The Effect of Speech Rate and Noise on Bilinguals' Speech Perception: The Case of Native Speakers of Arabic in Israel

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Abstract

Listening conditions affect bilinguals' speech perception, but relatively little is known about the effect of the combination of *several* degrading listening conditions. We studied the combined effect of speech rate and background noise on bilinguals' speech perception in their L1 and L2. Speech perception of twenty Israeli university students, native speakers of Arabic (L1), with Hebrew as L2, was tested. The tests consisted of CHABA sentences adapted to Hebrew and Arabic. In each language, speech perception was evaluated under four conditions: quiet + regular speaking rate, quiet + fast speaking rate, noise + regular speaking rate, and noise + fast speaking rate. Results show that under optimal conditions bilingual speakers of Arabic and Hebrew have similar achievements in Arabic (L1) and Hebrew (L2). Under difficult conditions, performance was poorer in L2 than in L1. The lowest scores were in the combined condition. This reflects bilinguals' disadvantages when listening to L2.

Introduction

Speech perception is a complex auditory and cognitive process, which in real life often occurs in adverse listening conditions. Perception of the speech message depends on many factors including those related to the speech signal, the physical properties of the degrading conditions and the listeners' characteristics. As real life situations are not always auditorily ideal, various factors may complicate speech perception. For example, a common situation for bilingual students is the need to follow the speech of a fast speaking lecturer in a relatively noisy classroom. Does this combined condition affect bilinguals' perception more than each listening condition by itself? One would expect that the combined effect of fast speech rate and noise would have a detrimental effect on intelligibility, but this issue is under-researched, as far as we know.

Bilinguals' speech perception in noise was found worse than that of native speakers of one of the bilinguals' languages under the same conditions ([1], [2], [3], [4], [5], [6], [7], [8], [9]). The effect of increased speech rate on bilinguals' speech perception has been found to contribute to intelligibility difficulties. Speech rate increase combined with frequency shift has also been found to cause the greatest deterioration in speech perception ([10]).

Investigating the combined effect of several degrading factors on the speech perception of bilinguals is of great importance considering the large number of bilinguals in the world that are required to communicate daily under such degrading listening conditions as background noise, reverberation and/or fast speech rate.

The purpose of the present study is to investigate the combined effect of two factors, speech rate and background noise, in bilinguals in Israel. In Israel native speakers of Arabic are very often bilinguals ([11]). In this population, the first language (L1) is Arabic, and L2 is Hebrew, the first official and dominant language of the country. Due to the fact that native speakers of Arabic constitute the largest minority in the country we investigated speech perception within speakers of this group.

It should be noted that Hebrew and Arabic are living Semitic languages and share several similar features (on all the levels of language structure) but differ in others [12], [13]. In addition to its general importance, the topic of this study has not been studied with this population or these languages either in Israel or elsewhere.

We focused, first of all, on the Arabic-Hebrew bilinguals' speech perception performance in each of these languages. Then, we investigated how different adverse listening conditions affected speech perception skills of these bilinguals, who were native speakers of Arabic in Israel.

We assumed that under optimal conditions, native speakers of Arabic would show similar results in speech perception tasks in both languages (Hebrew and Arabic). It was also assumed that each degrading auditory condition would have a greater detrimental effect in L2 than in L1. A further assumption was that the combination of background noise and fast speech rate would yield greater impact on L2 than on L1, and to a greater extent than on each of these effects on its own.

Method and Procedure

Subjects

The subjects were ten male and ten female university students, native speakers of Arabic, with Hebrew as L2. Their age range was 20-24 years old and they used Arabic at home. All began learning Hebrew at school in the 3rd grade. All were second year students of different university departments in a Hebrew-speaking Israeli university and had good hearing. Thus, their background was similar in terms of exposure to Hebrew and habits of its use.

Speech stimuli

Speech stimuli included 32 CHABA test sentences adapted to Hebrew ([14] [15]) and Arabic, making 64 sentences altogether. The Arabic test was presented in colloquial Arabic, which is *de facto* the subjects' L1. Since it was impossible to give a literal translation of the Hebrew sentences into Arabic while maintaining the same phonetic and other linguistic elements, the test sentences were adapted to Arabic in terms of content, length (number of syllables), grammatical structure, difficulty level, lexical frequency, phoneme distribution, redundancy and target words.

Recordings

The Hebrew and Arabic test sentences were read aloud by one and the same speaker, an early-bilingual female native speaker of Arabic, who had acquired Hebrew before school age. The speaker's pronunciation, as assessed by native speakers of the two languages, was found to be natural and with no identifiable accent. Recording was conducted in a sound-treated room via a microphone onto a Sony tape recorder (TCM – 5000EV).

