with a delay in onset of the first formant (F1) which represented an open glottis (or lack of voicing). VOT continua are therefore created by gradually changing the stimuli between these two states. Many researchers have shown that these type of stimuli are perceived categorically by adult English listeners (e.g. Abramson & Lisker, 1965; 1970; Williams, 1977).

Natural stimuli altered in terms of VOT can be created upon the same premise (i.e. the essence of VOT differences is the difference in time between the release burst and the onset of voicing). Lisker (1976) created the first natural VOT stimuli by editing natural syllables and the technique was later employed by Ganong (1980) and others. Taking voiced and voiceless tokens of naturally produced words, digital cross splicing can be used to create stimuli which vary in terms of VOT. That is, the parts of the naturally produced tokens that represent the voiced and the voiceless portions of speech sounds are replaced with each other to create changes in VOT. For example, an initial segment of a voiced syllable (e.g. /ba/) is spliced out and replaced with an equal length portion taken from

the beginning of a voiceless syllable (e.g./pa/). By doing this with successively larger pieces of each syllable, a continuum that varies in VOT is created. A number of researchers have shown that series of stimuli created in this manner are perceived categorically by adult listeners (e.g. Ganong, 1980, Lisker, 1976).

As categorical perception research progressed, the meaning of this perceptual pattern was further elaborated. For example, studies in infant speech perception revealed that the ability to perceive a dimension categorically was present at birth (e.g. Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Eimas, 1974; Jusczyk, 1977). At the same time, cross-language research showed that the effects of language experience are also clearly observed in categorical perception of adults (e.g. Lisker & Abramson, 1970; Strange, 1972; Abramson & Lisker, 1973; Keating, Mikos, & Ganong, 1981). With these findings researchers developed a great deal of interest in how language experience changes the perceptual system.

In one of the first cross-language studies, Abramson & Lisker (1970) presented Spanish, Thai, and English listeners three synthetic speech continua (/ba/ to /pa/, /da/ to /ta/, and /ga/ to /ka/), which were created by altering VOT. These continua contained stimuli that could be divided into English categories, Thai categories, and Spanish categories. Results showed that, as expected, each group performed according to the configuration of phonetic categories that each language applies to the VOT acoustic property. Specifically, English listeners divided each continuum into two categories corresponding to voiced stop consonants (zero or short lag VOT stimuli) versus voiceless aspirated stop consonants (long lag VOT stimuli). For the

alveolar and labial stops, Thai listeners demonstrated three categories corresponding to voicing lead VOT, zero or short lag VOT, and long lag VOT (pre-voiced, voiceless unaspirated, and voiceless aspirated). With velar stops Thai listeners demonstrated two categories that corresponded to voiced and voiceless aspirated stops. Finally, Spanish listeners divided each continua into two categories corresponding to voicing lead VOT verses zero or short lag VOT stimuli (pre-voiced verses voiceless unaspirated). Thus, VOT was perceived differently by speakers of different languages based on the phonetic categories utilized within their own language.

Another cross-language study conducted by Miyawaki, Strange, Verbrugge, Liberman, Jenkins, & Fujimura (1975) demonstrated that listeners may fail to show categorical perception altogether when presented with a continuum that represents a phonetic contrast that does not exist in their own language. They presented Japanese-speaking and American-English speaking adults with a discrimination task using a continuum composed of synthetic speech stimuli that gradually changed from /ra/ to /la/ by varying the onset frequency of the third formant and its transition to the vowel. The /r/ - /l/ distinction is phonetically important in English, however, it is not in Japanese.

As expected English listeners discriminated stimulus pairs that crossed the category boundary much better than they did the stimulus pairs drawn from within the same category. Japanese listeners performed at only slightly better than chance levels in discrimination of the stimuli along the entire continuum. For the most part, these results were true for individuals as well as the

group. Those few Japanese listeners who did show more of a discrimination peak were those who had early experience with languages that contained the /r/-/l/ contrast, or similar phonetic distinctions. Thus, clear discrimination peaks were only shown by those listeners who had the appropriate linguistic experience. The finding that language experience influences phonetic perception has now been repeatedly confirmed in cross-language research conducted over the past 20 years (For a detailed overview of this body of research see Strange, 1995).

Bilingual Phoneme Perception

In keeping with interest on the effects of language experience on speech perception, researchers turned to the study of bilinguals. Bilingualism presents an unique way to observe the effects of language experience since a bilingual person must deal with two languages, and consequently, their perceptual system must be organized in such a way as to allow them to do so. Therefore, unlike the monolingual perceptual system, the bilingual system can demonstrate some of the finer changes that occur as it is exposed to language, since the way in which the system deals with two, often very different, languages can be compared.

Studies using the categorical perception paradigm with bilingual subjects have looked almost exclusively at stop consonant voicing cued by VOT. Research in this area has focused primarily on two questions. Firstly, what similarities or differences are there in the perception of bilinguals and monolinguals, or alternatively, do bilinguals use the same criteria in perceiving a stimulus continua as monolinguals who speak one (or the other) of their languages?

Secondly, do bilinguals shift between two sets of different phonetic criteria depending on the language in which they are interacting (i.e. do bilinguals demonstrate perceptual shifting based on language)?

One of the earliest studies that examined bilingual categorical perception was that of Caramazza, Yeni-Komshian, Zurif, & Carbone (1973). This study used three synthetic speech continua that were created by altering VOT from /ba/ to /pa/, /da/ to /ta/, and /ga/ to /ka/. Caramazza et al. tested monolingual Canadian English, monolingual Canadian French, and bilingual English/French adults. Monolinguals were presented an identification task in a single test session conducted in their native language. Bilingual subjects were tested twice (on separate days) with each continuum, once in an English language set and once in a French language set. To establish a language set (i.e. to prime listeners for processing a particular language; or to establish a language context from which processing can occur) all interaction was in one language (French or English) and filler words in that language were presented along with test stimuli. In addition, prior to testing in the French session the bilingual subjects were asked to read words in French, and prior to testing in the English session they were asked to read a word list in English.

The results showed that French monolinguals and English monolinguals placed their boundaries at different points, whereas the category boundaries of bilinguals fell in between those set by the two monolingual groups. As well, for each continuum, the phonetic boundaries of the bilinguals occurred at the same point along the continuum in both language conditions, showing that bilinguals labeled the continua in essentially the same way regardless of

language context. These findings revealed differences between the bilinguals and both monolingual language groups, however, they failed to show perceptual shifting in the bilinguals. From this, Caramazza et al. suggested that bilinguals utilize a single hybrid perceptual system to deal with their two languages.

A later study by Williams (1977) found similar results, also using synthetic speech. In this case, Williams used a stimulus set that ranged from /ba/ to /pa/ varied on the basis of VOT. As Williams was primarily interested in the question of perceptual shifting, these stimuli were presented to Spanish-English bilinguals only. Both the discrimination and identification task portions of the categorical perception paradigm were presented twice, once in a Spanish language context and once in an English language context. Language set was achieved by restricting all interaction to the appropriate language in each condition, and as production measures were also being taken, the subjects repeated sentences and words from the appropriate language before beginning the perception tasks.

The results showed that bilinguals were similar to monolinguals in the shape and steepness of the slopes of the identification functions (i.e. the slope of the graphic representation of identification results at the point at which labeling shifts from one category to another). However, the boundaries were intermediary to those of monolinguals (who had been tested in previous studies). This suggested bilinguals were not using a double standard for labeling or discrimination. Furthermore, since there was no shift between language conditions, Williams concluded that there was no evidence that a 'language-specific perceptual set' affected the results.

Williams did find a range of individual differences, suggesting that bilinguals differed in how they used the acoustic-phonetic cues within the stimuli.

Though these early studies have not been discounted, some researchers have proposed that results based on synthetic speech stimuli alone, may not be representative of how the perceptual system deals with speech in general. It has been suggested that these type of stimuli are acoustically impoverished as compared to natural speech and therefore they do not possess all of the cues important for inducing language based processing at all. In fact, the studies just described look only at VOT perception rather than voicing perception. Moreover, VOT is the only cue manipulated in these continua while other cues are also important for voicing in English as well as other languages (e.g. the release burst, the frequency of F1, etc.). Furthermore, these stops are modeled after English stops. This may bias listeners to discriminate these stimuli in a particular way. For this reason many of the studies which followed this early work turned to the use of naturally produced speech tokens.

Elman , Diehl & Buchwald (1977) were the first to study bilingual categorical perception with natural speech. These authors hypothesized that earlier studies had not been able to achieve language set (or context) effects because they had not induced true language based processing due to the use of synthetic speech continua. They further proposed that a specific language set was not achieved because the interaction and instructions intended to induce language set occurred several minutes before the identification or

discrimination tasks were performed. Ladefoged (1967) observed that the carrier phrase can affect the stimuli being identified or discriminated (the effects can vary depending on the way in which it is manipulated), however a delay between the carrier phrase and the presentation of the target word eliminates any effects found. For this reason Elman et al. embedded each item in the carrier phrase 'write the word' in English and also in its analog in Spanish. The authors used an identification task with naturally produced speech tokens that varied on the dimension of VOT to range from /ba/ to /pa/. These stimuli were not altered in equally spaced steps, as in a true continuum, but were chosen from natural tokens produced by a bilingual English/Spanish adult that were similar in all ways except for VOT, and represented different amounts of voicing. They also interspersed filler words and nonsense syllables in the appropriate language with the test stimuli.

With this procedure, Elman et al. were able to show evidence of a shift in labeling as a function of language context, however, this effect varied considerably among their bilingual subjects. The largest shifts occurred with the bilinguals who were considered 'strongest' or most 'balanced', in that they were rated by native speakers of each language as being most monolingual-like in production of both their languages. Within the group of 'weaker' bilinguals, much more variability was noted. In this group, subjects tended to produce results that were either very similar to monolingual English speakers or very similar to monolingual Spanish speakers, such that individual differences canceled out group effects.

Since this was the first study to use natural speech, Elman et al. also wished to confirm the hypothesis that the lack of language set effects found in earlier studies was due to the nature of the synthetic stimuli. For this reason, they synthesized stimuli that corresponded to the VOT of the natural speech tokens that had been used. They presented these stimuli to the same subjects in the same manner as they had the natural speech stimuli. No language set effects were found leading the researchers to conclude that natural speech stimuli were required to induce language set effects.

In spite of the evidence provided by Elman et al., two more recent studies returned to the use of synthetic speech in order to look at some specific questions raised by this early work. Flege & Eefting (1987a) examined identification of a synthetic VOT series by 50 Dutch speakers who had begun to learn English after age 12. These authors were not primarily interested in the similarities and differences of bilinguals and monolinguals as were previous researchers (although some comparisons were made through the use of a very small control group of monolingual English speakers), but rather were very interested in perceptual set shifting in bilinguals. These authors were specifically interested in how the perceptual system was changed when learning a second language and how proficiency affected categorization of a continuum. Thus, Flege & Eefting separated their bilinguals into three groups (high, medium, and low proficiency) using self rating data, rating of their production in each language by native speakers, as well as measurement of VOT in their production of stop consonants. The stimulus series used ranged from /da/ to /ta/ altered on the basis of VOT. Flege & Eefting

felt that the natural stimuli used by Elman et al. were not appropriate to a categorization task since they were not evenly spaced and therefore did not truly represent a continuum. In addition, Flege & Eefting modeled their stimuli on natural productions by a bilingual speaker of Dutch and English to ensure they were as natural as possible. To induce language set, Flege & Eefting kept all interaction and instructions in the appropriate language in two sessions. As well, they required the subjects to read and respond to questions that were interspersed between trial blocks. The authors proposed that requiring on-line processing of language was a more appropriate way to induce language set since they felt that a carrier phrase may eventually be ignored.

The results showed a very small, but significant, shift in placement of the category boundaries as a function of language set. This proved to be the case for all the subjects regardless of proficiency level. Flege & Eefting interpreted their results as evidence that the procedures they used indeed induced language set effects. Their results showed that subjects' experience with English allowed them to modify their perceptual systems to some degree, however, the shift was very small. In comparing the bilinguals' category boundaries to those of the few monolingual English subjects, it became apparent that the bilinguals did not fully shift to monolingual-like boundaries. This was true, even when the bilinguals were considered very proficient. Flege & Eefting point out that these subjects learned English later in life. Based on other studies (e.g. Flege, 1987; Flege & Eefting 1987b) these researchers hypothesized that younger learners (i.e. those who begin to learn

their second language by ages five to six) may establish new phonetic categories more easily than older learners. Nevertheless, even the small shift in placement of category boundaries revealed that bilingual and monolingual subjects differed, with bilinguals showing evidence of altered categories due to their exposure to a second language. Besides the later exposure of the bilingual subjects to English, the authors speculated that the small shift may have been partially caused by the fact that the /da/ to /ta/ continuum was based on English production and contained long lag VOT tokens which do not exist in Dutch. This may have caused a bias in perception, reducing the bilinguals' need to use two different perceptual sets.

In another study that used synthetic speech, Mack (1989) looked at perception of a /da/ to /ta/ continuum varying in VOT. In this study, Mack focused on differences between monolinguals and bilinguals in particular; perceptual shifting was not addressed. English dominant early French-English bilinguals and English monolinguals were presented an identification and a discrimination task using synthetic speech stimuli (presented on two separate days). English dominance was determined by a combination of self ratings and ratings of the bilingual's production by native listeners of each language. These bilinguals were considered early bilinguals based on the fact that they began learning both languages before age eight.

The results showed only small differences between bilinguals and monolinguals in their perception of this continuum. The category boundaries of both groups were placed at the same point along the continuum. However, in general, the monolinguals showed

a steeper slope at the identification boundary than did the bilinguals, revealing a greater amount of uncertainty in labeling for bilingual subjects. The bilinguals' discrimination of this continuum was also similar to the performance of the monolinguals. It was therefore concluded that early language experience had allowed these English dominant bilinguals to develop near monolingual-like performance, at least in their dominant language, English.

A more recent study by Hazan & Boulakia (1993) returned to the use of natural speech stimuli to look at perception of voicing in French and English. They were interested both in shifts between perceptual sets/contexts in bilinguals, as well as differences between monolinguals and bilinguals. However, Hazan & Boulakia were also interested in how bilinguals perceive specific acoustic cues to voicing, including VOT and F1 onset frequency. They questioned the methods used in earlier studies for inducing a language set or context, particularly the use of nonsense syllables as the basis of a stimulus series.

