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Respiratory differences in spontaneous and scripted speech among bilingual adults

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RESPIRATORY DIFFERENCES IN SPONTANEOUS AND SCRIPTED SPEECH AMONG BILINGUAL ADULTS

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Abstract

This investigation explored respiratory differences between a speaker's first language (L1) and second language (L2) during spontaneous and scripted speech in six adult bilingual speakers (two native bilingual speakers and four non-native bilingual speakers). Respiratory kinematic data using Respitrace respiratory inductance plethysmography and acoustic recordings were collected during five tasks: tidal breathing at rest, scripted speech in L1, spontaneous speech in L1, scripted speech in L2, and spontaneous speech in L2. Results indicated a significant interaction effect between proficiency and syllables produced during spontaneous speech, but no other significant differences were found among inspiratory/expiratory duration, task, proficiency or language. The data provides insight into how a higher cognitive-linguistic load of speaking in a second language may affect speech breathing and contributes to the existing pool of knowledge on monolingual cognitive-linguistic demands and speech breathing.

Literature Review

It can be assumed that the field of speech-language pathology has intensively studied the science of speech. Speech is a complex process involving muscle groups, neurological planning, and the often overlooked aspect of breathing. As an unconscious life function, the ability to breath can be taken for granted by those who breath with ease. Others who experience more difficulties in the respiratory system may appreciate the function on a higher level. Speech breathing in healthy individuals involves an organized pattern of breaths taken in (inspirations) and breaths pushing out (expirations). The science of speech breathing has formed a solid foundation in the research, paving the way for research on speech breathing disoders and clinical implications. Though this information is significant, it almost exclusively applies to individuals who are monolingual. Little is known about the speech breathing patterns of individuals who are learning a new language or who are natively bilingual. This population and their speech breathing patterns are explored in the following thesis.

Numerous studies have investigated the respiratory behaviors of speech breathing in typical monolinguals (Henderson, Goldman-Eisler, & Skarbek, 1965; Hixon, Goldman, & Mead, 1973; Hixon, Mead, & Goldman, 1976; Winkworth, Davis, Adams, & Ellis, 1995; Winkworth, Davis, Ellis, & Adams, 1994). Additional research has focused on various linguistic tasks and their effect on respiratory behaviors including reading (Winkworth et al., 1994) and spontaneous speech (Winkworth et al., 1995), as well as differences between subject groups and the effect of posture (Hixon et al., 1973), body type (Hoit & Hixon, 1986), and age (Hoit & Hixon, 1987). These comprise just a small sample of the literature that has suggested that many factors can contribute to the complexity needed in speech breathing.

Spontaneous Speech vs. Speech Reading

Speech exists in multiple forms including spontaneous speech and scripted speech or reading aloud. The breathing behaviors of individuals during spontaneous speech and reading aloud differ. Reading is associated with increased speech rate, fewer disfluencies, and more inspirations taken at grammatical locations (Henderson et al., 1965). Other differences involve use of lung volumes and the influence of cognitive and linguistic factors.

Lung Volumes

Lung volumes differ between tidal breathing (breathing without speech), spontaneous speech breathing, and scripted speech breathing. Hixon et. al. (1973) reported that healthy adults typically use a lung volume ranging from 20% to 70% of vital capacity with most expirations initiated between 50% to 60% vital capacity and terminated between 50% to 30% vital capacity. A mean lung volume around 39% is generally agreed on among researchers and has shown to be similar in spontaneous speech and in speech reading (Russell & Stathopoulos, 1988; Winkworth et al., 1994; Winkworth et al., 1995). Although, as discussed in Winkworth et al. (1995), spontaneous speech commonly has a larger range in lung volume, which accounts for longer utterances typically used in spontaneous speech when compared to speech reading. Speech inspirations typically comprise 10% of a respiratory cycle whereas expiration is 90%, indicating a control of these lung volumes throughout the spoken utterance versus metabolic rest breathing, which is closer to 50% each.

