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Language Familiarity Modulates Relative Attention to the Eyes and Mouth of a Talker

Elan Barenholtz^{*},

Department of Psychology/Center for Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, FL

Lauren Mavica, and

Department of Psychology, Florida Atlantic University, Boca Raton, FL

David J. Lewkowicz

Department of Communication Sciences and Disorders, Northeastern University, Boston, MA

Abstract

We investigated whether the audiovisual speech cues available in a talker's mouth elicit greater attention when adults have to process speech in an unfamiliar language vs. a familiar language. Participants performed a speech-encoding task while watching and listening to videos of a talker in a familiar language (English) or an unfamiliar language (Spanish or Icelandic). Attention to the mouth increased in monolingual subjects in response to an unfamiliar language condition but did not in bilingual subjects when the task required speech processing. In the absence of an explicit speech-processing task, subjects attended equally to the eyes and mouth in response to both familiar and unfamiliar languages. Overall, these results demonstrate that language familiarity modulates selective attention to the redundant audiovisual speech cues in a talker's mouth in adults. When considered together with similar findings from infants, our findings suggest that this attentional strategy emerges very early in life.

Speech processing depends on the rapid encoding and interpretation of a complex auditory signal. Fortunately, natural languages contain a high degree of structure at the phonetic, lexical, syntactic, and semantic levels and prior knowledge of these structures can facilitate processing. For example, under noisy conditions, speech perception is more accurate when the spoken language is familiar (Cutler, Weber, Smits, & Cooper, 2004; Gat & Keith, 1978; Lecumberri & Cooke, 2006; Mayo, Florentine, & Buus, 1997; Van Wijngaarden, Steeneken, & Houtgast, 2002), suggesting that language familiarity can reduce the amount of bottom-up information needed to successfully process it.

While the effects of familiarity in language processing have primarily been considered in relation to auditory stimuli, linguistic communication is typically multisensory in nature consisting of integrating audible and visible speech (McGurk & MacDonald, 1976). Such audiovisual integration lead to increased perceptual salience, effectively amplifying the

^{*}Correspondence concerning this article should be addressed to: Elan Barenholtz, Department of Psychology, Florida Atlantic University, Boca Raton, FL, 34331, elan.barenholtz@fau.edu.

sensory signal (Meredith & Stein, 1986; Partan & Marler, 1999; Rowe, 1999). In the specific case of auditory speech, concurrent access to redundant visible speech cues can enhance speech perception under noisy conditions (Middelweerd & Plomp, 1987; Rosenblum, 2008; Rosenblum, Johnson, & Saldana, 1996; Sumby & Pollack, 1954; Summerfield, 1979).

How does language familiarity interact with audiovisual speech processing? Several recent studies have found that familiarity with a language modulates the timecourse of perceived synchrony between an auditory and visual speech signal (Love, Pollick, & Petrini, 2012; Navarra, Alsius, Velasco, Soto-Faraco, & Spence, 2010) (Navarra, Alsius, Velasco, Soto-Faraco and Spence, 2010; Love, Pollick and Petrini, 2012), perhaps by speeding up the auditory processing of familiar speech. Another potential effect of familiarity is that it may modulate selective attention during speech encoding. Because familiarity reduces the amount of bottom-up information needed to process the speech signal, perceivers of an unfamiliar language may take relatively greater advantage of audiovisual speech redundancy by deploying selective attention to the source of audiovisual redundancy: the interlocutor's mouth.

Recent evidence indicates that the tendency to deploy greater attention to a talker's mouth emerges during the second half of the first year of life, during the time when infants begin acquiring their initial native-language expertise. Lewkowicz and Hansen-Tift (2012) presented monolingual, English-learning infants of different ages with videos of talkers speaking either in their native language or in a non-native language (i.e., Spanish). At 4 months, infants fixated the talker's eyes whereas at 8 and 10 months of age—when infants enter the canonical babbling stage and begin to acquire spoken language—they fixated the talker's mouth. At 12 months of age, the infants no longer fixated the mouth more than the eyes when the talker spoke in the infants' native language but continued to fixate the mouth more when the talker spoke in the non-native language. Lewkowicz and Hansen-Tift (2012) attributed the difference in attention to the talker's mouth at 12 months to the emergence of initial native-language expertise and a concurrent narrowing of perceptual sensitivity to other languages leading to increased reliance on audiovisual redundancy in the case of unfamiliar language input.