To study these issues, Hazan & Boulakia created two continua that ranged from /bɛn/ to /pɛn/, both of which are real words in French ("benne" and "penne") and in English ("ben" and "pen"). The endpoints were produced by a male French-dominant bilingual speaker. The two continua were the same except that one had the vowel portion from /bɛn/ and one had the vowel portion from /pɛn/. That is, in one condition, the vowel portion of /bɛn/ was used throughout the continuum, therefore, the lower onset frequency for the F1 transition always indicated a voiced initial consonant, even at the voiceless end of the continuum. In the other continuum, the

vowel portion of /pɛn/ was used throughout, therefore, the higher onset frequency for the F1 transition always indicated a voiceless initial consonant, even at the voiced end of the continuum. Previous studies suggested that the onset frequency of the F1 transition is an important cue in voicing perception for monolingual English listeners, but this cue is less salient for French listeners (e.g. Liberman, Delattre, & Cooper, 1958; Hazan, 1989; Serniclaes, 1987; Simon & Fourcin, 1978).

Hazan & Boulakia expected English listeners to be sensitive to both VOT and F1 onset. Thus, at the end of the continuum in which these cues conflict, English subjects were not expected to identify the stimuli with 100 percent consistency. As well, it was felt that the identification boundaries may be shifted between the two types of continua. Therefore, in the continuum with the /bɛn/ vowel portion used throughout, the /pɛn/ end of the continuum may not be labeled as 'pen' 100 percent of the time and the identification boundary would be shifted due to the increased percentage of 'ben' responses. The opposite would then occur for labeling of the continuum with the /pɛn/ vowel portion. If bilinguals showed similar disturbances in their labeling of the continua with conflicting cues, this would indicate that they had developed the cue weighting associated with processing VOT in English.

In order to assess language set effects, as had earlier authors, Hazan & Boulakia had subjects read and interact in the appropriate language, and included a precursor word from that language, prior to the presentation of stimuli in each of the continua. Thus, four conditions were created; 1) a French precursor word plus a VOT

series with the /pɛn/ vowel portion; 2) an English precursor word plus a VOT series with the /pɛn/ vowel portion; 3) a French precursor word plus a VOT series with the /bɛn/ vowel portion; and 4) an English precursor word plus a VOT series with the /bɛn/ vowel portion. This also provided a way to assess whether subjects would shift labeling as a function of language set. Four groups were tested on identification of the two series in each condition. Subjects included monolingual English and French speakers and two groups of bilinguals, one group that resided in Britain and the other that resided in France. Monolinguals completed a single session, hearing the two continua only in the context that corresponded to their native language. Bilinguals were tested on both series in a French and an English context.

The results revealed three main points. First, as expected, the F1 onset cue caused a much stronger effect on identification in English monolinguals than French monolinguals. Second, bilinguals who were English dominant (dominance was based on the language of early exposure) were more strongly affected by the F1 onset cue than were French dominant bilinguals. These results indicate that language dominance is an issue, at least for the specific cues involved in this study. In particular, Hazan & Boulakia speculated that the presence of the F1 cue is a marked cue[1] and, therefore is evident only in the perception of English dominant bilinguals. Finally, there

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[1] The term 'marked' in this case refers to its status among sounds of the worlds languages. An unmarked cue would be one that is regularly found across languages to indicate a particular phoneme etc. A marked cue would be one that is not usually found. In this case, Hazan & Boulakia speculate that the use of the F1 cue to indicate differences in voicing is not usual in most languages. They further speculate that specific early experience with the F1 cue is needed for it to be used in perceiving differences in voicing.

was a small but significant effect of language set which was more prominent in 'strong' bilinguals, with strength of bilingualism based on assessment of bilinguals' production. This finding is consistent with earlier results (e.g. Elman et al., 1977).

In a recent study, Bohn & Flege (1993) challenged the interpretation of the studies of bilingual categorical perception reviewed thus far. They raised the question of whether the 'language set' effects that had been found by many researchers were in fact due to the use of different language-specific phonetic criteria by bilinguals. These researchers questioned the results found using VOT continua, focusing on studies which examined Spanish/English bilinguals. Bohn & Flege suggested that the shifts in category boundaries labeled as language set effects were similar to shifts found in monolinguals tested on other speech continuum in which the characteristics of the procedure and stimuli were altered. Specifically, they speculated that language set (or context) effects found in previous studies were in fact not an unique property of bilingual phoneme perception and the nature of their phonetic system, but were due to a stimulus 'range' effect. That is, shifts resulted from post-perceptual cognitively based biases rather than the application of phonetically based categorical criteria. A 'range effect' is an effect that alters labeling due to changes in the range of stimuli that are presented in a particular condition.

The authors based their hypothesis on previous studies which examined such range effects (e.g. Lisker, 1970; Ades, 1977; Rosen, 1979; Brady & Darwin, 1978). For example, Brady & Darwin (1978) were able to change the point at which the boundary was placed by

English monolinguals by varying the range of VOT values that were presented to these subjects. The magnitude of the shift found in this study was very similar to the magnitude of the shifts that have been attributed to language set effects. Due to these findings, Bohn & Flege suggested that a range effect may be caused by the acoustic/phonetic characteristics of the materials used to induce language set, rather than through processing of the stimuli based on language set.

In order to examine this issue, Bohn & Flege tested three linguistic groups: monolingual Spanish speakers, monolingual English speakers, and Spanish/English bilinguals, with all three groups being tested in both language contexts. While previous studies had included monolingual groups, these groups had only been exposed to the language context that corresponded to their native language. Bohn & Flege reasoned that if the findings of previous studies could be explained by a range effect rather than by bilinguals' language experience, then monolinguals as well as bilinguals would show a perceptual shift as a function of language context.

The authors formulated their first experiment to confirm that range effects could be shown in both monolinguals and bilinguals. In this first study Spanish/English bilinguals, English monolinguals, and Spanish monolinguals were tested. Consonant-vowel stimuli, excised from naturally produced whole words, were used (e.g. 'ta' from 'tall'). The subjects' task was to label nine consonant-vowel stimuli beginning with Spanish /t/ (produced with a short-lag VOT) as either /t/ or /d/. This was done in two 'phonetic' contexts. In one condition listeners identified the nine tokens when they were

presented along with English /d/ tokens, also produced with a short-lag VOT. In another condition the nine Spanish short lag VOT /t/ tokens were presented along with English /t/ tokens (produced with a long-lag VOT). Results showed that all three groups labeled the Spanish short lag VOT tokens as /t/ more often when presented along with English short lag /d/ VOT tokens than when they were presented along with English long lag /t/ VOT tokens. Since both monolinguals and bilinguals showed the same patterns of results in this experiment, Bohn & Flege questioned whether the language set effects found in earlier studies can be taken as evidence for bilinguals' use of separate phonetic criteria from each of their languages. The authors point out that the materials used to induce language context in earlier studies often had phonetic elements that could induce similar range effects.

To address this issue, a second experiment was conducted which provided a direct test of the hypothesis that range effects can be induced in both monolinguals and bilinguals by manipulating the carrier phrase. Confirmation of this hypothesis would indicate that something other than switching between phonetic criteria can explain the shifts in boundary placement found in earlier studies of bilingual categorical perception. This study consisted of two contexts that all groups were exposed to. Subjects included a monolingual English control group and two bilingual groups, one group who had acquired both languages early and one group who had acquired their second language later. The two bilingual groups were included because earlier findings indicated that language set effects were larger for early learners of a second language than later learners

(this however, did not prove to be the case for this study). In this second study, the Spanish short lag VOT tokens used in the first study were presented in a carrier phrase. In one condition the carrier phrase was English, while in the other condition the carrier phrase was Spanish. In each condition questions from that particular language were also interspersed with the test stimuli. Bilinguals were required to respond to the questions in both languages; monolingual English speakers responded to questions in English, and placed a check mark on their response sheet when they had heard a question in Spanish.

Results from this study showed that both bilinguals and monolinguals labeled the Spanish short lag VOT stimuli differently depending on the language context. Specifically, all three groups labeled Spanish short lag /t/ tokens as /d/ more often in the English condition than in the Spanish conditions. The authors felt it was unlikely that this context effect was due to the use of language-specific phonetic criteria since this effect was evident in monolinguals as well as bilinguals. Bohn & Flege concluded that the phonetic elements contained in the carrier phrases, words, and conversation used to induce 'language set effects' may produce context effects which are not necessarily attributed to language specific phonetic processing. Thus, the processes underlying a 'language set' effect cannot be clearly established in studies which do not include monolingual subjects.

Bohn & Flege did not entirely discount the effects of language experience as they did find general differences between monolingual groups (i.e. Spanish monolinguals labeled Spanish short lag VOT

tokens as /t/ more often, whereas English monolinguals labeled them as /d/ more often). Rather, they propose that both language specific factors and post-perceptual processes play a role in phoneme perception. Nevertheless, this study forces researchers to consider a broader range of factors in the interpretation of results and to recognize the importance of including monolingual subjects in studies of perceptual switching.

Summary

The small group of studies discussed here comprise the body of research on bilingual phoneme perception. Although thought on speech perception has progressed as each group of results has been presented, this research has given rise to as many questions as it has answered. Firstly, since the focus has almost solely been on the VOT acoustic cue, caution must be taken when applying any of the conclusions based on this cue to other aspects of speech perception. There is already some evidence that other acoustic dimensions and/or other classes of speech sounds may reveal a different pattern of results than those typically found with VOT stop consonant continua. For example, as described earlier, Mack (1989) found only very minor differences between bilinguals and monolinguals in their identification of a VOT series that ranged from /da/ to /ta/. However, clear differences were observed when these same subjects were tested on identification of an English vowel continuum that ranged from /i/ to /ɪ/.

Other issues have also arisen with such factors as language dominance, strength of bilingualism, interaction between test stimuli and language set inducing materials, and individual differences, all

affecting the results of bilingual categorical perception tasks. As each factor is assessed, the interpretation of results in terms of the similarities and differences between bilingual and monolingual processing can change, and this is also true for assessing the existence and nature of bilingual perceptual shifting. Furthermore, the meaning of the 'language set' effects that have been observed has recently come into question (e.g. Bohn & Flege, 1993).

Still, these studies do reveal some answers to questions that researchers have asked with regard to bilingual speech perception. First of all, there is evidence that there are significant differences, as well as similarities between monolingual and bilingual categorical perception and these can be highlighted or minimized depending on the factors mentioned above (e.g. language dominance, strength of bilingualism, etc.). Secondly bilinguals can accommodate both the similarities and the differences of their two languages (e.g. they can develop the cue weighting used in only one of their languages (Hazan & Boulakia, 1993)); however, true and complete perceptual set switching has not yet been firmly established. Thus, the final conclusion can only be that it is worthwhile, and necessary, to continue this line of research in order to study how various factors affect processing, particularly in terms of categorical perception, as well as what this reveals about the nature of speech perception in general.

Speech Processing in Bilinguals

Speech processing in bilinguals has also been investigated within the psycholinguistic tradition. The work emerging from this perspective has explored the cognitive mechanisms involved in language processing, often relying on measures of processing time as a dependent measure. This contrasts with speech perception studies reviewed in the previous section which have focused on what listeners perceive, typically utilizing identification and discrimination measures to assess perception. This section begins with an overview of bilingual speech processing research, and then focuses on several studies which have examined the role of the acoustic/phonetic properties on perception of code-switched words in bilinguals. This section concludes with a detailed discussion of the study that serves as the primary impetus for the present research.

Background

The central issue underlying speech processing studies is whether bilinguals possess a single unified language processing system, which is used for both languages, or whether they have two separate processing systems, one for each language. A related question is whether or not bilinguals can demonstrate monolingual-like performance in one or both of their languages. For an overview of research on language and speech processing in bilinguals see Keatley (1992) and Vaid (1986).

Considerable support for the dual system hypothesis has been found in many studies. The dual system has been revealed by a range of studies which have focused on different levels of processing using various types of processing tasks and measures

(e.g. Macnamara & Kushnir, 1971; Altenburg & Cairns, 1983; Blair & Harris, 1981; Preston & Lambert, 1969). Along with providing evidence for the availability of two linguistic systems to the bilingual, many researchers have found that bilinguals can, in certain circumstances, perform as a monolingual in both their languages. One exception to this is found in studies of speech segmentation, in which it appears that bilinguals can only use the type of speech segmentation strategy associated with their dominant language, and therefore, can only obtain monolingual-like performance in that language (Cutler, Mehler, Norris, & Segui, 1993).

The discovery that most evidence points toward the existence of two linguistic systems prompted interest in the status of these two language systems during on-line speech processing. This literature began to compare the processing of bilinguals in a monolingual mode (i.e. when the each of the bilingual's languages is presented separately for processing) and in a bilingual mode (i.e. when the two languages are mixed together when presented for processing). This research questioned whether the two systems were active together during processing (i.e. the interaction hypothesis (Blair & Harris, 1981; Preston and Lambert, 1969)), or whether one language was selectively deactivated when processing occurred in the other language (i.e. the independence hypothesis (Macnamara & Kushnir, 1971)).

The support for the idea that the two systems are independent has, thus far, been weak. If there were two independent systems then one language must be completely deactivated during the processing of the other. If this were the case one would expect that

bilinguals and monolinguals would need the same amount of time when processing in the monolingual mode, and that bilinguals would always be slower when processing in the bilingual mode. Some research on bilingual speech perception, which is discussed below, has shown that this in not true, and that, at least at some times, the two systems are active together.

Interaction between the two systems, as suggested by the interaction hypothesis, has been supported by a number of studies (e.g. Altenburg & Cairns, 1983; Blair & Harris, 1981; Preston & Lambert, 1969). Some of these studies provide data showing bilinguals to be slower than monolinguals when processing in a monolingual mode, which has led researchers to conclude that there is interference from the second language. It has even been shown that the bilingual's weaker language can interfere with processing in their dominant language under certain circumstances (e.g. Preston & Lambert, 1969). Alternatively, bilinguals have been shown to be faster than monolinguals when processing monolingual passages in those cases when the interference from the other language assists processing (e.g. Blair & Harris, 1981). Furthermore, some studies (as in Grosjean, 1988) have also revealed that bilinguals are not always faster when processing in a monolingual mode than they are when they are processing in a mixed language (or bilingual) mode.