Linguistic Factors

Linguistic factors such as length of utterance and grammatical segmentation have effects on speech breathing, particularly the volume inspired and the timing of inspirations and expirations (Conrad, Thalacker, & Schönle, 1983; Winkworth et al., 1994). During speech reading, research has indicated that nearly every paragraph and sentence boundary co-occurs with an inspiration (Conrad et al., 1983; Winkworth et al., 1994). Winkworth et al. (1994, 1995) concluded that the strongest indicator of an upcoming inspiration was a new paragraph or sentence; however, during spontaneous speech, speakers are less likely to take inspirations at grammatically appropriate locations. Henderson et al. (1965) presented that 100% of reading inspirations were taken at grammatical locations compared to roughly 69% of spontaneous speech inspirations taken at grammatical locations. Winkworth et al. (1994, 1995) corroborated their findings by reporting that 88% of reading inspirations were taken at grammatical locations compared to 63% of spontaneous speech inspiration taken at grammatical locations. This relates to differing functions of each breath.

Inspirations taken during speech reading seem to be driven by the sentence structure of the language whereas inspirations taken during spontaneous speech are often more variable and flexible in what drives them, based on the upcoming demands. During fluent spontaneous speech, inspirations can be driven by sentence structure of the language (similar to speech reading) but during periods of indecisiveness when the speaker is unsure what they will say, inspirations can be caused by hesitancy and planning, therefore not always at grammatical junctures (Henderson et al., 1965). Throughout spontaneous speech is this organized pattern of speech and pauses, which suggests periods of planning and cognition followed by continuous/fluent speech. These organized patterns do not occur during speech reading (Henderson et al., 1965); therefore, pauses taken during reading and pauses taken during spontaneous speech serve different purposes. Primarily, spontaneous speech pauses are a period of preplanning and reading pauses are a result of text structure or metabolic need.

Other linguistic factors also alter speech breathing. During reading, Winkworth et al. (1994) reported that longer sentences were more likely to be followed by an inspiration than following shorter sentences. For example, the 22-word sentence of the Rainbow Passage was followed by an inspiration 100% of the time while the eight-word sentence of the passage was followed by an inspiration 80% of the time. This would be expected, but the variations in the ranges by subject were quite different for the two tasks, with the percentage of inspirations taken at structural boundaries during spontaneous speech ranging from 22-92% whereas the range was just 65-100% during reading (Winkworth et al., 1994). The decreased variability in inspiratory locations in reading probably relates to the predetermined linguistic markers that are available to speakers, whereas these linguistic markers during spontaneous speech may be adjusted in real time.

When looking at linguistic factors and how they influence lung volume, Winkworth et al. (1994) discussed that inspirations before a new paragraph were often composed of relatively greater lung volume than inspirations at sentences within paragraphs. Further, inspirations at sentences within paragraphs contain a greater lung volume than those at clauses and phrases within sentences (Conrad et al., 1983; Winkworth et al., 1994). This correlation of major (paragraph and sentence) boundaries using greater lung volume and minor (within sentences) boundaries using less lung volume suggests that readers scan ahead to what they will read next and take an inspiration that will last the length of the following utterance (Winkworth et al., 1994). In other words, neural planning in the respiratory system might be occurring.

Neural Planning for Respiratory Behaviors

Determining the depth of an inspiration before a speech utterance is an unconscious function Some studies suggested that speakers may scan ahead in text to pre plan their inspirations for the length of the utterance they are about to say (Winkworth et al., 1995) while others claimed ongoing adjustments are made as the speaker talks (Winkworth et al., 1994), and both of these may be occurring during different scenarios. Winkworth and colleagues (1995) argued that inspirations during spontaneous speech were appropriately coordinated by anticipating the duration of the following expiration. For example, longer inspirations preceded long utterances (expirations) more often than they preceded shorter utterances (expirations). This suggests a neural planning system with the respiratory system. Winkworth et al.'s (1994) previous study suggested an online adjustment system may also be present during spontaneous speech that continues utterances to a lower lung volume until a reasonable linguistic stopping point. In other words, a generic inspiration was taken, and the expiration stopped when the speaker's phrase reached a linguistic barrier (sentence, phrase, paragraph, etc.). This would result in the speaker having a lower ending lung volume, suggesting it was a preference to finish a phrase or thought before taking another inspiration. Both theories hold substance and both, in the end, rely on linguistic factors to determine length of expiration.