The results from the Lewkowicz and Tift study provide the first evidence that selective attention to the multisensory redundancy of the mouth is modulated by language familiarity. If this early lip-reading behavior reflects a general encoding strategy in response to differences in linguistic familiarity, these differences in fixation behavior may persist into adulthood. As pointed out by Lewkowicz and Tift (2012), however, infants are not only learning to encode and understand speech but are also learning to produce speech. Thus, lipreading in infancy may not only reflect speech processing but may also reflect the acquisition of speech production capacity. If so, fixation of the mouth in infancy may specifically reflect the fact that infants are learning how to imitate and produce human speech sounds and may or may not generalize to adults. Indeed, data from another experiment Lewkowicz and Tift (2012) support this conclusion. They found that monolingual English-speaking adults looked longer at the eyes of a talker, regardless of whether she spoke in their native language or not.

Crucially, the adults in the Lewkowicz and Tift study were only asked to watch and listen to the talker without any explicit task. Studies with adults indicate that the distribution of attention to the eyes and mouth is modulated by task. When speech cues are relevant, the mouth attracts more attention (Buchan, Paré, & Munhall, 2007; Driver & Baylis, 1993; C. Lansing & McConkie, 2003; C. R. Lansing & McConkie, 1999). This is especially true when the auditory signal is degraded (Driver & Baylis, 1993; C. Lansing & McConkie, 2003; Vatikiotis-Bateson, Eigsti, Yano, & Munhall, 1998). When, however, social reference, emotional, and deictic cues are relevant, the eyes elicit more attention (Birmingham, Bischof, & Kingstone, 2008; Emery, 2000).

Given these findings, we asked whether speech in an unfamiliar language might cause adults to attend more to a talker's mouth if their explicit task is to process the speech. To test this possibility, we tracked selective attention in adults while they watched and listened to people speaking either in their native and, thus, familiar (English) language or in an unfamiliar (Icelandic or Spanish) language. The participants were explicitly required to encode the speech stimulus by subsequently being asked to perform a simple match-to-sample task. We expected that the participants would attend more to the mouth in the unfamiliar than in the familiar language condition.

Experiment 1

Methods

Participants—Participants were 60 self-described English-speaking monolingual, Florida Atlantic University undergraduate students, participating for course credit. Thirty participants were randomly assigned one of two Language groups (English/Icelandic or English/Spanish). Each group of 30 was further subdivided into two groups of 15 with the order of language presentation (i.e. familiar or unfamiliar first) counterbalanced across participants.

Stimuli—Stimuli consisted of movie recordings of two female models, recorded in a sound-attenuated room and presented on an infrared-based eye tracking system (T60; Tobii Technology, Stockholm, Sweden¹) on a 17-inch computer monitor. Both models were fully bilingual speakers of both English (with no discernible accent) and one other native language (one Spanish, one Icelandic). Each model was recorded speaking a set of 20 sentences in English and the same 20 sentences in her other, native language. The models were recorded from their shoulders up and were instructed to speak naturally in an emotionally passive tone without moving their head. The face of the models measured approximately 6 degrees visual angle width (ear to ear) by approximately 11 degrees visual angle length. The recorded individual sentences averaged 2.5 seconds each for all three recorded languages.

Procedure—A single trial is schematized in Figure 1. Participants were presented with sequentially presented pairs of video segments, each consisting of the same person audibly

¹Technical specifications are available at: http://www.tobii.com/Global/Analysis/Downloads/User_Manuals_and_Guides/Tobii_T60_T120_EyeTracker_UserManual.pdf

uttering a short sentence, followed by an audio-only clip of one of the two sentences (Figure 1). Participants had to choose which of the two previously presented audiovisual movie segments corresponded to the audio-only clip. For half the participants, the video sequences consisted of a bilingual female speaking English (familiar) sentences in one block and the same model speaking Icelandic (unfamiliar) sentences in a different block (English/Icelandic group). For the other half of the participants, the sequences consisted of a different model speaking English sentences in one block and the same model speaking Spanish sentences in a different block (English/Spanish group). Participants indicated whether the auditory-only clip was extracted from the first or second movie by pressing a key on the keyboard.

Each participant completed two experimental blocks, each consisting of ten pairs of sentences. In one block, all of the sentences were in English while in the other block they were all in an unfamiliar language, either Icelandic or Spanish. Each group was only presented with one model, speaking both English and Icelandic (Icelandic Group) or English and Spanish (Spanish Group). This ensured that the same visual features were present across the familiar and unfamiliar blocks for each participant. Block order (i.e. familiar or unfamiliar presented first or second) was counterbalanced across participants.