Overall, the findings indicate that in bilinguals the impact and amount of interaction/interference between the two languages depends on the level of language processing that is examined (e.g. semantic, lexical, syntactic, phonotactic, phonetic, etc.), the way in which language processing is assessed (e.g. using written versus

spoken language and the type of response required), as well as, the nature of the subject pool (i.e. the degree and dominance of the bilinguals). Thus, speech processing in bilinguals has been shown to be a complex task with many variables influencing the processing of mixed language input at each level of processing (see Grosjean, 1995 for more details regarding some of these variables). Researchers studying speech processing in bilinguals, particularly those interested in the processing of mixed language, or code switches, have begun to look at the factors that affect specific levels of processing in detail in an attempt to define their impact more fully.

Bilingual Code-switching

An interest in factors that influence processing in bilinguals prompted Grosjean and colleagues to examine how phonotactic and acoustic/phonetic properties of code-switched words affect their recognition and processing by bilinguals (Grosjean & Soares, 1984; Grosjean, 1988, Burki-Cohen, Grosjean, & Miller, 1989; see also Grosjean & Soares, 1986 for a review). This work is described in detail as it has particular relevance to the present thesis, in that it focuses specifically on the processing of segmental speech units in spoken language. In addition, a study by Burki-Cohen et al. emerging from this research employs the categorical perception paradigm and, thus, makes it possible to link studies of speech processing and speech perception more directly. The present thesis builds directly on the Burki-Cohen et al. study.

Grosjean & Soares (1984) delved into bilingual processing of code-switched words and the factors that influenced this. They presented stimuli to bilinguals in both a 'monolingual mode' (that is,

where the bilingual is presented utterances in only one of their two languages) and a 'bilingual mode' (where the bilingual is presented a mixed language utterance, in this case a single code-switched word).

Grosjean & Soares used a phoneme triggered lexical decision task and measured reaction time during on-line processing. Bilingual subjects were presented with sentences that were in the monolingual mode or in the bilingual mode; monolingual subjects were presented with English sentences only. Subjects were required to listen for a particular phoneme within the sentences. This phoneme indicated that they had to decide whether the word the phoneme was within was a word or a non-word.

Results showed that bilinguals were always slower than monolinguals when the target phoneme was within a non-word, regardless of the language mode (bilingual/code-switched or monolingual). Additionally, bilinguals took longer when judging a code-switched word in the bilingual speech mode (i.e. when the base-language[2] and the target word were not from the same language) than a base-language word in the monolingual mode (i.e. when the base-language and the target word are the same). These results were explained by the authors in terms of two assumptions. Firstly, bilinguals appeared to search both lexicons when confronted with a non-word, regardless of language modality. Secondly, bilinguals appeared to search the base-language lexicon before the alternate language lexicon when confronted with a code-switched

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[2] The base language is defined as the language that is being used for the majority of the utterance/conversation that is being presented to and/or used by bilinguals. Thus, code-switched words are words from the other language which are brought in occasionally (or purposefully as is the case in code-switching research).

word, which suggests that the base-language produces an assimilation effect.

While these types of lexicon searches appeared to be the norm for this study, the authors suggested that many things can affect how bilinguals conduct a lexical search during processing. For example, from Grosjean's previous research with monolinguals (Grosjean, 1980) and from studies by other researchers (e.g. Preston & Lambert, 1969; Altenburg & Cairns, 1983), they predicted that the greater the acoustic/phonetic difference between the two languages for a given acoustic pattern, the smaller the difference between monolinguals and bilinguals on response time associated with judgments of lexical status. Furthermore, it was felt that words that violate the phonotactic rules of the non-base language would be reacted to quickly, since a search of the alternate language lexicon would not be necessary.

To study these possibilities further, Grosjean used the Gating paradigm (Grosjean, 1988) to look at bilingual lexical access. The Gating paradigm had first been used by Grosjean in a study with monolinguals (Grosjean, 1980). While focusing on issues of lexical access, he discovered that the acoustic/phonetic make-up of words presented to monolingual subjects in the Gating paradigm clearly interacted with the phonotactic and semantic context in which they were presented. In this paradigm, subjects were presented successively longer portions of target words over various 'passes'. These are either presented in isolation or within the context of a phrase or sentence. Grosjean discovered that to clearly identify a word with certain initial consonants, subjects needed more of the

acoustic signal (i.e. needed further 'gates') than a word with other initial consonants. Subjects could also identify words more easily (i.e. at earlier 'gates') if the words were heard in the context of a phrase or sentence. These findings suggested that the acoustic/phonetic patterns of some phonemes are more likely than others to interact with the semantic or phonotactic context provided by the carrier phrase.

In the study particular to bilinguals (Grosjean, 1988), French-English bilinguals were presented words that were phonotactically possible in only one of their two languages, and words that were language neutral, i.e. were phonotactically possible in either language. The results of this study revealed that whenever a word could be phonotactically assigned to either of a bilingual's two languages, at early gates bilinguals were more likely to identify the word as belonging to the base language. In other words, for these stimuli, a lot more of the word had to be heard before it could be accurately assigned to the appropriate language. That is, for words whose phonotactics were permissible in both languages, there was an assimilation effect to the base language. On the other hand, when the word was phonotactically possible in only one language, bilinguals were able to accurately identify it at very early gates, particularly when the language of the word and the base language did not match. That is, for words that were phonotactically appropriate for only one language a 'contrastive effect' of the base language was found.

Categorical perception and base language effects

In an effort to look at base language effects in a different way, Grosjean and his colleagues used the categorical perception paradigm. A study by Burki-Cohen, Grosjean, & Miller (1989) (on which the present thesis builds) was designed to assess more directly whether the acoustic/phonetic properties of a target word interact with the base language in the perception of bilinguals.

Two continua were created in which one endpoint was an English word and the other a French word. One continuum was considered 'language-neutral'. In this series the endpoints were French and English words ('day' in English and 'de' in French) that began with an initial consonant that has similar, but not identical acoustic/phonetic characteristics in both languages. The other continuum was considered 'language-contrastive'. In this series the endpoints were French and English words ('ray' in English and 're' in French) that began with an initial consonant that has quite distinct acoustic/phonetic properties in each language. The English word 'ray' begins with a lateral /ɹ/, produced by curving back the tongue or bunching it up while voicing and allowing the air to escape freely around the sides, creating a periodic sound. The French word 're' begins with an uvular fricative /ʁ/ produced with the back of the tongue against the uvula which causes the air to be forced through a small constriction, creating an aperiodic sound which accompanies the voicing of this phoneme. Thus, these sounds are quite different, both articulatorily and acoustically. Nevertheless, these sounds have an underlying functional equivalency and are typically substituted

for one another in French-accented English, and English-accented French.

Burki-Cohen et al. first had to ensure that these cross-language continua were heard categorically, that is, at a certain point along the continua, subjects perception shifted from identifying the stimuli as English to identifying them as French. Subjects were French dominant late (or successive) bilinguals, in that all had acquired French as their first language and learned English later in life, after age 12 or older. They were tested using both a discrimination and identification task to determine if the continua were perceived categorically. This experiment revealed that bilingual subjects indeed perceived the continua categorically, much as monolingual subjects perceive within-language continua.

In a second experiment each of these continua were placed within the context of each language (i.e. at the end of an English or French carrier phrase). In this case the carrier phrase in English was 'We have to categorize _____' and the French carrier phrase 'Il faut qu'on categorise _____' . By presenting each series in a French and an English context it was possible to examine how the phonetic characteristics of the stimuli interacted with the language of the carrier phrase (i.e. the base language).

Burki-Cohen et al. predicted that perception of the 'language neutral' continuum ('day to de') would be affected by the base language such that subjects would <u>assimilate</u> the stimuli to the base language especially for stimuli near the category boundary. Thus, they predicted that in the English context, the category boundary would be closer to the French end of the continuum (i.e. more stimuli

categorized as an English word), while in the French context, the category boundary would be closer to the English end of the continuum (i.e. more stimuli categorized as a French word). Their results failed to show an assimilation effect for this 'language neutral' continuum ('day to de'); that is, the category boundary did not shift according to the language context in which it was presented, although this assumption was predicted based on previous work (e.g. Grosjean, 1988; Grosjean & Soares, 1984).

For the 'language-contrastive' continuum ('ray to re' series), Burki-Cohen et al. hypothesized that bilinguals would tend to place their category boundaries closer to the end of the continuum that was associated with the base language of presentation. That is, when the base language was English, more French stimuli would be heard, and in the French context, more English stimuli would be heard. These results would demonstrate a contrastive effect. This hypothesis was confirmed, as the category boundary shifted according to the language context in which it was placed. This result verified that the acoustic/phonetic make-up of the target word interacted with the base language in the perception of bilinguals.

The authors offer three possible explanations for the lack of an assimilation effect in the language neutral continuum. Firstly, they suggest that it is possible that, because the 'day to de' series they developed had a larger step size (compared to the 'ray to re' series), an assimilation effect was masked. The authors discount this possibility since the number of stimuli that were labeled ambiguously was the same in both series, in spite of the step-size differences. This allowed an opportunity for the base-language to

affect the same number of stimuli. A second, more likely possibility suggested is that the assimilation and contrast effects arise at different points in processing. Therefore, a categorical perception paradigm and other paradigms that had previously revealed an assimilation effect (i.e. the gating paradigm (Grosjean, 1988)) may not be equally sensitive to each effect.

The third and final suggestion raised was the possibility that the subjects ignored the carrier phrase. This could have been due to the nature of the categorical perception paradigm which forces a choice between only two alternatives, whereas previous studies used paradigms in which any number of responses were possible. This coupled with the fact that the carrier phrase remained stable may have allowed subjects to selectively attend to certain acoustic/phonetic information while ignoring the carrier phrase. Additionally, the code-switched words always occur at the same point in this paradigm. This may also have allowed the subjects to ignore the carrier phrase. The authors remained unsure as to why this had not occurred with the 'language contrastive' series as well.

Findings that were reported in the speech perception literature review suggest two additional explanations for Burki-Cohen et al.'s results. Several studies suggest that language set effects were more prominent in balanced or early bilinguals (e.g. Mack, 1989; Flege & Eefting, 1987a). In Burki-Cohen et al.'s study, late bilingual subjects were tested. Bilinguals who began learning their second language very early in life may show different patterns.

Secondly, issues raised by Bohn & Flege (1993) in the speech perception literature suggest the possibility that characteristics of

the carrier phrase (or base language) may affect the identification of the stimuli in ways that have nothing to do with processing the carrier phrase as meaningful language. That is, the carrier phrase may still interact with the target (or code-switched) word, but not on a meaningful linguistic level. Thus, it is possible that the contrastive base-language effects observed by Burki-Cohen et al. can be explained on the basis of processing mechanisms which are not particular to bilinguals. This issue cannot be addressed by the Burki-Cohen et al. study since only bilingual perception was tested. Further, it may be that the stimuli in each condition ('ray' to 're' verses 'day' to 'de') are not equally sensitive to the effects of the preceding carrier phrase. A comparison of monolinguals and bilinguals would also clarify this issue. Thus, there is a need to explore further the conditions under which language 'assimilation' and 'contrastive' base language effects occur to clarify the nature and the meaning of these effects.

Goals of the present study

The proposed study builds on research by Burki-Cohen et al. and aims to address two questions. Firstly, can the identification patterns reported by Burki-Cohen et al. be attributed only to the effects of bilingualism on speech processing?. Secondly, are there differences in the processing operations that monolinguals and bilinguals engage in to identify a bilingual speech continuum?

The present study will address the first question by comparing bilingual (French/English) and monolingual (anglophone and francophone) listeners' identification of the same stimuli used by Burki-Cohen et al. Additionally, the bilingual subjects in this study are those considered 'early' bilinguals, that is, those who began to learn both languages before age five. Some researchers have suggested that the effects of bilingualism are more prominent in early bilinguals (Flege & Eefting, 1987a; Mack, 1989).

Recall that in Burki-Cohen et al., bilinguals showed two patterns of identification responses. When bilinguals were presented a 'language-contrastive' stimulus series (the 'ray' to 're' continuum) a contrastive effect of base language was observed. For example, when the base language was English, more stimuli at the category boundary were identified as the French word 're', and in the French context, more stimuli at the category boundary were perceived as the English word 'ray'. However, when bilinguals were presented with a 'language-neutral' stimulus series (the 'day' to 'de' continuum), no effect of base language was observed, although an assimilation effect had been predicted. It was concluded that the base language effects in categorization of a bilingual stimulus

continuum depended on the acoustic/phonetic nature of the code switched words. While Burki-Cohen et al.'s data are entirely consistent with this conclusion, it is possible that their findings do not uniquely reflect bilingual language competence. For example it was found by Bohn & Flege (1993) that the language context effects found in other categorical perception studies may not have been due to processing the two languages as meaningful linguistic codes, but may in fact have been due to more general speech perception capacities. To test this hypothesis categorization of each series used by Burki-Cohen et al. ('ray to re' and 'day to de') will be examined as a function of the base language (i.e. French versus English) in three subject groups, monolingual francophones, monolingual anglophones, and early French /English bilinguals.

As in the Burki-Cohen et al. study, this hypothesis will be evaluated using category boundary as the dependent variable to compare where boundaries are placed in each language context for each group. If the effects found in Burki-Cohen et al. are specific to bilingual processing, as was concluded in that study, then monolinguals and bilinguals are expected to respond differently to a change in the carrier phrase. Accordingly, an interaction between group and language context is expected.

If general perceptual abilities are responsible for the effects found in the Burki-Cohen et al. study, as this thesis proposes, then language context effects are expected to be the same for both the monolinguals and the bilinguals. Specifically, for the 'ray to re' series an effect of base language consistent with a contrastive effect is predicted for both monolinguals and bilinguals. Accordingly, a

significant main effect of language context and no significant interaction between group and language context is expected. That is, both monolingual and bilingual subjects are expected to label more stimuli as 'ray' in the French context than in the English context (and vice versa more 're' in the English context than in the French context). For the 'day to de' series no language context effect is expected to be found for either monolingual or bilinguals, replicating the results of Burki-Cohen et al. As well, no interaction between group and language context is expected.