All the sentences were recorded at two speaking rates (by the same speaker): normal and fast. At the normal speech rate, syllables' average duration was 0.3305 sec/syllable whereas the fast speech rate was determined at an average of 0.2505 sec/syllable. Syllable duration was measured using the Sound Forge 4.0 (Sonic Foundry) waveform analysis software. Sentences were mixed with babble noise at signal-to-noise ratio (S/N) of +6dB (RMS level) using a Sony mixer (Mu-x 121) and then recorded onto a Revox tape-recorder (type B215). The output level at the earphone was 70 dB SPL.

Procedure

Each subject was examined separately in a quiet room. After a short familiarization with the task, subjects were instructed to repeat each sentence as best they could. Subjects were tested in two half-hour sessions. The first testing session included the hearing-screening test and half of the test lists (Hebrew or Arabic). In the second session the other half of the test lists (Hebrew or Arabic) was administered. The sentences were presented via earphones (TDH 49) to one ear chosen at random, using a Sony tape-recorder (TCM – 5000EV). Between any two sentences a pause equal to the sentence duration plus three seconds was inserted, to provide sufficient time for repetition. In addition, the examiner wrote down subjects' answers after each sentence.

In this study speech perception in Arabic (L1) and Hebrew (L2) was tested under the auditory conditions speech rate and background noise, separately and in combination. This yielded four test conditions per language: (a) no background noise + regular speaking rate (QR), (b) no background noise + fast speaking rate (QF), (c) background noise

(+6dB) + a regular speaking rate (NR), and (d) combination of background noise + a fast speaking rate (NF).

Scoring

Following the scoring method of the CHABA tests, each sentence was assigned with target words. The position in the sentence and the function of the target words were similar across the two languages. An exact repetition of the target word was worth 2.5 % points.

Results

The mean word identification scores were studied using a three-way repeated-measures MANOVA on the arcsine transformation of the data in order to test the main effects of Language (L1 and L2), Background (Quiet and Noise), and Speech Rate (Regular and Fast), as well as interactions. The results of this analysis are shown in Appendix A. It can be seen that all main effects were found to be significant. Specifically, group mean word identification score in L1 (79.8%) was significantly better than in L2 (66.1%), identification of words in quiet (87.26 %) was significantly better than in background noise (58.65 %), and words in normal speech rate were better identified (83.56%) than when produced at a faster rate (62.36%). Similarly, all two-way interactions were found to be significant. The significant Language x Background interaction revealed that word identification in L1 deteriorated by approximately 23 percentage points when introduced in noise (from 91.5% to 68.06%) compared to a greater decrease of 33 percentage points when listening in L2 (from 83.03% to 49.26%). The significant language x speech rate showed that faster speech has a detrimental effect on L2 compared to L1. In L2, fast speech resulted in a decrease of approximately 28% points (in reference to regular speech rate) compared to a decrease of only 19% points in L1. The results also show that the combined effect of fast speech rate and background noise (NF) had a greater detrimental effect for L2 (a decrease in performance of approximately 61% from QR) than this combined effect in L1 (a decrease in performance of approximately 39% compared to QR).

Discussion and Conclusions

The aim of this study was twofold: (1) to study the differences in speech perception of L2 vs. L1 in bilingual native speakers of Arabic whose L2 was Hebrew, and (2) to study the effect of different listening conditions on their speech perception. An important feature of our study resides in its testing simulated natural and real-life conditions by this test method.

As expected, there was no significant difference between the bilingual listeners in testing their L1 and L2 speech perception under optimal conditions (cf. [5], [9]). We also found that speech perception deteriorated due to fast speech rate and background noise compared to normal speech condition in both L1 and L2. In this the results are similar to results of other studies (e.g., [5], [7], [9]). An unexpected finding was that the effect of fast speech rate was significant on its own, whereas the effect of noise on speech perception in L1 or L2 on its own was not significant.

The lower perception effect due to background noise was found much stronger than in other studies on other languages ([14], [15]). In this regard we note that the babble noise type used here is considered especially difficult, because it contains misleading cues which increase memory and attention load ([16]). The severity of the affected perception in L2 (compared to data given in the literature) was especially noted in this population.

These results reveal the importance of good acoustic conditions for non-balanced bilingual students who study in their L2 ([4], [17]).

Acknowledgment

We thank Mrs. L. Haik-Andrea for her contribution to this study and Ms. Esther Shabtay for statistical help in this study.

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Appendix A.

Repeated measures analysis of variance separating the effects of Language (L1, L2), Background (quiet, noise), and Speech Rate (regular, fast).

Source	df(n,d)	F	p
Language (L)	(1,19)	62.59	0.0001
Background (BG)	(1,19)	188.88	0.0001
Speech Rate (SR)	(1,19)	155.29	0.0001
L x BG	(1,19)	4.06	0.058
L x SR	(1,19)	14.46	0.0012
BG x SR	(1,19)	13.70	0.0015
L x BG x SR	(1,19)	0.01	0.92

Note Performed on the arcsine-transformed data