Participants' eye movements were recorded with an eye tracking system (T120; Tobii Technology, Stockholm, Sweden) and analyzed with the Tobii Studio 3.0.6 software. Gaze was monitored using near infrared and both bright and dark pupil-centered corneal reflection. Stimuli were presented on a 17-inch flat panel monitor with a screen resolution of 1280×1024 pixels and a sampling rate of 120 Hz. All participants were tested in a quiet room that was illuminated by the stimulus display and were seated ~60 cm from the screen. A standardized five-point calibration was performed prior to tracking as implemented in Tobii Studio software.

Fixation Analyses—We defined three principal areas of interest (AOIs): the mouth, the eyes, and the whole face. For each condition, we calculated the time spent fixating the eye and mouth AOIs as a percentage of the total time spent fixating anywhere within the face AOI (Note that fixations within either the mouth or eyes AOI were counted toward the total fixation duration to the face). Fixation (as contrasted with saccades or other eye movements) durations were determined using Tobii Studio's fixation filter algorithm², which distinguishes between time spent fixating within an AOI (which were the basis of our analyses) and time spent engaging in a saccade (which were not included in the analyses).

Results

Performance in the matching task was near ceiling (between 95%–97%) across all conditions. Figure 2a shows the proportion of time spent fixating the mouth and eye regions for the English/Icelandic group. Figure 2b shows the same results for the English/Spanish group. Consistent with previous studies of selective attention in adults during active speech processing (Driver & Baylis, 1993; C. Lansing & McConkie, 2003; C. R. Lansing & McConkie, 1999), we found greater overall fixation of the mouth than the eyes, $t(59) =$

²<http://www.tobii.com/eye-tracking-research/global/library/white-papers/the-tobii-i-vt-fixation-filter/>

10.209, $p < .001$ for the English/Icelandic Group. In addition, and of particular interest given our initial hypothesis, we found that participants' looked more at the mouth vs. the eyes when the speech was unfamiliar compared with when it was familiar in each respective group. Specifically, in the English/Icelandic group, the mouth-vs.-eyes difference score was greater for the Icelandic block of trials, $M = .42$, $SD = .24$ than for the English block of trials, $M = .23$, $SD = .27$, $t(29) = 5.877$, $p < .001$, two-tailed, $d = .74$. Similarly, in the English/Spanish group, the mouth-vs.-eyes difference score was greater for the Spanish block of trials, $M = .53$, $SD = .26$ than for the English block of trials, $M = .40$, $SD = .30$, $t(29) = 4.596$, $p < .001$, two-tailed t-test, $d = .46$. Thus, across both language pairs, participants looked more at the mouth and less at the eyes when exposed to an unfamiliar language.

Experiment 2

Experiment 1 was designed to compare fixation behavior during encoding of familiar and unfamiliar languages. Because we only included monolingual English speakers as participants, English served as the familiar language in both groups. This raises the possibility that some property of the English stimuli, other than familiarity itself, contributed to lower amounts of attention directed at the speaker's mouth compared with the Spanish and Icelandic stimuli. To test whether familiarity *per se* modulates mouth fixations, in Experiment 2 we employed the same task and stimuli as in the English/Spanish group in Experiment 1 except that this time we tested bilingual English/Spanish participants. If language familiarity mediated the increase in attention to the mouth in Experiment 1 - and not some inherent property of the English language stimuli - then bilingual participants, who are equally familiar with both languages, should exhibit equal amounts of attention to the talker's mouth for both languages.

Methods

Participants—Participants in Experiment 2 were 30³ self-described Spanish/English bilinguals who reported being equally familiar with both languages.

Stimuli and Procedure—Stimuli and Procedure were identical to those employed in the English-Spanish group in Experiment 1.