To address the second question (are there differences in the processing operations that monolinguals and bilinguals engage in to identify a bilingual speech continuum?), group differences will be analyzed with respect to three dependent variables: category boundary, response time, and the slope of the identification function at the category boundary. These measures assess differences across the three subject groups in the weighting of acoustic information, differences in processing time, and differences in the relative confidence level of subjects in the labeling of the series, respectively.

An analysis of group variations in location of category boundary may reveal differences in how each group labels the stimuli at the category boundary. That is, due to language experience each language group may not weight the acoustic information in the same way. Accordingly, this outcome can reveal differences between the bilinguals, French monolinguals, and English monolinguals which point to differences in perception due to linguistic experience.

Response time is another way to view differences in bilingual and monolingual processing. Although identification patterns may be the same across groups, response time may reflect differences in the processes utilized within each group. Fluctuations in response time can reflect when, and with what stimuli, processing is more complex. Complexity of processing, including interference, etc. has been equated with longer response times in studies of language processing for some time (e.g. Altenburg & Cairns, 1983; Blair & Harris, 1981; Preston & Lambert, 1969).

Response time will be measured (in milliseconds) from the onset of the target word in the identification task. For each series, response time to a stimulus token consistently labeled as English, a stimulus token consistently labeled as French, and an ambiguous stimulus near the category boundary will be compared. It is predicted, for all groups in both series, that response time will be shorter for stimuli that are consistently labeled in the same way (i.e. clear English and clear French) compared to those stimuli that are not consistently labeled (i.e. ambiguous stimuli). In addition, to the extent that bilingualism complicates the categorization of the stimulus series (i.e. increases uncertainty), response time is expected to be slower for bilinguals than for monolinguals, particularly for ambiguous stimuli. That is, categorization of ambiguous stimuli may be more difficult for the bilingual than the monolingual since they must sort out the acoustic properties of two languages, rather than simply comparing stimuli to a single perceptual pattern. Alternatively, to the extent that familiarity with both languages

facilitates categorization of the stimulus series, response time is expected to be faster for bilinguals than monolinguals.

Analyzing the slope of the function at the category boundary may also uncover between group differences, even if their category boundaries have fallen at the same point. This dependent variable taps the relative confidence (certainty versus uncertainty) of the subjects in their labeling responses. Steep slopes reflect a higher degree of certainty in labeling, whereas, less steep slopes are associated with a lower degree of certainty (e.g. Mack, 1989; Caramazza & Yeni-Komshian, 1974). That is, if subjects have well defined categories for each category endpoint, then the shift from labeling stimuli as English to labeling them as French will be quick with very few ambiguous stimuli, resulting in a steep slope in the identification function at the category boundary. When one or both categories are not well defined, subjects may be less confident in their labeling responses, resulting in a gradual shift from labeling the stimuli as English to labeling them as French and, therefore, a shallow slope in the identification function at the category boundary.

Slope will be calculated by linear regression. For each series, slope will be compared across groups for each condition. Interpretation of these data is similar to that of response time. That is, to the extent that bilingualism complicates the categorization of the stimulus series (i.e. increases uncertainty), bilinguals are expected to have more shallow slopes at the category boundary compared to monolinguals. Again, this pattern would suggest that categorization of ambiguous stimuli is more difficult for the bilingual than the monolingual subjects since they must sort out the acoustic

properties of two languages, rather than simply comparing stimuli to a single perceptual pattern. Alternatively, to the extent that bilingualism facilitates categorization of the stimulus series, bilinguals may show steeper slopes than monolinguals.

It is difficult to make specific predictions regarding how group differences in response time or slope may interact with effects of language context since this is the first study to utilize these dependent variables to evaluate perception of a cross-language continuum. Nevertheless, analysis of these dependent variables may be very informative. Patterns of response time and slope steepness at the category boundary may parallel patterns in categorization, thus providing converging evidence for interpretation of base language effects. Diverging patterns for response time and slope measures across subject groups may point to differences in processing operations underlying the perception of bilinguals and monolinguals.

Method

Subjects

Thirty normally hearing adults participated in this study; ten monolingual Canadian French speakers, ten monolingual Canadian English speakers, and ten bilinguals who speak both of these languages. Subjects were recruited from ads in local university and community newspapers and via ads posted in CEGEPS[3] and universities in Montreal. Subjects were paid to attend a single one hour session.

The monolingual anglophone group included adults with little or no experience with any language other than English. They had no experience with French beyond elementary or secondary school language classes and have resided in Montreal for less than four years, during which time they did not use French in their daily lives. This group was composed of three males and ten females ranging in age from 18 to 28 years (with a mean of 22 years). The monolingual francophone group included adults who had little or no experience with any language other than French. These subjects had no more than elementary, secondary, or CEGEP English classes and had never used English on a regular basis in their daily lives. This group was composed of five males and five females, ranging in age from 19 to 40 years (with a mean of 24 years). Bilingual subjects in this study were early bilinguals, i.e. adults who gained regular exposure to both French and English before age five. Early bilinguals were used

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[3]CEGEP refers to the level of schooling after high school which leads to a diploma, or to entrance into university. As an institution, it is found exclusively in Quebec.

because of suggestions in the literature that the effects of bilingual processing may be more evident with these individuals (e.g. Mack, 1989, Flege & Eefting, 1987a). A further requirement included consistent use of both languages in their daily routine throughout most of their lives. This group was composed of two males and ten females, ranging in age from 20 to 33 years (with a mean of 25 years).

Monolingual subjects were screened over the phone and with a language questionnaire designed to ensure they fit one of the above monolingual groups. (See Appendix A). Although also screened by phone, bilinguals completed a more detailed language questionnaire upon arriving at the lab (Appendix B) which included questions to assess their proficiency in each language. Proficiency was primarily determined through self-rating scores. These scores were used since subjects' self rating has been found to be highly correlated with more formal methods/tests used to assess language proficiency (e.g. Macnamara, 1967; Fishman & Cooper, 1969). While the present study was not designed to assess effects of language dominance, this information was gathered for analysis of its possible effects. Language dominance was based on subjects' responses to the question regarding their language preference (see Question 10 in Appendix B). This preference has been found to be an important predictor of language dominance in previous research (e.g. Cutler et al., 1992). Table 1 provides a summary of the information obtained from bilingual subjects.

As can be seen from Table 1 all bilingual subjects had a very balanced exposure to their two languages. Seven out of the ten

Subject #	Language of Formal Education		Language(s) In Home		Self Rating English		Self Rating French		Language
	English	French	English	French	Speaking	Comprehension	Speaking	Comprehension	Preference
1	+	+	+	+	10	10	9	10	English
2	+	+	–	+	9	10	10	9	French
3	+	+	+	+	10	10	9	10	English
4	+	+	+	–	10	10	10	10	English
5	+	+	+	+	10	10	8	10	English
6	+	–	–	+	10	10	10	10	English
7	+	+	+	+	6	7	6	7	English
8	+	–	+	+	7	6	6	5	English
9	–	+	+	+	7	7	5	6	English
10	–	+	+	+	7	7	7	7	Either

Table 1: Description of bilingual group. Note: Subjects 1-6 used a rating scale from 1 to 10
Subjects 7-10 used a rating scale from 1 to 7

subjects had used both languages in the home. The remaining three subjects (two, four, and six) were exposed to only one language at home but had extensive schooling in the other language. Six out of ten subjects had formal education in both languages, and where education was in one language only (subjects six, eight, nine, and ten), the other language was used extensively in the home. Subjects one through six in the bilingual group rated their proficiency in comprehension and speaking of both English and French on a scale from one to ten (a rating of one was equated with no facility, while ten was equated with facility 'like a native speaker'). Of these six subjects, five rated themselves as nine or ten. The sixth subject (subject eight) rated herself as eight in spoken French, but the rest of her profile showed that she had a good deal of formal education in French. Due to an error in translation of the language questionnaire, subjects seven through ten rated themselves on a scale from one to seven (a rating of one was equated with no facility, while seven was equated with facility 'like a native speaker'). All four subjects rated themselves as six or seven in English. One subject (subject nine) rated herself as five in spoken French, however, it must be noted that she had all of her formal education in French and also spoke French with her mother in the home, making it likely that she under-rated her proficiency in French.

Finally, bilinguals were questioned on their language preference (as an indication of language dominance) in several ways. The question reflected in this table was one which attempted to avoid the influence of the political and cultural implications of the choice of one language over the other, if indeed this is actually

possible. Subjects were asked to indicate which language they would want a second person to speak if they were stranded on a deserted island with only that one other person. Eight out of ten subjects indicated English, one subject indicated French, and one subject expressed no preference. Overall then, this group of bilinguals can likely be considered English dominant, even though they were fairly balanced in proficiency.

Stimuli

Two sets of speech stimuli developed by Burki-Cohen et al. (1989) were employed in this study. Burki-Cohen et al. chose a minimal word pair in which the initial consonant is phonetically similar in both French and English (a 'language-neutral' pair), and a minimal word pair in which the initial consonant is phonetically distinct (a 'language-contrastive' pair). For the 'language-neutral' pair, Burki-Cohen et al. chose the English word 'day' and the French word 'de' (meaning thimble, or dice). For the 'language-contrastive' pair the English word 'ray' and the French word 're' (a musical note) were chosen. A series of stimuli was then created using each word pair. Each of the continua was embedded in the English carrier phrase 'We have to categorize _____', and the French carrier phrase, 'Il faut qu'on categorise _____', so that the effects of language context in categorization of each series could be assessed. A male British English and Parisian French accent-free bilingual produced ten tokens of the English carrier phrase with the English word 'day' and ten with the English word 'ray'. The determination of 'accent free' was made through ratings of the speaker by monolingual peers who spoke each of the languages. The speaker then did the same with the

French carrier phrase for the two French words ('de' and 're'). Each production was digitized for measurement and manipulation.

The length of time in milliseconds from the beginning of the sentence to the onset of the target word, the length of time from the onset of the target word until the vowel, and the length of the transition from the consonant to the vowel were all measured. For each sentence type (the English sentence with 'day' and again with 'ray' and the French sentence with 're' and again with 'de'), one sentence was selected which was closest to the average on all of these measures. Four sentences were therefore used to construct the two series. The target word in each of these sentences was then spliced out and the four words were used to construct two stimulus series 'ray to re' and 'day to de'.

To create the 'language neutral' ('day to de') series, Burki-Cohen et al. had chosen words so that the consonants, as well as the vowels, were similar in quality. For example, although the consonant /d/ in French and English tends to be produced in different places, that is, as on the back of the teeth (dental) and on the alveolar ridge respectively, these two realizations of /d/ occur often in both languages (Ladefoged, 1975). It was therefore concluded that this difference would not likely be a perceptually salient one. The consonants as realized in French and English can also differ in the amount of pre-voicing they are produced with; again this was considered to be a nominal concern as amount of pre-voicing also varies within both languages (Ladefoged, 1975). Furthermore, the vowels were similar in quality as the vowel in the English word 'day' was not produced as a diphthong.

To create the 'day to de' series Burki-Cohen et al. first truncated the vowel in the English endpoint 'day' to make it exactly twice the length of the French endpoint 'de'. Over the course of the continuum increasingly longer segments of the beginning of the word 'day' were replaced with increasingly longer segments of the beginning of the word 'de', until 100% of 'day' was replaced with 100% of 'de'. Since 'day' was twice as long as 'de', for approximately every 20 ms removed from 'day', approximately 10 ms were inserted from 'de'. Cuts were made at zero crossings on the wave form. The continuum was altered in 16 steps, and contained 17 stimuli. Once the series was completed, each of the stimuli was spliced back into both the carrier phrases resulting in two conditions for the one series (i.e. English 'day to de' and French 'day to de'). Illustration of the development of the continuum is contained in Table 2[4].

Stimulus	
1	0ms 'de' (0%) + 318ms 'day' (100%)
2	10ms 'de' + 298ms 'day'
3	20ms 'de' + 278ms 'day'
...	continued
17	159ms 'de' (100%) + 0ms 'day' (0%)

[4] The figures provided in this table and Table 3 are not exact, as such figures were not provided by Burki-Cohen et al. They do however, illustrate the development of the continua.

Table 2: Description of the 'language-neutral' continuum ('day to de').

For the 'language-contrastive' word pair ('ray' and 're'), Burki-Cohen et al. also chose words that were similar in vowel quality, however, the initial consonants were quite different. The English word 'ray' begins with the semi-vowel /ɹ/, which does not appear in French. Conversely, the French word 're' begins with the uvular fricative /ʁ/, which does not exist in English. In spite of the clear phonetic differences in these two phonemes, they do have functional equivalency for listeners from each language. For example, speakers of English will often replace the uvular fricative /ʁ/ with the semi-vowel /ɹ/ from English when trying to imitate a French word containing that sound, and the opposite typically occurs with French speakers imitating the English semi-vowel /ɹ/.

To create this continuum, increasingly longer segments of the beginning of the word 'ray' were replaced with increasingly longer segments of the beginning of the word 're' until the initial 49% of the English word 'ray' was replaced with the initial 50% of the French word 're'. Since 're' was only 75% of the length of 'ray' for approximately every 13.5 ms of 'ray' that was deleted, approximately 10 ms of 're' was inserted. Again, cuts were made at zero crossings on the wave form. The continuum changed over 11 steps creating 12 stimuli in total. Although unaltered 'ray' was used as the English endpoint, the original 're' was not used as the French endpoint, however, the endpoint used was always perceived as the French word 're' (it is not clear why Burki-Cohen et al. did not choose to use the 100% 're' token, although it may have been too short). Upon completion, each stimulus from the series was spliced back into

the context of both carrier phrases, creating two conditions (i.e. English 'ray' to 're' and French 'ray' to 're'). Illustration of the development of the continua is contained in Table 3.

Stimulus	
1	0ms 're' + 299ms 'ray' (0%) (100%)
2	13ms 're' + 282ms 'ray'
3	21ms 're' + 272ms 'ray'
...	continued
12	112ms 're' + 149ms 'ray' (50%) (49%)

Table 3: Description of the 'language-contrastive' continuum ('ray to re').

To test subjects in Montreal, a tape recording of the completed stimuli was provided. Stimuli and carrier phrase were digitized (20,000 Hz, low pass filtered at 9800 Hz) from the tape using a Sony TC-K81 stereo cassette tape deck. Bliss software (Mertus, 1990) was used to edit the stimuli so that each 'carrier phrase plus target word' token was contained in its own filename in computer storage.