Cognitive-Linguistic Demands

As linguistic factors play a role in speech breathing, cognitive-linguistic demands also influence speech. Henderson and colleagues (1966) stated that during spontaneous speech, sentences with hesitation pauses caused slow speech with an increased number of inspirations. This highly ventilated speech suggests linguistic structuring processes. The pauses also suggest a higher cognitive-linguistic load due to the decision making and need to formulate words (Henderson et al., 1965). This is different from speech reading because the process of determining what to say does not exist during reading.

To measure the cognitive-linguistic influence on speech breathing, two tasks were compared, one of which contained a higher cognitive-linguistic load than the other. Results showed that participants during the higher cognitive-linguistic task produced fewer syllables per breath group, spoke at an overall slower rate, and expired a greater lung volume than during the lower cognitive-linguistic task (Mitchell, Hoit, & Watson, 1996). However, they did not report temporal differences in inspiratory and expiratory durations by cognitive-linguistic load. This suggests that the presence of higher cognitive demands may cause deviation from the typically organized pattern of speech breathing.

L2 Speech Breathing

Increased cognitive-linguistic demands are present during speech production in L2 (Hanulova, Davidson, & Indefrey, 2011; Michel, Kuiken, & Vedder, 2007; Mitchell et al., 1996; Nip & Blumenfeld, 2015). Multiple possible hypotheses exist to explain this: a) the Weaker Links Hypothesis (Gollan, Montoya, Cera, & Sandoval, 2008) which states that lower frequency words in L2 have weaker connections between concepts and word generation and therefore tend to be produced slower with an increase in errors; b) the hindrance of choosing the correct language to speak and suppressing the more dominant L1 can lead to less cognitive resources available to support L2 (Hanulova et al., 2011; Nip & Blumenfeld, 2015); and c) a later age of acquisition to L2 suggests a lower frequency count, which can lead to demanding a heavier cognitive load (Hanulova et al., 2011).

Since slower speech tends to be highly ventilated and suggests an increased structuring processes in progress (Goldman-Eisler, 1966) and it has been shown that there is an increased cognitive load of speaking in L2 (Michel et al., 2007; Nip and Blumenfeld, 2015; Hanulova et al., 2011), it is suggested that speaking in an L2 may be slower, more thought out speech and therefore highly ventilated.

Methodology

Participants

Six participants (2 males and 4 females; Mean age = 21.06, SD = 1.73) were recruited through foreign language classes and student organizations at the University of Northern Iowa. All participants met the following criteria: English as a first language, Spanish as a second language, non-smoker, no chronic health conditions, and no pre-existing respiratory, voice, or speech disorders as determined by a short questionnaire. In order to keep participant information confidential, each participant was given a participant number based on order of recruitment. Participant proficiencies were: P1 was a native speaker and P3 was fluent. P2 was rated as Advanced High, P4 and P5 were Advanced Mid, and P6 was Intermediate High.

Apparatus

Participants were seated upright throughout the session and were monitored for changes to eliminate variability within posture. An Audio-technica ATM75 head-mounted microphone was placed 6 cm away from the mouth, and two Respitrace respiratory inductance plethysmography (RIP) bands tightly fit over the shirt, across the ribcage and abdomen. RIP is a noninvasive approach to measure lung volume through means of cross-sectional displacement of the rib cage and abdomen. Wires within the bands transmit a voltage change when stretched during breathing, which are interpreted as chest wall and abdominal movement. All chest wall (i.e., rib cage and abdomen) and acoustic data were digitized and sent to the Time-Frequency Analysis 32-bit (TF32: Milenkovic, 2002) software program for subsequent temporal analysis.