Results—As predicted, the mouth-vs.-eyes difference scores were not significantly different for the Spanish block of trials, $M = .04$, $SD = .34$, compared with the English block of trials, $M = .12$, $SD = .33$, $t(29) = 1.705$ for a two-tailed t-test, $p = .09$. These findings presumably reflect the fact that both languages were equally familiar to these participants and, thus, that the encoding task was equally difficult. They also indicate that the lower amount of looking at the mouth obtained in response to the English sentences in Experiment 1 was not due to some visual or auditory properties of English *per se* but, rather, to the familiarity of this language to the monolingual, English-speaking participants in that experiment. Because the Spanish/English stimuli were identical in Experiment 1 and 2, we

³Sample size was equated to a single language group in Experiment 1. Power analyses of the English vs. Spanish comparison in Experiment 1, which yielded a critical sample size of 22 in order to detect an effect with 80% confidence.

could compare the difference scores between the monolingual and bilingual participants in the two respective experiments. A 2-way Mixed ANOVA with language as the within-subject variable and bilingualism as the between-subjects variable found a significant effect of language (English vs. Spanish), $F(1) = 21.866, p < .001$, a significant effect of bilingualism, $F(1) = 18.484, p < .001$, and a significant interaction, $F(1) = 21.866, p < .001$. This interaction supports the hypothesis that familiarity was the determining factor in producing the difference in fixations for the English and Spanish stimuli in Experiment 1.

Experiment 3

The participants in the Lewkowicz and Hansen-Tift (2012) study looked more at the eyes regardless of language familiarity. As indicated earlier, however, they were not required to perform any sort of information-processing task. Given our active-processing hypothesis, it is not surprising that in the absence of an explicit information-processing task, adults do not deploy greater attentional resources to a talker's mouth. The current experiment explicitly tested this possibility by, once again, administering the English/Icelandic comparison from Experiment 1 with monolingual English-speaking adults. This time, however, we did not impose an explicit speech processing task.

Methods

Participants—Participants were a new cohort of 30⁴ self-described English-speaking monolinguals.

Stimuli and Procedure

Stimuli and procedure were identical to those employed in the English-Icelandic group in Experiment 1. The only difference was that the two movies were not followed by an auditory-only test trial and that the participants were not given any specific task except to freely watch and listen to the movies.

Results and Discussion

We found that participants did not attend more to the speaker's mouth in the Icelandic block of trials, $M = .50, SD = .29$, than in the English block of trials, $M = .44, SD = .30, t(29) = 1.7, p = .1$. Likewise, they did not look longer at the talker's eyes in the English block of trials, $M = .23, SD = .28$, than in the Icelandic block of trials, $M = .23, SD = .24$, than in the = .145, $p > .50$. Thus, as predicted, the familiar vs. an unfamiliar difference in fixations was not present when participants were not required to process the audiovisual speech. However, it should be noted that the overall preference to fixate the mouth over the eyes across both language conditions is not consistent with those of Lewkowicz and Tift (2012). These differences may be due to the nature of the stimuli which, in our case, consisted of brief, isolated sentences pronounced in monotone while their stimuli consisted of longer monologues pronounced in 'motherese'. In any case, this difference in general fixation

⁴Sample size was equated to a single language group in Experiment 1. Power analyses of the English-Icelandic blocks in Experiment 1 yielded a critical sample size of 13 in order to detect an effect with 80% confidence.

behavior suggests that direct comparison between our results and theirs may not be appropriate.

Because the Icelandic/English stimuli were identical in Experiment 1 and 3, we could compare the difference scores between the monolingual and bilingual participants in the two respective experiments. A 2-way Mixed ANOVA with language as the within-subject variable and task vs. no task as the between-subjects variable found a significant effect of language (English vs. Icelandic), $F(1) = 21.003$, $p < .001$, a non significant effect of bilingualism, $F(1) = 1.086$, $p < .1$, and a significant interaction, $F(1) = 7.802$, $p = .007$. This interaction supports the hypothesis that an encoding task was a critical factor in producing the differences in fixations for the English and Icelandic stimuli in Experiment 1.

General Discussion

We found that adults devote greater attention to the source of audiovisual speech, namely a talker's mouth, when their task is to encode speech in an unfamiliar language than in an unfamiliar one. These findings complement previous results indicating that adults seek out audiovisual redundancy cues when the auditory signal is poor (Driver & Baylis, 1993; C. Lansing & McConkie, 2003; Vatikiotis-Bateson et al., 1998)a. Here, we show that adults also rely on audiovisual redundancy cues when dealing with high-quality speech but in an unfamiliar language. This suggests that adults possess a highly flexible system of attentional allocation that they can modulate based on the discriminability of an audiovisual speech signal, their particular speech-processing demands, and their perceptual/cognitive expertise in the particular language being uttered.