Design

Each subject was tested in four conditions: 1) the 'day to de' series with a French carrier phrase, 2) the 'day to de' series with an English carrier phrase, 3) the 'ray to re' series with a French carrier phrase, and 4) the 'ray to re' series with an English carrier phrase. Within each subject group these four conditions were counterbalanced so that each subject received a unique order. To do

this ten combinations of the four conditions were chosen from the 24 possible combinations (See Appendix C for order assignment of subjects).

Procedure

Subjects participated in a 2-item forced choice identification task. They responded by pressing one of two buttons on a computer mouse using the fore and middle fingers of their dominant hand. Subjects were told to keep their hand on the buttons at all times and to respond as soon as they had made their decision. They were instructed that they would be hearing French or English sentences (depending on the condition) in which the final word was either English or French. Their task was to decide whether the final word of each sentence was English or French and to indicate their decision by pressing one of the buttons on a mouse, labeled 'F' and 'E' (For monolingual francophones and some of the bilinguals 'E' was replaced with 'A' for Anglais). The position of the English and French response was counterbalanced on the mouse buttons (See appendix C).

Instructions were given in the appropriate language for monolinguals. For bilinguals the language of instruction was counterbalanced so that six of the bilingual subjects were interacted with and instructed in English, and four in French[5]. This was done to minimize the effect of the subjects developing a specific 'language

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[5] Originally, subject groups were going to contain twelve subjects. In order to complete the groups during the course of the experiment, this number was changed to ten, unfortunately, six subjects in the bilingual group had already received instructions in English. To ensure that each order of condition was equally represented in each group only four more subjects were available to receive instructions in French. Since the carrier phrase was the most important way to attempt to induce language set, and interaction and instructions have not been clearly found to influence language set, this slight imbalance was not felt to be a major problem for the present study.

set' through verbal interaction (e.g. Elman, Diehl, & Buchwald, 1977, Hazan & Boulakia, 1993,.), although it is not clear whether language of interaction is sufficient to establish a fixed language set (e.g. Bohn & Flege, 1993, Hazan & Boulakia, 1993). (See appendix D for the exact instructions and appendix C for subject assignment to either French or English as the language of interaction).

At the beginning of each condition six practice trials were given; three trials with the English endpoint and three trials with the French endpoint. During the actual experiment subjects were presented ten repetitions of the 12 stimuli in the 'ray to re' conditions for 120 trials in all (for each condition), and ten repetitions of the 17 stimuli in the 'day to de' conditions for 170 trials in all (for each condition). Trials were arranged into blocks of ten with an inter-block interval of 6000 ms. The inter-trial interval was 2500 ms measured from the start of the target word. As well, response time was measured in milliseconds from the onset of the target word. Short breaks were given between conditions during which subjects were asked to rate the naturalness of the stimuli and relative difficulty of decision making for each condition on a five point scale (See appendix E for an example of the rating scales). These data were used to evaluate the possible impact of perceived naturalness and difficulty on the results.

The procedure was carried out in a sound treated room with subjects listening over TDH-39 headphones. The stimuli were presented binaurally to be consistent with procedures used by Burki-Cohen et al. The stimuli were played at 72 dBA via a 486 Packard Bell personal computer equipped with a DT 2801A sound

board routed through a Sony TC-K81 tape deck and a GSI10 audiometer. Randomization and presentation were controlled by Bliss software.

Results

ANOVAs were conducted separately for the 'ray to re' and the 'day to de' stimulus series. With each series results were evaluated with respect to three dependent variables:

1. Category boundary
2. Slope of the identification function near the category boundary.
3. Response time to clear versus ambiguous tokens.

In each condition subjects responded to ten repetitions of each token. Since there was a suggestion by Burki-Cohen et al. that the carrier phrase maybe ignored at some point during categorization, the first two dependent variables were analyzed by comparing the first half of the responses (the first five repetitions) to the second half of the responses (the last five repetitions). The third dependent variable, that of response time, was analyzed with respect to performance across the ten repetitions .

A. Results for the 'ray to re' series.

1. Category Boundary.

In each language condition percent labeled English was computed for each of the twelve tokens in the series for each subject. Figure 1 shows the identification functions for the 'ray' to 're' series for each language context plotted separately for each subject group.

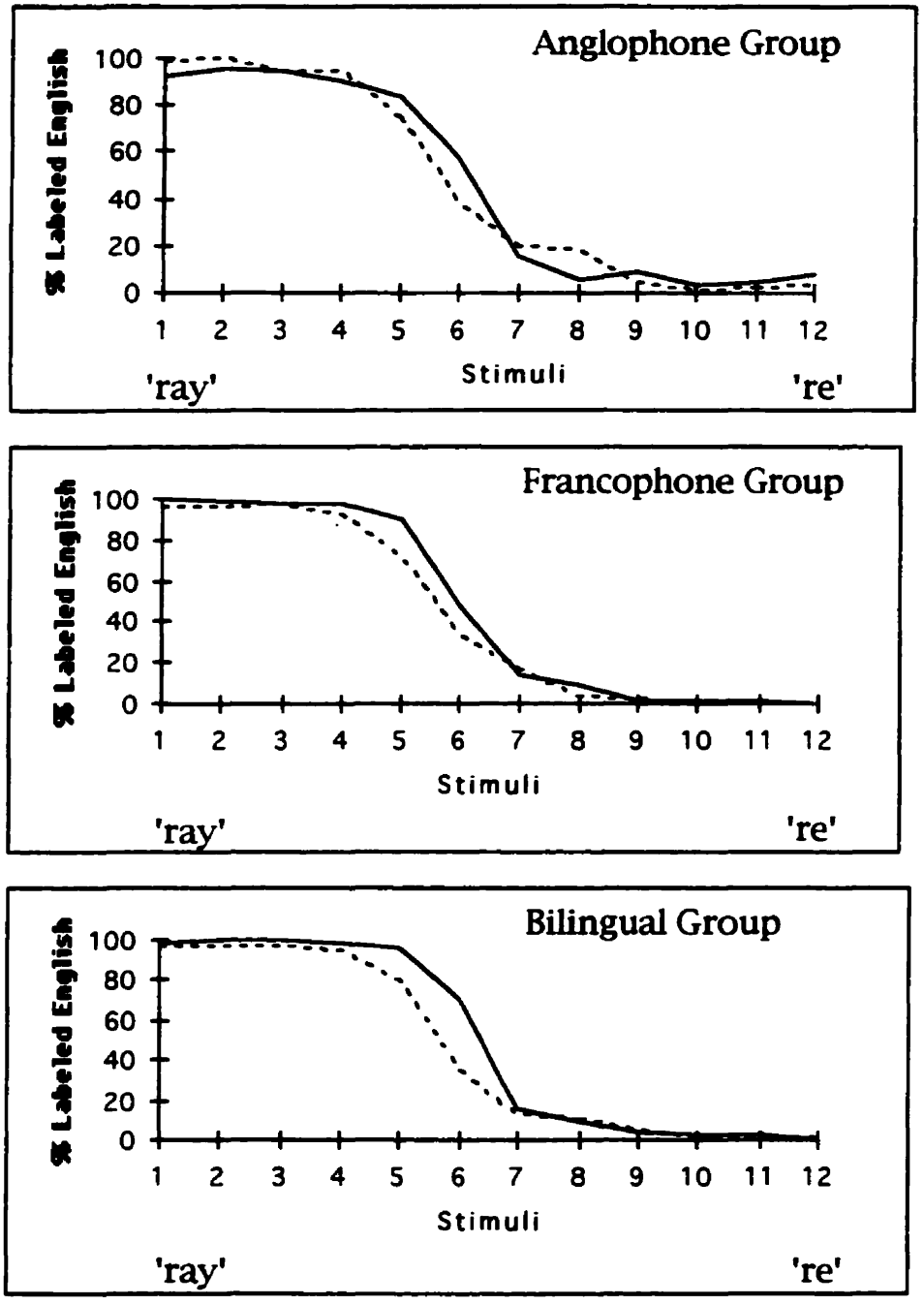

Figure 1: Identification functions for the 'ray to re' series for each language context (_ _ _ English Context; ____ French Context), plotted separately for each language group.

Category boundary scores were computed for each subject by fitting a linear regression line to that part of the identification function in which the shift from predominantly English to

predominantly French responses occurred. This section of the function included (going from right to left) the last stimuli labeled as 100 percent English (or 90 percent if 100 percent was never reached), the first of two stimuli labeled French 100 percent of the time, and all stimuli falling between these two points. The slope and intercept of this line were computed using a linear equation. The stimulus number corresponding to 50 percent English was computed using the linear equation to determine the category boundary. Table 4 shows the mean and standard deviation of the category boundary scores for each group of subjects for the first half (1st five repetitions) and the second half (last five repetitions) of the task.

Group	English Context		French Context	
	1st Half	2nd Half	1st Half	2nd Half
Anglophones	M = 5.73 SD = 1.08	M = 6.21 SD = 1.24	M = 6.36 SD = .67	M = 5.98 SD = .74
Francophones	M = 5.62 SD = .81	M = 5.78 SD = .99	M = 6.28 SD = .94	M = 5.88 SD = .86
Bilinguals	M = 5.72 SD = .79	M = 6.12 SD = .74	M = 6.49 SD = .78	M = 6.43 SD = .56

Table 4: Mean and standard deviation of category boundary scores for 'ray to re' series.

A mixed model ANOVA was conducted on the category boundary scores with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Trial position (first half versus second half) and Language Context (French versus English) as within subject factors. This ANOVA revealed a significant main effect of Language Context ($F(1,27) = 4.556$ $p < .0420$) in which

all three groups labeled more of the continuum as English in the French context as compared to the English context. This is consistent with a contrastive effect of base language. Furthermore, there was a significant interaction of Trial Position and Language Context ($F(1,27) = 13.011$ $p < .0012$). The simple effects of Trial Position showed that there were significant differences in position of the category boundary from first half to second half in both the French language context ($F(1,27) = 8.369$ $p < .007$) and the English language context ($F(1,27) = 6.199$ $p < .019$). In this case the category boundaries from both conditions move closer together by the second half. Additionally, an analysis of the simple effects of Language Context revealed that the context effect was only significant in the first half of the task ($F(1,27) = 12.522$ $p < .001$). This suggests that an effect of the carrier phrase on categorization is apparent only in early trials of the task.

2. Slope of the identification function at the category boundary.

The mean and standard deviation for the slope values for each subject group are shown in Table 5 (the larger the negative score the steeper the slope). A mixed model ANOVA was conducted using slope as the dependent variable with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Trial Position (first half versus second half) and Language Context (English versus French) as within subject factors.

Group	English Context		French Context	
	1st Half	2nd Half	1st Half	2nd Half
Anglophones	M=-26.62 SD=12.11	M=-31 SD=14.61	M=-31.35 SD=19.13	M=-28.71 SD=13.96
Francophones	M=-35.3 SD=14.39	M=-43.6 SD=23.15	M=-56.11 SD=33.07	M=56.4 SD=31.87
Bilinguals	M=-37.37 SD=25.03	M=-39.38 SD=26.6	M=-42.2 SD=23.22	M=-48.54 SD=30.64

Table 5: Mean and standard deviation of slope values for 'ray to re' series for each subject group.

A significant main effect of Group was found ($\underline{F}(2,27) = 3.801$ $p < .0351$). Tukey pairwise comparisons ($p < .05$ level) reveal that group differences occurred only between the monolingual francophone and monolingual anglophone groups. In this case, the francophone group had significantly steeper slopes than the anglophone group for both language contexts. This suggests that anglophones showed more gradual slopes (and thus greater labeling uncertainty) compared to francophones. As well, a significant effect of Language Context was found ($\underline{F}(1,27) = 4.631$ $p < .0405$) with all three subject groups having significantly steeper slopes in the French context than in the English context. No other significant effects or interactions were found.

3. Response time to clear versus ambiguous tokens.

Recall that response time was measured (in milliseconds) from the onset of the target word. For each subject the average response time to the ten repetitions of each stimulus was computed. For each series average response time was compared for three stimuli in the series: 1) a clear unambiguous exemplar of the English endpoint of the series, 2) a clear unambiguous exemplar of the French endpoint of the series, and 3) an ambiguous stimulus located near the category boundary, i.e. a stimulus that was not consistently labeled as either English or French. For each condition and language group the clear English token was selected by taking a token that virtually every subject labeled as English 100 percent of the time. Likewise, in each language condition, the clear French token was selected for each group such that virtually every subject labeled it as French 100 percent of the time. The stimulus items selected as the 'clear English' and 'clear French' tokens for each group in each context are listed in Table 6.

Group	English Context		French Context	
	Clear English	Clear French	Clear English	Clear French
Anglophones	2	11	2	11
Francophones	3	12	1	12
Bilinguals	2	11	2	12

Table 6: Stimulus numbers selected for clear English and clear French tokens.

For each language context the ambiguous token was selected for each subject by taking the token closest to 50 percent English responses (i.e. the category boundary). Thus, the actual stimulus defined as the ambiguous token was different for each subject. [6] Table 7 shows the mean and standard deviation for the average response time score for each type of token for each subject group.

Group	Anglophones		Francophones		Bilinguals	
Language Context	English Context	French Context	English Context	French Context	English Context	French Context
Clear English	M=667ms SD = 129	M=676ms SD = 127	M=847ms SD = 227	M=763ms SD = 134	M=795ms SD = 144	M=678ms SD =84
Clear French	M=726ms SD = 239	M=728ms SD = 147	M=865ms SD = 161	M=790ms SD = 196	M=849ms SD = 137	M=815ms SD = 162
Ambiguous	M=969ms SD = 195	M=923ms SD = 141	M=1139ms SD = 218	M=1013ms SD = 220	M=1042ms SD = 164	M=1005ms SD = 257

Table 7: Mean and standard deviation of response times for the 'ray to re' series.