Procedures

Each participant completed one 30-minute session with the investigator (PI) and research advisor. Prior to the start of the session, each participant was required to give informed written consent. All procedures were approved by the University of Northern Iowa Institutional Review Board for the protection of human subjects. Participants were then asked to complete a short survey asking for a self-identified speaking proficiency rating for English and Spanish using guidelines from the American Council on the Teaching of Foreign Languages (2012), date of birth, and six yes/no questions (see Appendix A). The participant then completed the following 3-5 minute tasks in random order: tidal breathing at rest, scripted speech in L1 (twice) using the Rainbow Passage, scripted speech in L2 (twice) using La Oveja passage, spontaneous speech in L1 without the PI or advisor present, and spontaneous speech in L2 without the PI or advisor present. Tasks were randomized to avoid learning effect throughout the session.

Results

The participant data are presented in two groups: native Spanish speakers (NSS) and non-native Spanish speakers (non-NSS). NSS include P1 and P3, non-NSS include P2, P4, P5 and P6. The data were subjected to a multivariate analysis of variance (MANOVA, SPSS). Independent variables included Proficiency (2 levels; NSS and Non-NSS), Task (2 levels; Reading and Spontaneous Speech) and Condition (2 levels; Spanish and English). Dependent variables were inspiratory duration, expiratory duration, inspiratory ratio, expiratory ratio, syllables per breath group, and syllables per second. There were no significant overall main effects on any of the dependent variables; however, there was a significant interaction effect of proficiency and syllables per breath group (F (1,7) = 9.512, p= .002), with the difference being that non-NSS produced fewer syllables per breath group during spontaneous speech in Spanish than did the NSS with the independent.

The relationship between inspiratory and expiratory durations (ms) is shown in Figure 1. Though not significant, the NSS group produced expiratory durations that were more variable between reading and spontaneous speech in Spanish than that of non-NSS with expiratory means during reading and spontaneous speech in Spanish of 3094 ms and 5077 ms, respectively. The expiratory means during Spanish reading and spontaneous speech in the non-NSS group were very similar with 4198 ms and 4248 ms, respectively.

Syllables per breath group and rate (syllables per second) are shown in Figure 2. No significant differences were found in terms of rate although non-NSS speaking spontaneous Spanish were more variable in their rates of speech with a standard deviation almost four times that of NSS' rates in spontaneous Spanish (2.08 syllables/second; 0.53 syllables/second). A statistically significant difference was found when comparing the two groups' data of syllables per breath group during Spanish spontaneous speech. It showed that non-NSS (mean: 13.9 syllables per breath group) produced fewer syllables per breath group than NSS (mean: 20.5 syllables per breath group).

The relationship between inspiratory and expiratory ratios are shown in Figure 3. No significant data is presented, and little variability is shown between the two groups, within each of the groups, and between reading and spontaneous speech.