These results suggest that previous reports of enhanced mouth fixations in both adults and infants may reflect the same strategy: increased reliance on multisensory redundancy in the face of uncertainty about an audiovisual speech signal. According to this view, linguistic experience may account for the shifting developmental pattern of selective attention obtained by Lewkowicz and Tift (2012). During speech and language acquisition, initially infants seek out a talker's mouth to overcome the high degree of uncertainty. Once they begin to master the various properties of their language, however, infants reduce their reliance on audiovisual redundancy for their native/familiar language but continue to rely on them for a non- native/unfamiliar language. Consistent with this, recent evidence shows that bilingual infants, who face the enormous cognitive challenge of learning two different languages, rely even more than monolingual infants on audiovisual speech redundancy cues (Pons, Bosch, & Lewkowicz, In Press). The current findings indicate that when adults encounter unfamiliar speech, they resort to the same attentional strategy used by infants to disambiguate it.

Our results add to a growing body of literature demonstrating that the mouth can serve as an important source of information during audiovisual speech encoding. Nonetheless, it should be noted that attention to the mouth is not essential for integrating visual and auditory information. Audiovisual speech integration, as in the McGurk effect, can be found even at high levels of eccentricity (Paré, Richler, ten Hove, & Munhall, 2003). Thus, attention to a talker's mouth may reflect a strategy of perceptual enhancement beyond that which is

absolutely necessary for integration, particularly under suboptimal encoding conditions. This enhancement may be primarily perceptual in nature, based on the higher resolution of the mouth region that comes with fixation. Alternatively, it may be primarily attentional in nature, based on additional *processing* of the fixated region. Finally, it may be due to a combination of both perceptual and attentional enhancement of the audiovisual stimulus. Additional research will be required to disentangle these potential contributing factors.

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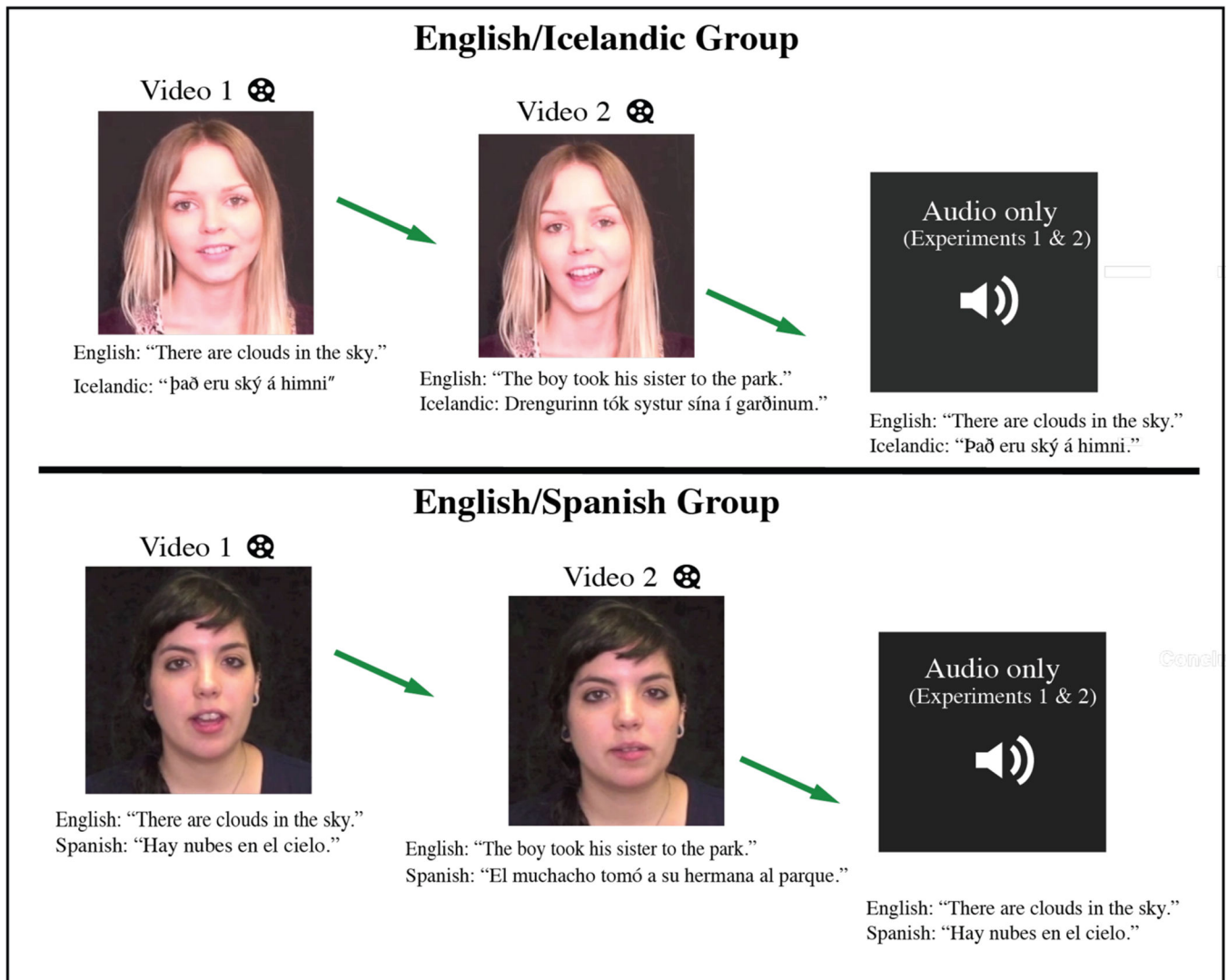