A mixed model ANOVA was carried out on these mean response time scores with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Language Context (French versus English) and Token (clear English versus clear French versus Ambiguous tokens) as within subject factors. As expected

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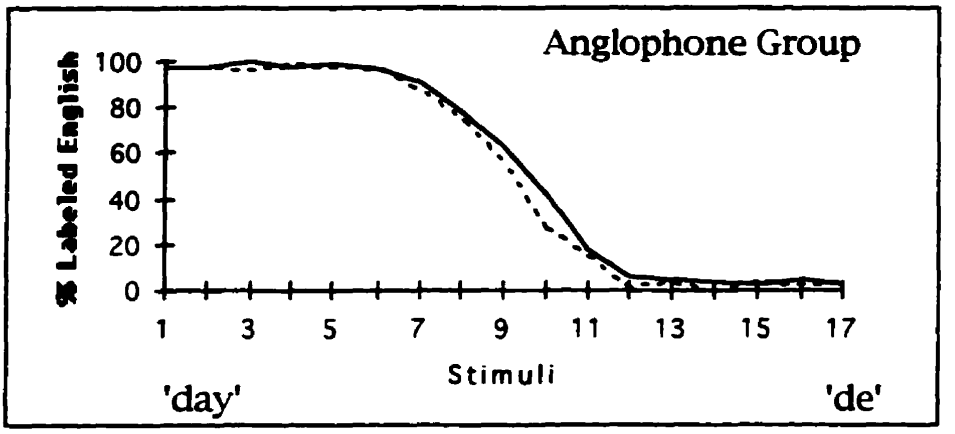
[6] An attempt was made to break up the continuum into sections and average several tokens in each section to define clear English, clear French, and ambiguous tokens. However, subjects varied in labeling consistency as well as in the exact location of their category boundaries . This made it difficult to place stimuli into groups that were equally ambiguous and unambiguous for each subject and thus to devise a grouping in which response time and identification status were not confounded. For this reason, this method was abandoned in favor of the selection of three single tokens, as well as selecting ambiguous tokens individually.

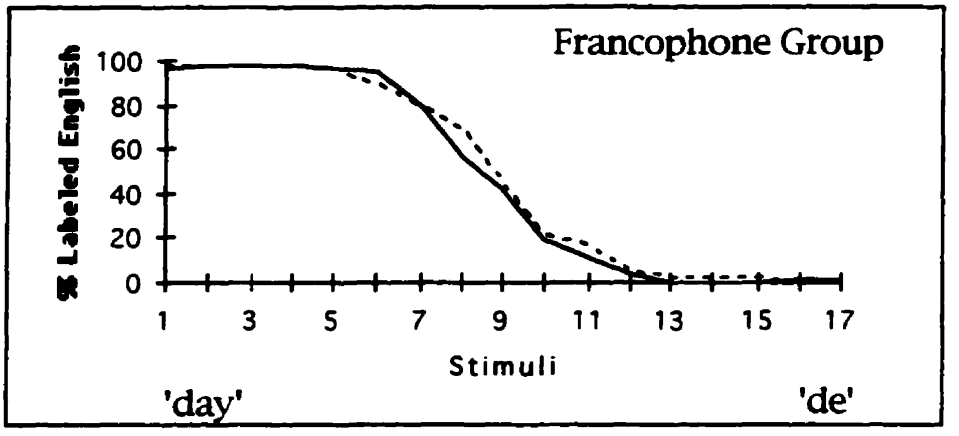
there was a significant main effect of Token (F (2,54) = 79.626 p< .00001). Tukey pairwise comparisons ($p < .01$ level) revealed that subjects were significantly slower in responding to ambiguous tokens than to both clear French and clear English tokens. Additionally, subjects were faster in responding to clear English tokens than to clear French tokens ($p < .05$ level). A significant effect of Language Context was also revealed (F (1,27) = 11.313 $p < .0023$) indicating that subjects in all three groups responded faster in the French context than the English context.

B. Results for the 'day to de' series.

1. Category Boundary

In each language condition, percent labeled English was computed for each of the 17 tokens in the series for each subject. Figure 2 shows the identification functions for the 'day to de' series in each language condition, plotted separately for each subject group.





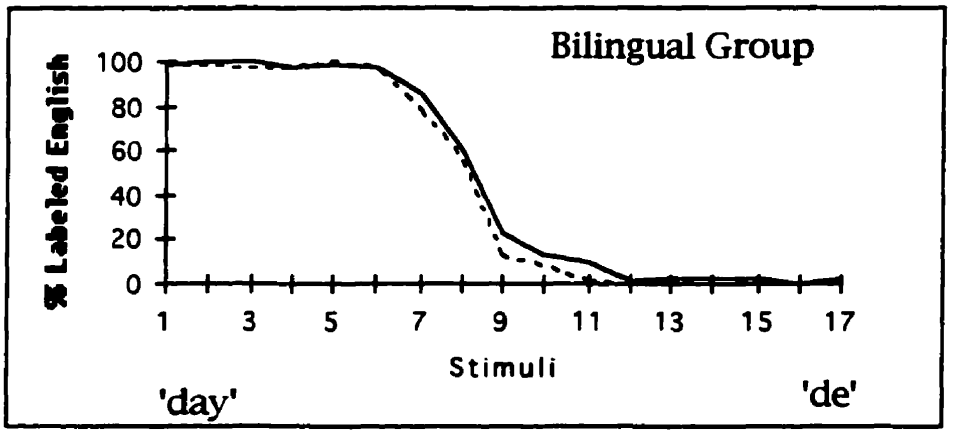


Figure 2: Identification functions for the 'day to de' series for each language context (_ _ _ English Context; ____ French Context), plotted separately for each language group.

A linear regression line was fitted to the identification function, as described earlier for the 'ray to re' series. Slope and intercept were computed and the category boundary (the stimulus number

corresponding to 50 percent English for each subject in each condition) was calculated. Table 8 shows the mean and standard deviation of the category boundary scores for each group of subjects. A mixed model ANOVA was performed using Group (anglophones versus francophones versus bilinguals) as a between subject factor and Trial Position (first half versus second half) and Language Context (French versus English) as within subject factors.

Group	English Context		French Context	
	1st Half	2nd Half	1st Half	2nd Half
Anglophones	M=9.27 SD=1.02	M=8.67 SD=1.4	M=9.68 SD=.78	M=10.03 SD=2
Francophones	M=8.93 SD=1.39	M=8.67 SD=1.13	M=8.76 SD=1.33	M=8.45 SD=1.34
Bilinguals	M=8.21 SD=.69	M=7.95 SD=.70	M=8.57 SD=1.1	M=8.44 SD=.71

Table 8: Mean and standard deviation of category boundary scores for the 'day to de' series.

The ANOVA revealed a significant main effect of Group ($F(2,27) = 4.144$ $P < .0269$). Tukey pairwise comparisons ($p < .05$ level) showed significant group differences between the bilinguals and the anglophones only. That is, the anglophone group placed its category boundary closer to the French endpoint than the bilinguals in both language conditions. This indicates that anglophones heard more of the continuum as English 'day' regardless of language context. No other significant effects or interactions were found.

2. Slope of the function at the category boundary.

The mean and standard deviation for the slope values for each subject group are shown in Table 9. Slope was computed by linear regression in the same manner as was described for the 'ray to re' series. A mixed model ANOVA was conducted with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Trial Position (first half versus second half) and Language Context (French versus English) as within subject factors.

Group	English Context		French Context	
	1st Half	2nd Half	1st Half	2nd Half
Anglophones	M=-25.33 SD=8.98	M=-29.1 SD=17.44	M=-25.81 SD=14.96	M=-26.39 SD=15.07
Francophones	M=-21.84 SD=5.89	M=-18 SD=6.66	M=-26.23 SD=11.58	M=-30.27 SD=11.06
Bilinguals	M=-38.8 SD=22.87	M=-29.14 SD=8.46	M=-27.51 SD=12.08	M=-30.14 SD=15.65

Table 9: Mean and standard deviation of slope values for the 'day to de' series.

This ANOVA revealed a significant interaction of Group and Language Context ($F(2,27) = 6.519$ $p < .0049$). An analysis of the simple effects of group showed that group differences were apparent only in the English context ($F(2,39) = .221$ $p < .009$). Essentially, the francophone group demonstrated significantly shallower slopes compared to the other two groups, but only in the English context. This suggests that in the English context francophones were less certain in their labeling responses for this continuum. An analysis of

the simple effects of language revealed that language context effects occurred only in the francophone group ($F(1,27) = 9.452$ $p < .005$), such that francophones were more certain (had steeper slopes) in the French context than in the English context.

3. Response Time.

Again response time was measured in milliseconds from the onset of the target word. For each subject the average response time to the ten repetitions of each stimulus was computed. The average response time was compared for three stimuli in the series, as described for the 'ray to re' series. Thus, one stimulus token was selected as the clear English token for each group in each condition and one stimulus token was selected as the clear French token, however, the ambiguous tokens were chosen separately for each subject. The stimuli selected as the 'clear English' and 'clear French' tokens for each group in each language context are shown in Table 10.

Group	English Context		French Context	
	Clear English	Clear French	Clear English	Clear French
Anglophones	4	14	3	17
Francophones	2	17	3	15
Bilinguals	5	16	2	16

Table 10: Stimulus numbers used for clear English and clear French tokens.

Table 11 shows the mean and standard deviation of the average response times for each type of token.

Group	Anglophones		Francophones		Bilinguals	
Language Context	English Context	French Context	English Context	French Context	English Context	French Context
Clear English	M=706ms SD = 162	M=682ms SD = 126	M=814ms SD = 214	M=818ms SD = 172	M=752ms SD = 149	M=727ms SD = 149
Clear French	M=687ms SD = 159	M=658ms SD = 177	M=759ms SD = 114	M=837ms SD = 127	M=736ms SD = 123	M=805ms SD = 190
Ambiguous	M=1060ms SD = 299	M=1022ms SD = 249	M=1122ms SD = 237	M=1174ms SD =249	M=1096ms SD = 187	M=1079ms SD =239

Table 11: Mean and standard deviation for response times for 'day to de' series.

A mixed model ANOVA was done on these response times with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Language Context (French versus English) and Token (clear English versus clear French versus ambiguous) as within subject factors. Only a significant main effect of Token was found ($\underline{F}$ (2,54) = 101.862 $p < .00001$). As expected, Tukey pairwise comparisons ($p < .01$ level) revealed that all three groups responded more slowly to the ambiguous tokens than to either the clear French or the clear English tokens, confirming that tokens which are labeled more consistently were reacted to faster than tokens labeled inconsistently.

C. Results for Ratings of Naturalness and Difficulty.

Recall that after completing each condition subjects were asked to rate the difficulty and the 'naturalness' of the sentences they had just heard. For the naturalness ratings, subjects used a five point rating scale with 1 being very natural and 5 being very unnatural. An ANOVA was run on the naturalness ratings of each subject with Group (anglophone versus francophone versus bilingual) as a between subject factor and Continuum ('ray to re' versus 'day to de') as a within subject factor. A significant main effect of Continuum was found (F (1,27) = 5.909 $p < .0220$) with 'ray to re' (mean rating of 2.4) being judged as less natural than 'day to de' (mean rating of 2.1). No other significant differences between conditions were found.

An analysis was also done on ratings of the subjects' perceived difficulty in deciding whether the final word in each sentence was French or English in each condition. Subjects rated difficulty on a five point scale with 1 being not difficult and 5 being very difficult. An ANOVA was run on these scores with Group (anglophones versus francophones versus bilinguals) as a between subject factor and Condition ('ray to re' English context, 'ray to re' French context, 'day to de' English context, and 'day to de' French context) as a within subject factor. The ANOVA revealed no main effects or interactions, thus no significant differences in difficulty among the conditions was found with any subject group.

Discussion and Conclusions

In this study two questions were explored. The first question was; can the identification patterns reported by Burki-Cohen et al. be attributed only to the effects of bilingualism on speech processing? The second asked; are there differences in the processing operations that monolinguals and bilinguals engage to identify a bilingual speech continuum? This final section aims to discuss how the findings outlined in the results section answer these two questions. To do so, this section is divided into three sub-sections which discuss the first question, the second question, and outline the overall conclusions.

Base language effects

Recall that Burki-Cohen found that the acoustic/phonetic characteristics of code-switched words interacted with a carrier phrase (i.e. the base language) when bilinguals were categorizing a language contrastive stimulus continuum (i.e. the 'ray to re' series). Two interpretations of the language context effect found in that study have been proposed in the present thesis. One was the interpretation taken by Burki-Cohen et al., which presumably requires the carrier phrase to be processed as a meaningful linguistic code. The other interpretation was that general processing mechanisms may have produced these results. Identification performance by both monolingual and bilingual subjects was compared in the present study to test whether bilingual processing was necessary to produce the effects found by Burki-Cohen et al. Additionally early bilingual subjects were used in order to ensure

that if bilingualism is associated with unique processing strategies, the evidence of such strategies would be clear.

To answer this question an analysis of the language context effects on the placement of category boundary was performed separately for each series. Findings replicated Burki-Cohen et al. in bilinguals, but similar patterns of performance were also found for the two monolingual groups. For the 'ray to re' series all three subject groups demonstrated a language context effect consistent with a contrastive effect of base language. However, the contrastive effect of base language was evident only in the first half of each test condition. For the 'day to de' series no effect of base language was found in the bilingual or the monolingual groups.

These findings suggest two conclusions. First, that the production of a contrastive effect of base language is not dependent on bilingual processing mechanisms. Second, that differences between bilinguals and monolinguals in how they are affected by the base language were not found even when balanced, early bilinguals were tested. The data are, therefore, consistent with the alternative hypothesis. That is, the language context effects found in this, and in the Burki-Cohen et al. study appear to be due to general perceptual processing strategies, not to processing strategies specific to bilinguals.

This raises the question of why differences in the effect of the carrier phrase on bilinguals and monolinguals were not found. The most likely explanation is that the base language does affect the processing of code-switched words differently in bilinguals and monolinguals, however, these effects are task specific. It can be

speculated that the present task was not appropriate to reveal such differences. Furthermore, it is likely that a higher level of processing must be invoked in order to see an interaction of base language and the acoustic/phonetic properties of code-switched words that is unique to bilinguals.

There are several potential inadequacies of the present study to induce processing at a higher level. Firstly, the two endpoints of both series were chosen to be within a functionally equivalent phonetic category. This is likely to encourage the use of auditory or acoustic/phonetic cues to divide the continua into categories. Furthermore, the carrier phrase is neutral in that it places minimal syntactic or semantic constraints on the target word. In addition, the carrier phrase is stable and the response required is limited (i.e. this task uses a closed set of possible responses). Due to these factors there is little need to attend to the carrier phrase to perform the task at hand. That is, because the carrier phrase was stable it's meaning did not have to be processed, although the subjects still received the acoustic signal. Thus, the carrier phrase was still able to interact with the target stimuli to cause an effect, albeit at the acoustic/phonetic level. Since the contrastive effect of base language was transient, it is possible that initially subjects attended to both the carrier phrase and the target word, but with time subjects paid less attention to the carrier phrase and attended only to the particular acoustic cues within the stimuli themselves in order to categorize them.