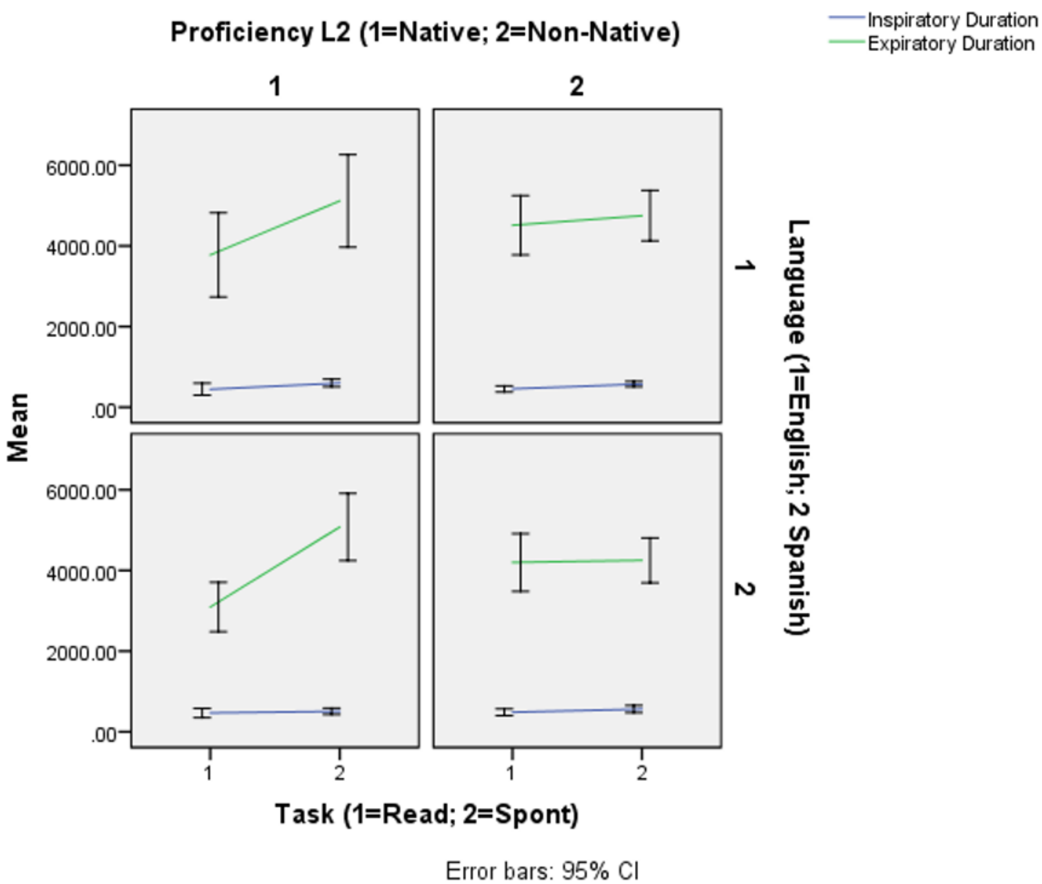

Figure 1. *Inspiratory and expiratory durations when comparing proficiency, language, and task, by group.*