Figure 1.

Schematic representation of the experimental procedure in all three experiments. On each trial, participants were first presented sequentially with two movies showing a person uttering two sentences in either a familiar (English) or unfamiliar (Icelandic or Spanish) language. In Experiments 1 and 2, these movies were followed by an auditory only sample of one of the two sentences previously presented. Participants' task was to report whether the audio-only sentence corresponded to the first or second movie. Experiment 3 did not have an auditory-only experimental task. See text for details.

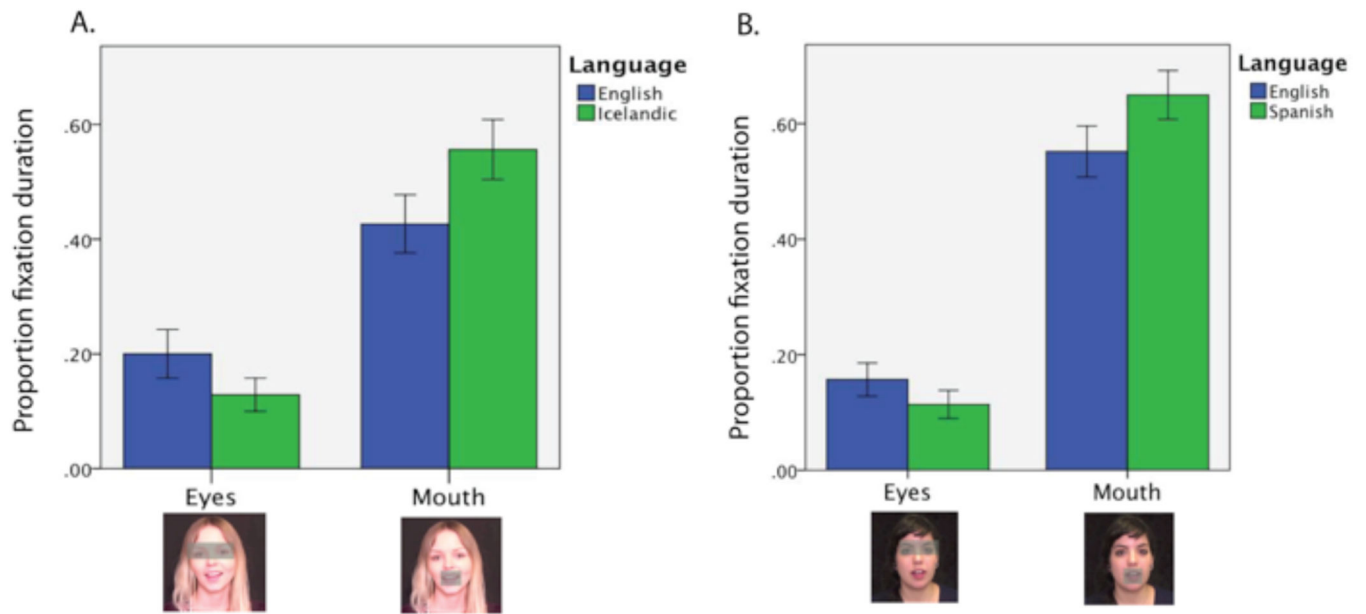


Figure 2.

Proportion of fixation duration (relative to the whole face), for the eyes and mouth AOI's, across languages in the English-Icelandic (A) and English-Spanish (B) blocks in experiment 1. AOIs are shown as gray bars in the face images for illustration; they did not appear in the experimental stimuli.