Bohn & Flege (1993) also proposed that manipulation of the carrier phrase is inadequate to invoke a language-based perceptual

shift in processing. Additionally, other researchers have suggested that higher levels of processing are invoked only with certain processing demands. In particular, Werker & Logan (1985) found that when a perceptual task is manipulated processing can be broken down into various levels, all of which are normally used when processing natural speech. They provide evidence to support three processing strategies; general auditory processes (which are not specific to the perception of language), phonetic processes (which are involved in processing sounds as language, but are not specific to one language), and phonemic processes (which are language-specific and develop through language experience). These researchers demonstrated that when performing a speech perception task in which memory load and stimulus uncertainty is low subjects are unlikely to invoke phonemic processing. However, under conditions which are more akin to natural speech communication (i.e. high memory load, high stimulus uncertainty) subjects will use their language-specific processing strategies. Thus, it is important to consider the various conditions under which a subject is processing stimuli, as well as the materials used to create context effects, to understand the nature of processing operations underlying the subject's performance.

Having said this, it is important to consider why a contrastive effect of base language was observed for the 'ray to re' series, but there was a lack of any context effect for the 'day to de' series. Clearly, the stimuli in the 'ray to re' series were categorized differently in the English carrier phrase than in the French carrier phrase, whereas, there was no interaction between the target stimuli

and either of the two carrier phrases in the 'day to de' series. For the 'ray to re' series, there was further evidence that the stimuli interacted with the carrier phrase. The analysis of slope revealed a language context effect, such that all three groups had steeper slopes and were, therefore, more certain in the French context than in the English context. Response time also revealed a language contrast effect, in this case, all three groups were faster in the French context than in the English context. Both these findings suggest that categorization was easier in the French context. Since the effects found in slope and response time are so similar to the base-language effect, it is likely that they also reflect the contrastive effect of base language, and can be seen as converging evidence for it.

There are at least two possibilities which explain the clear effect of language context for the 'ray to re' series and the absence of a language context effect for the 'day to de' series. Firstly, it is possible that the acoustic/phonetic characteristics of the target words in the 'ray to re' series signaled a language switch better than the target words in the 'day to de' series. This assumes that subjects processed the stimuli as speech, although it does not depend on language specific processes. That is, subjects were processing at the phonetic level in which a shift in language may be indicated, however, knowing which language has been shifted to was not necessary.

Alternatively, it is possible that something in the auditory processing of the acoustic characteristics of the code-switched words, as they interacted with the carrier phrase, caused a contrastive effect. This is possible because the target words in the 'ray to re'

series begin with either a fricative or a liquid, while the target words in the 'day to de' series always begin with a stop consonant. Since the final sound of both carrier phrases is always a fricative, there may be some acoustic effects in the perception of a fricative moving to a fricative or a liquid that do not occur when moving from a fricative to a stop consonant. This implies a very low level of processing which does not depend on the perception of either the carrier phrase or the target word as speech (i.e. subjects may be processing at the auditory level). There is some evidence supporting this explanation in that the 'ray to re' series was judged as being less natural than the 'day to de' series by all subject groups. Whether this judgment is due to the nature of the words themselves or is a by product of the creation of a cross-language continuum is not clear.

It is not necessary that processing stimuli at the phonetic and at the auditory levels are mutually exclusive. It could be that the acoustic and phonetic characteristics work in concert to highlight a language shift. One way to resolve this issue would be to conduct an experiment with animals using the same carrier phrases and target words. If animals show the same patterns as found in the present study, then an acoustic explanation is sufficient. Otherwise, it must be concluded that such effects are confined to the processing of speech, even though familiarity with a particular language is not necessary.

Processing differences between monolinguals and bilinguals.

It is possible that even if language context effects in identification patterns were similar in all groups, differences in processing may have nevertheless occurred. In order to address this issue three dependent variables were examined in an attempt to find differences in the processing operations used by monolinguals and bilinguals. Firstly, the analysis of category boundary was examined with respect to group differences. It was predicted that this would reveal overall differences in all three groups in how they weight the acoustic properties of the code-switched word, apart from any effects of language context. Secondly, the dependent variable of slope of the identification function at the category boundary was also analyzed in an attempt to expose differences in the relative confidence each group had when dividing the continua. Finally, response time was analyzed to reveal group differences in the complexity of processing.

For the 'ray to re' continuum no evidence of differences in processing between the monolingual groups and the bilinguals was found with respect to category boundary, slope, or response time. As expected, all three groups had slower response times for ambiguous tokens than for clear English or French tokens.

For the 'day to de' continuum, again no bilingual/monolingual differences in response time or slope were found, although all three groups had the expected slower response times for ambiguous tokens than for clear English or French tokens, as was found for the 'ray to re' series. However, difference between bilinguals and monolinguals were found in the analysis of category boundary showing that

bilinguals labeled more of the stimuli at the category boundary as French 'de' compared to the anglophones. This is an expected finding and reflects biases related to differences in language experience. That is, bilinguals, with their greater experience with French were expected to label more of the stimuli as French compared to the monolingual anglophones.

There were no differences in where the francophones placed their category boundary and where the bilinguals placed theirs. If the bilinguals could have been considered French-dominant this would have been much easier to explain. However, since the bilinguals were English-dominant another explanation must be found. It is possible that these monolingual francophones were not as 'monolingual' as the anglophones. Although these subjects were screened carefully, it is still possible that the monolingual francophones have had more exposure to English than the anglophones had to French. The monolingual anglophones had spent most of their lives out of the province of Quebec. Since most of these subjects had lived in other parts of Canada they had all had some exposure to French in school, however this was probably less than the monolingual francophones' exposure to English in school. In spite of the monolingual francophones' immersion in French, it is likely that they still experienced a great deal of ambient English simply because they live in North America. As well, Montreal is, at least functionally, a bilingual city and English is spoken regularly on the street. It is possible that this limited exposure, as well as the occasional exposure to English media, helped to reduced the difference between the bilinguals and the francophones.

While the similarities in category boundary may explainable when considering francophones and bilinguals, it was expected that there would at least be differences in category boundary between the francophones and the anglophones, if there were differences at all. It is difficult to explain why the anglophones and francophones did not also show differences. However, the fact that the francophones were more variable in their responses may explain the lack of any group effect. A future study with a larger number of subjects may be necessary to find such differences.

Like the analysis of base language effects, these findings regarding processing differences raise the question of why bilingual/monolingual differences, were only found in one series. Finding them in the 'day to de' series is in fact consistent with hypotheses made by some cross-language researchers. For example, Flege (1981,1984, and 1987) suggests that the ease of creating a new category for a particular phoneme from a second language depends on whether this category can be considered as equivalent to a similar category from the first language. Phonemes that are very different from any category in the native language can be easily learned as a new category, and are relatively free from the effects of previous language experience. However, if a non-native phoneme can be fit into a native category, that phoneme is likely to be treated as an instance of the native category. In this case it takes time for a perceiver to be able to detect the finer details which would allow them to perceive a similar non-native phoneme as part of a separate phonemic category.

As well, Best (Best, McRoberts, & Sithole, 1988; Best & Strange, 1992) suggests that cross-language effects are strongest for phonemes which can be 'mapped' (i.e. assimilated) into a single native category. Language experience is less likely to be revealed with phonemic contrasts which map to different native categories. This is also true of contrasts which map to the same category but one of the phonemes provides a better match to the native phoneme category than the other. In the present study the minimal pair used to create the 'ray to re' series represents this type of contrast. That is, the initial phonemes presented in this minimal pair may be mapped onto the monolinguals' native category (/ɹ/ for anglophones and /ʁ/ for francophones.) as 'good' versus 'less good' exemplars.

Alternatively, language experience is revealed when subjects must separate stimuli that they might have otherwise considered the same: in other words, when phonemic contrasts are presented that are equally good exemplars of one native category. This situation will reveal biases because categorization is taking place through the filter of one's native phonemic inventory, and this is different depending on language experience. In the present study the minimal pair used to create the 'day to de' continuum is such a contrast with the initial phonemes of the minimal pair equally able to be good exemplars of the category /d/ for both languages.

A few other findings also deserve mention. For the 'ray to re' series, along with the findings already discussed, response time revealed that all three groups responded faster to the clear English token ('ray') than to the clear French token ('re') in both language contexts. Acoustic differences in these two sounds likely explain this

effect. Further, in the analysis of slope for the 'ray to re' series it was also observed that monolingual francophones had steeper slopes than monolingual anglophones, regardless of language conditions. This effect may have again been due to the possibility that the monolingual francophone subjects had a greater likelihood of being familiar with English acoustic/phonetic structure than monolingual anglophones had with French, as discussed before. Thus, including a larger number, or recruiting francophone subjects who have not had any exposure to English may clarify this issue as well.

The 'day to de' series revealed only one effect apart from those already discussed. The analysis of slope for this series revealed that monolingual francophones had shallower slopes than the other two groups in the English context, but were similar to them in the French context. It is not clear why this may have occurred since no other language context effects were evident for this series. Further study, perhaps by including more subjects or by comparing francophones with varying degrees of exposure to English, is needed before speculation regarding the origin of this interaction can be explained.

Summary

Overall, it can be concluded that the contrastive effect of base language, as described in this and in the study by Burki-Cohen et al. is a result of general perceptual capacities and is not dependent on bilingual language processing. Evidence for this effect is not only found in an analysis of category boundary, but also in analysis of other dependent variables, namely response time and slope of the identification function at the category boundary. Demonstration of a

base language effect does appear to depend on the acoustic/phonetic characteristics of the code-switched word, with a contrastive effect of base language only apparent for a continuum whose endpoints have very different acoustic/phonetic characteristics. This is a conclusion shared with Burki-Cohen et al. in their study. It also appears that carrier phrases such as the one utilized in this study are not adequate to induce higher level language based processing which may have revealed the effects of bilingual language experience.

Apart from the similarities demonstrated by bilinguals and monolinguals regarding the effects of base language, group differences between bilinguals and monolinguals were evident in this study. With the 'day to de' series, bilinguals and monolingual anglophones demonstrated bias differences related to differences in language experience. This findings suggests that group differences based on language experience only become evident with a continuum whose endpoints have very similar acoustic/phonetic characteristics.

Although there are some fairly clear conclusions to be made from this study, certain limitations have made it difficult to clearly explain all the findings. Firstly, although all the subjects were screened very carefully and the bilingual subjects were quite balanced, neither group of monolingual subjects was free from exposure to the other language. This may be particularly true of the francophone group. In Quebec it is very difficult to recruit monolingual anglophones who have never had exposure to French and francophones who have never had exposure to English. A study that uses subjects who have truly had exposure to only one of these languages may have helped to clarify the results. Finally, it may be

that including more subjects would have strengthened some of the effects, particularly the group differences found in the 'day to de' series.

Future research may wish to deal with these issues. Additionally, it would be prudent to attempt to replicate these findings with different stimulus pairs, to ensure that the effects are not solely due to the stimuli that were used and the way in which the cross-language continua were created. Also, replication of these findings with other language groups would allow the conclusions made to be more generally applied.

Finally, it would be of great interest to explore the various conditions under which a subject is processing stimuli, as well as, the materials used to create context effects. It is important to understand the nature of processing operations underlying subjects' performance, otherwise, further research into the processes involved in speech perception that are particular to bilinguals will be difficult to conduct. For example, since it appears that simply including a carrier phrase is insufficient to induce language based processing, it would be very interesting to discover what characteristics of a task can invoke such processing. Developing new techniques or adapting existing paradigms may allow future researchers to be assured that, when studying bilingual processing, the results they have discovered have been influenced by specific linguistic experience. Without establishing the basis of processing within a study, future researchers will be unable to make clear conclusions or develop their hypotheses further.

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Appendix A: Linguistic profiles in French and English: monolinguals and first page for bilinguals.

PROFILE LINGUISTIQUE

No. de sujet: _____

Nom: _____

Age: _____

Sexe: _____

Lieu de Naissance (Ville & état/province et Pays):_____

Est-ce que votre ouïe est dans les limites de la normale? Oui Non

Si Non, svp expliquez

_____

Quelle est votre main dominante: Droite Gauche Les deux

Indiquez les lieux où vous avez habité (depuis votre naissance) et l'âge que vous aviez à ces périodes.

Lieu de naissance de vos parents (ville, etate/prov. ou pays)

Pere:

_____

Mere:

_____

Parlez-vous une autre langue courament? Oui Non

Si oui, laquelle (lesquelles):

_____

Le français, était-il la premiére langue dont vous avez appris? Oui Non

Si non,
laquelle(lesquelles):_____

Avez-vous déjà été exposé à une autre langue? Oui Non

Si oui, indiquez dans quel context (e.g. cours au secondaire, immersion, grandparents, travail, etc.)

_____

Avez vous déjà suivi un cours de PHONÉTIQUE (l'etude scientifique des sons des mots). Ce cours est enseigné au niveau universitaire en linguistiques ou en cours de science de la parole?

Oui Non

Language Profile

Subject #:_____
Name:_____
Age:_____ Sex:_____
Birthplace:_____
Town/City State or province/Country

As far as you know, is your hearing within normal limits? Yes No
If no, please explain: _____
_____

Which is your dominant hand? Right Left Both

List the places you have lived (from birth) and the ages you were when you lived there:

Parents' birthplace (City and State/Province or Country).
Father:_____
Mother:_____

Do you speak any languages other than English fluently?
Yes No
If Yes, what languages (s)?_____

Was English the first language you learned? Yes No
If No, which language (s) was/were? _____

Have you ever had any exposure to another language? Yes No
If so, please state the context (e.g. single classes in school, immersion, grandparents, work, etc.).
_____

Have you ever had Phonetics (the scientific study of speech sounds. Phonetics is taught only at the college level in either a linguistics or speech science class)?
Yes No

Appendix B: Linguistic profiles for bilinguals in French and English.