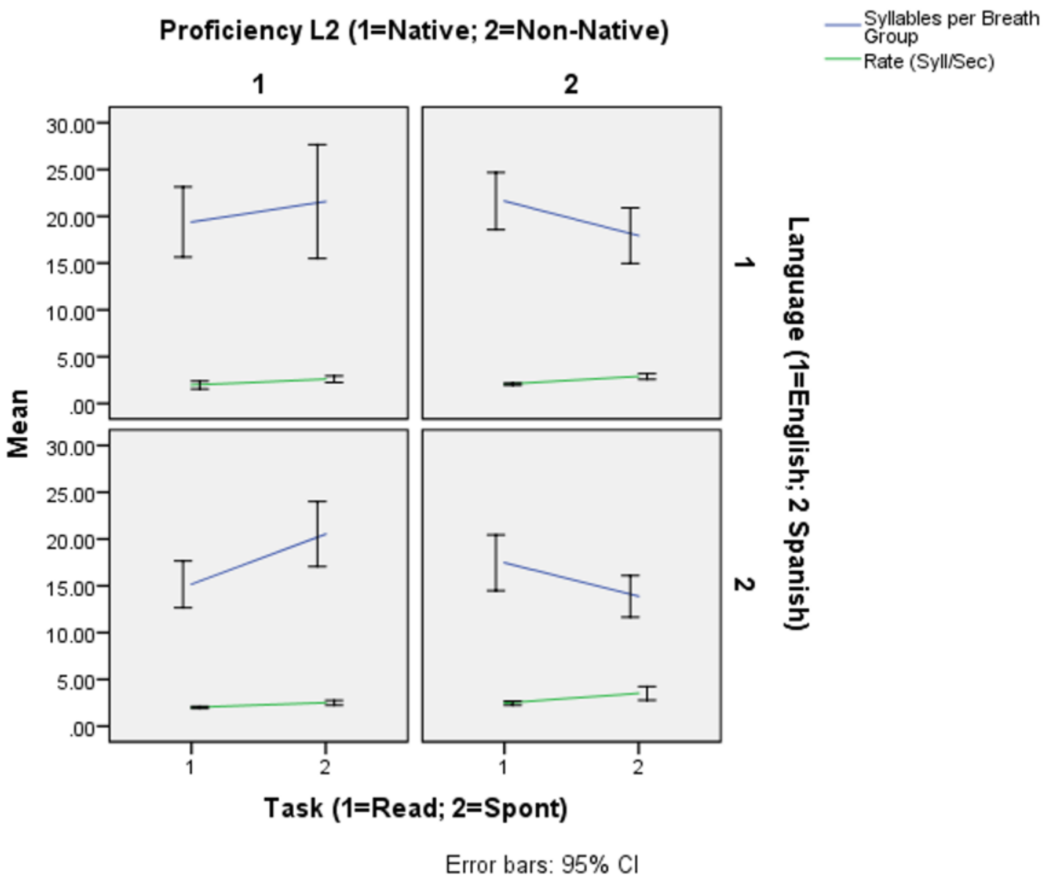

Figure 2. *Syllables per breath group and syllables per second when comparing proficiency, language, and task, by group.*

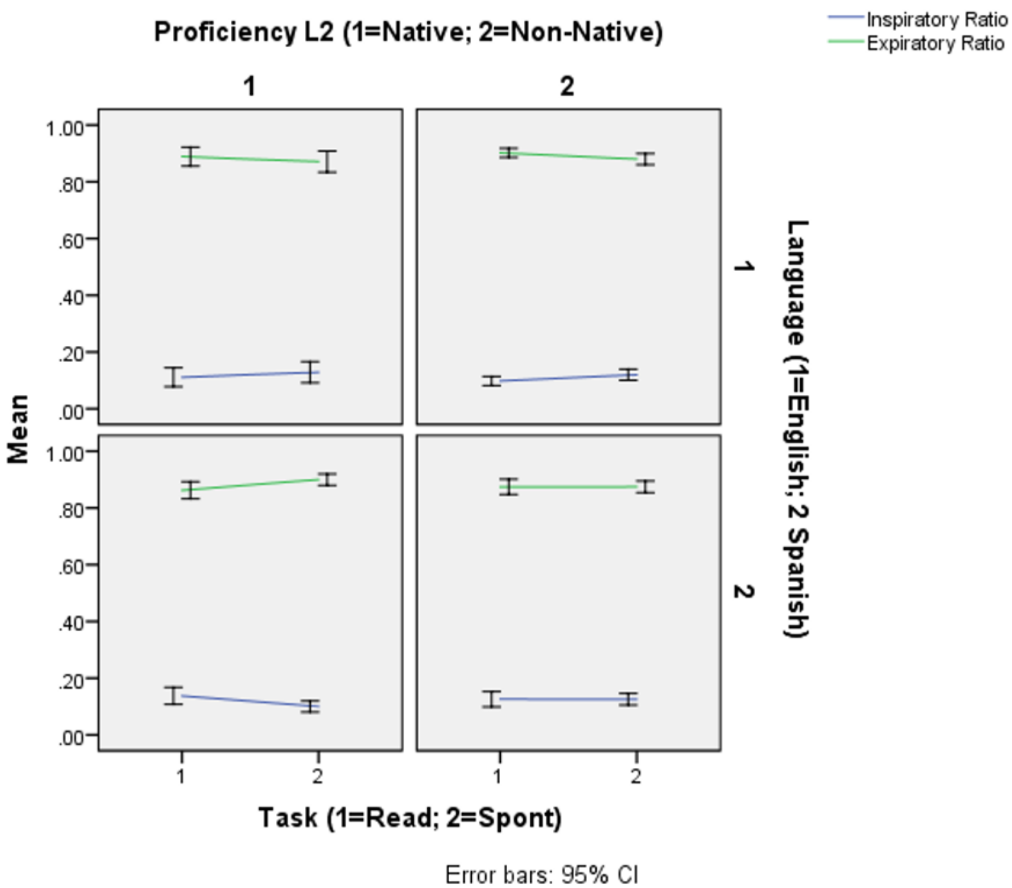

Figure 3. *Inspiratory and expiratory ratios when comparing proficiency, language, and task, by group.*