PROFILE LINGUISTIQUE

NOM: _____ NO. TEL: _____

AGE: _____ SEXE: _____

1. LIEU DE NAISSANCE (Ville et Pays): _____

2. QUELLE EST LA PREMIÉRE LANGUE DONT VOUS AVEZ APPRIS: _____

3. PARLEZ-VOUS UNE AUTRE LANGUE? SI OUI, LAQUELLE? _____
(Si non, répondez seulement les questions 9, 10, 11 et 12).

4. À QUEL AGE AVEZ-VOUS APPRIS CETTE DEUXIEME LANGUE? _____

5. PAR QUEL MOYEN AVEZ-VOUS APPRIS CETTE DEUXIEME LANGUE? (À l'école? Autre?) _____

6. SI VOUS TRAVAILLEZ ACTUELLEMENT, QUELLE LANGUE UTILISEZ-VOUS AU TRAVAIL? _____

_____

7. A L'AIDE D'UNE ÉCHELLE ALLANT DE 1 À 7, POURRIEZ-VOUS ÉVALUER VOTRE COMPETENCE LINGUISTIQUE DANS CHACUN DES DOMAINES SUIVANTS ET POUR CHAQUE LANGUE:
(1 = aucune facilité et 7 = comme un interlocuteur natif).

	FRANÇAIS	ANGLAIS (ou autre)	
DISCOURS	_____	_____	_____
COMPRÉHENSION	_____	_____	_____
LECTURE	_____	_____	_____
ÉCRITURE	_____	_____	_____

8. EN QUELLE LANGUE VOUS AVEZ FAITS VOS ÉTUDES?
* école primaire _____
* école secondaire _____
* CEGEP _____
* université _____

9. QUELLE LANGUE UTILISEZ-VOUS LORSQUE VOUS PARLEZ AVEC:

FAMILLE PROCHE(parents, frères, soeurs): _____
VOS GRANDSPARENTS: _____
VOS AMIS: _____

VOUS MEME (quand vous êtes en colère, quand vous rêvez, ...):

_____

10. VOUS REGARDEZ LA TÉLÉ EN QUELLE LANGUE? _____

11. VOUS ÉCOUTEZ LA RADIO EN QUELLE LANGUE? _____

12. AVEZ-VOUS JAMAIS PASSÉ UNE LONGUE PÉRIODE DANS UN AUTRE PAYS VOUS AVEZ DU COMMUNIQUER DANS UNE LANGUE AUTRE QUE VOTRE LANGUE MATERNELLE? (Si oui, quell langue et pour combien de temps): _____

_____

LANGUAGE PROFILE

1 WHAT IS THE FIRST LANGUAGE YOU LEARNED? _____
2 WHEN DID YOU START LEARNING YOUR SECOND LANGUAGE?_____
3 HOW DID YOU COME INTO CONTACT WITH YOUR SECOND LANGUAGE? (School or other)
_____
4 IF YOU ARE WORKING NOW, WHAT IS YOUR LANGUAGE OF WORK? _____
5 ON A SCALE FROM 1 TO 10, HOW WOULD YOU RATE YOURSELF IN THE FOLLOWING DOMAINS FOR EACH LANGUAGE (1 = no facility and 10= like a native speaker)

	ENGLISH	FRENCH	OTHER?_____
SPEAKING	_____	_____	_____
COMPREHENSION	_____	_____	_____
READING	_____	_____	_____
WRITING	_____	_____	_____

6. IN WHICH LANGUAGE WERE YOU EDUCATED?
*elementary school: _____ *CEGEP: _____
*high school: _____ *university: _____
7. WHAT % OF TIME DO YOU SPEAK EACH LANGUAGE WITH (please indicate F or E & %):
CLOSE FAMILY (parents, siblings): _____
GRANDPARENTS: _____
FRIENDS: _____
SELF (when angry, dreaming or expressing affection): _____
8. WHAT % OF TIME DO YOU DO THE ACTIVITIES BELOW IN EACH LANGUAGE:
WATCH TV _____
LISTEN TO THE RADIO _____ (please indicate F or E and %)

9. HOW COMFORTABLE DO YOU FEEL SPEAKING IN ENGLISH & FRENCH?
ENGLISH: _____
FRENCH: _____

10. IF YOU WERE STRANDED ON A DESERTED ISLAND WITH ONLY ONE PERSON,, WHICH OF YOUR TWO LANGUAGES WOULD YOU MOST WANT THE OTHER PERSON TO SPEAK?
_____

11. DO YOU OFTEN SWITCH FROM ONE LANGUAGE TO THE OTHER WHEN SPEAKING TO ANOTHER BILINGUAL?
_____

12 ARE YOU FAMILIAR WITH A LANGUAGE OTHER THAN FRENCH OR ENGLISH? IF SO, WHICH ONE AND WHEN DID YOU START LEARNING IT?
_____

13. HAVE YOU EVER HAD FORMAL TEACHING (e.g. classes in elementary, public, high school, CEGEP, or university) IN ANY LANGUAGE (If yes, which ones and for how long):
_____
_____

14. HAVE YOU EVER SPENT A SIGNIFICANT TIME IN ANOTHER COUNTRY WHERE YOU HAD TO COMMUNICATE IN A LANGUAGE OTHER THAN YOUR FIRST (if so, with what language and for how long):
_____

Appendix C: Order of presentation of conditions and language of interaction for bilinguals.

Order of Presentation of Conditions

1 = 'ray to re' in the English context.

2 = 'ray to re' in the French context.

3 = 'day to de' in the English context.

4 = 'day to de' in the French context.

Subject #	Order
1	1 2 4 3
2	1 3 2 4
3	1 4 3 2
4	2 3 4 1
5	2 1 3 4
6	2 4 1 3
7	3 1 2 4
8	3 2 4 1
9	3 4 1 2
10	4 1 2 3

For subjects 1 through 6: 'E' (English) response was on left mouse button.
'F' (French) response was on right mouse button.

For subjects 7 through 10: 'E' (English) response was on right mouse button.
'F' (French) response was on left mouse button.

Designation of order and response button was the same for all three groups.

Language of Interaction for Bilinguals

Subjects 1 - 6 : English
Subjects 7 - 10: French

Appendix D: Instructions in French and English.

Instructions

English Context

You will hear some sentences in English. The final word in the sentence will be the French word (Re or De) or the English word (Ray or Day). Your task is to decide whether the last word is the English word or the French word. With the first two fingers of your dominant hand, press E on the mouse when you think the word is English and press F on the mouse when you think the word is French as soon as you have made your decision. There is no 'correct' answer, we are interested in your perception, therefore, if you aren't sure just make your best guess. Before the actual experiment begins you will hear several practice items, after which any further questions you may have will be answered.

** Play practice items

Now you will be hearing 120/170 more sentences. After every ten sentences, there will be a short pause. While you are being tested an experimenter is always present who can hear you at all times

French Context

You will hear some sentences in French. The final word in the sentence will be the French word (Re or De) or the English word (Ray or Day). Your task is to decide whether the last word is the English word or the French word. With the first two fingers of your dominant hand, press E on the mouse when you think the word is English and press F on the mouse when you think the word is French as soon as you've made your decision. There is no 'correct' answer, we are interested in your perception, therefore, if you aren't sure just make your best guess. Before the actual experiment begins you will hear several practice items, after which any further questions you may have will be answered.

** Play practice items

Now you will be hearing 120/170 more sentences. After every ten sentences, there will be a short pause. While you are being tested an experimenter is always present who can hear you at all times

French Instructions
English block

Vous allez entendre des phrases en anglais. Le dernier mot de la phrase sera le mot (Ré ou Dé) ou le mot anglais (Ray ou Day). Votre tâche consiste d'indiquer si ce dernier mot est le mot français (Ré ou Dé) ou bien le mot anglais (Ray ou Day). En utilisant les deux premiers doigts de votre main dominante, appuyez sur le bouton avec la lettre A si vous pensez d'avoir entendu le mot anglais. Appuyez sur le bouton marqué F si vous croyez d'avoir entendu le mot français. Appuyez sur le bouton aussitôt que vous avez faite votre décision.

Il n'y a pas de bonne réponse, on est simplement interéses à comprendre comment vous percevez ces sons. Si vous n'êtes pas certains, choisissez la réponse qui vous sembe plus apprpriée. Avant que l'expérience débute, vous allez avoir quelques essaies de pratique. Si vous avez des questions, elles seront répondus à ce moment-là.

**PRACTICE ITEMS

Vous allez entendre 120/170 phrases en tout. Après chaque groupe de 10 phrases, i y aura une courte pause. Pendant l'expérience, un chercheur peut vous entendre en tout temps et sera à votre disposition si vous en avez besoin.

French Block

Vous allez entendre des phrases en français. Le dernier mot de la phrase sera le mot (Ré ou Dé) ou le mot anglais (Ray ou Day). Votre tâche consiste d'indiquer si ce dernier mot est le mot français (Ré ou Dé) ou bien le mot anglais (Ray ou Day). En utilisant les deux premiers doigts de votre main dominante, appuyez sur le bouton avec la lettre A si vous pensez d'avoir entendu le mot anglais. Appuyez sur le bouton marqué F si vous croyez d'avoir entendu le mot français. Appuyez sur le bouton aussitôt que vous avez faite votre décision.

Il n'y a pas de bonne réponse, on est simplement interéses à comprendre comment vous percevez ces sons. Si vous n'êtes pas

certains, choisissez la réponse qui vous sembe plus apprpriée. Avant que l'expérience débute, vous allez avoir quelques essaies de pratique. Si vous avez des questions, elles seront répondus à ce moment-là.

**PRACTICE ITEMS

Vous allez entendre 120/170 phrases en tout. Après chaque groupe de 10 phrases, i y aura une courte pause. Pendant l'expérience, un chercheur peut vous entendre en tout temps et sera à votre disposition si vous en avez besoin.

Appendix E: Example of the post-test questionnaire; ratings of naturalness and difficulty.

English:

CONDITION: _____
How natural did the last word in these sentences sound to you, on a scale from 1 to 5 with 1 being very natural and 5 being very unnatural?
1 2 3 4 5

On a scale from 1 to 5, how difficult was it to decide which language the final word in each sentence was for this group of sentences; with 1 being very easy and 5 being very difficult?
1 2 3 4 5

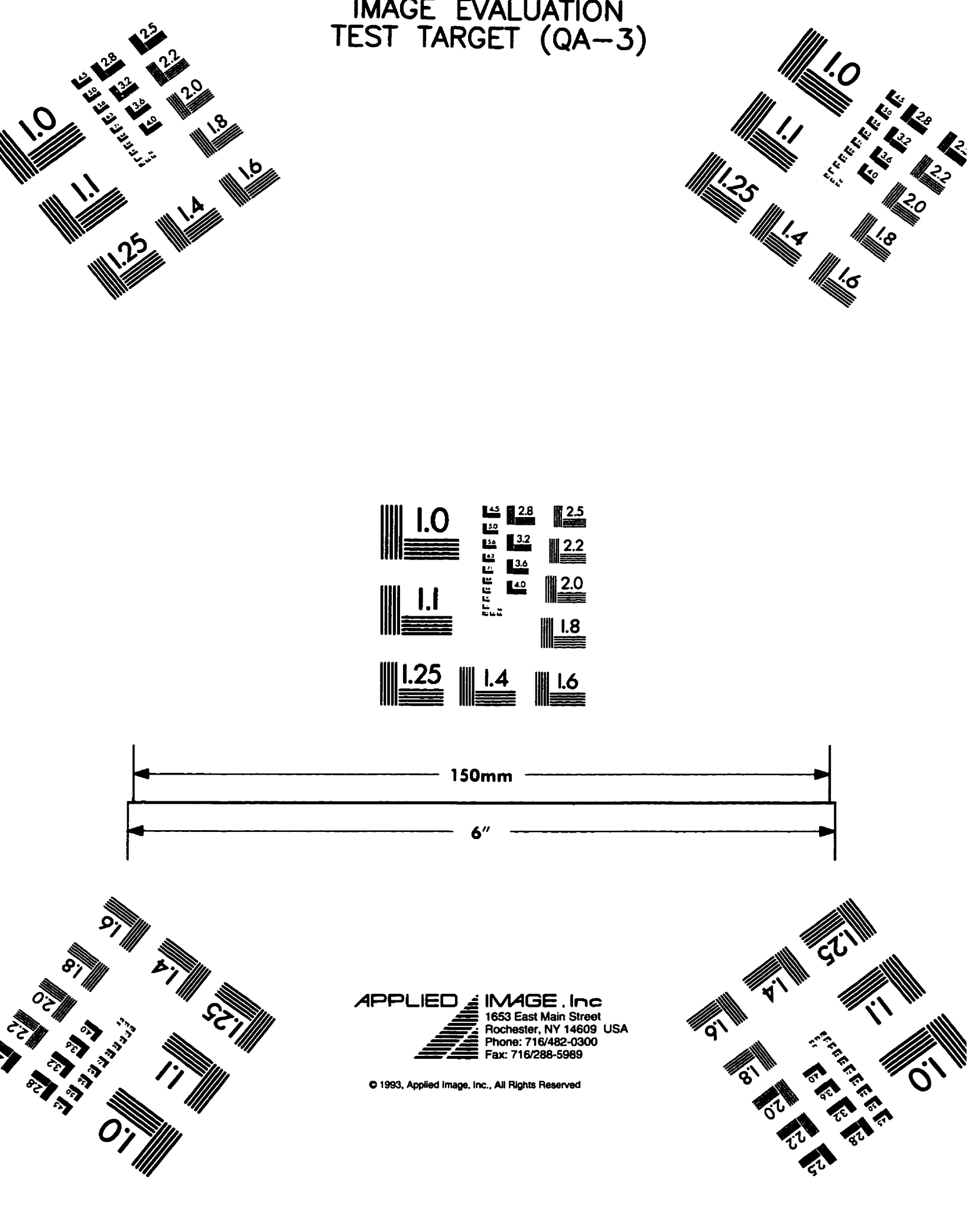
French:

Condition: _____

Sur une échelle de 1 à 5, indique si le dernier mots de chaque phrase vous semble naturel ou pas.
(Echelle: 1 - trés naturel, 5 - pas du tout naturel)
1 2 3 4 5

Indique le degré de difficulté à determiner dans quelle langue le derniers mots de cette serie de phrases fût présentés. (Echelle 1 - trés facile, 5 - trés difficile)
1 2 3 4 5

Ratings were done by each subject after each test condition.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