Discussion

Non-NSS speakers were less variable between reading and spontaneous Spanish speech than NSS, perhaps indicating that the non-NSS group took very similar inspirations and expirations during the two tasks. The non-NSS group also produced fewer syllables per breath group during spontaneous speech than during reading. This relates to the differing theories on neural planning for respiration. The results differ from Winkworth et al.'s (1994, 1995) studies and suggest a general inspiration was taken for each utterance unconcerned with the number of syllables that would be produced. The higher cognitive demands of speaking a second language without strong proficiency is what likely caused this difference in data between studies.

Speaking rates reported by Mitchell et al. (1996) on the influence of increased cognitive-linguistic demands on speech were found to be slower during the task that required the higher cognitive-linguistic load. This differs from the results shown in Figure 2. While non-NSS were more variable, rate of speech was not significantly slowed as seen in Mitchell et al.’s study. This may be due to differences in task between the two studies. Speaking in L2 is arguably a more complex task. The increased variability found in the rate of speech of non-NSS compared to NSS may be due to the range of proficiency within the non-native Spanish speaking group. Despite the variability, the natural output of the speech was unaffected.

A significant interaction effect of task and proficiency was found after running a multivariate analysis of variance. Non-NSS used significantly less syllables per breath group during spontaneous Spanish speech than NSS. This is similar to results found in Mitchell et al.’s (1996) study on the influence of increased cognitive-linguistic loads on speech. They reported a decrease in syllables per breath group during the higher cognitively demanding task. As discussed, pauses also suggest a higher cognitive-linguistic load due to the decision making and formulation of words (Henderson et al., 1965). These pauses could account for less syllables spoken by non-NSS in spontaneous Spanish.

Inspiratory and expiratory ratios were similar among all groups and variables. No trends in means or standard deviations stood out in the data. This continuity of inspiratory/expiratory ratios compared to the significant change in syllables per breath group reinforces the idea that non-NSS speaking spontaneous Spanish may use generic breaths for each utterance. Non-NSS syllables per breath group in English and Spanish were not statistically significant but differed in 4 syllables (19.9; 13.9). This shows in a different light that the non-NSS took similar breaths for spontaneous Spanish (shown by inspiratory/expiratory ratios) as they would for a spontaneous utterance in English but did not say as many syllables.

Conclusion

This study explored differences in speech breathing between a speaker's L1 and L2 during spontaneous and scripted speech in six adult bilingual speakers. Results from several speech tasks indicated that during spontaneous Spanish speech, native Spanish speakers produced significantly more syllables than that of non-native Spanish speakers. The data provides insight into how a higher cognitive-linguistic load of speaking in a second language affects speech and contributes to the existing pool of knowledge on monolingual cognitive-linguistic demands and speech breathing.

Limitations

This study presents multiple limitations, the biggest being the low number of participants. With only six participants, the data may not be a true representation of the bilingual population. Within the participant population, gender, body type, and mood were not controlled or monitored, despite previous studies reporting these subject groups present differing respiratory behaviors during speech. This is partially due to the focus of the thesis on language effect and partially due to limited recruitment time. While language proficiency was requested from the participants, it was self-identified and expressive language was not formally assessed. This may have impacted the data if participants were previously inclined to say more or less. RIP bands were placed over the shirt of participants opposed to directly on the skin. This was done in order to be a noninvasive study but may have impacted results.

Future Research

This research is a pilot study for future investigations that could recruit a larger participation group and eliminate inconsistent variables discussed. A larger participant size within each proficiency level would provide data with more substance and give more concrete numbers for each of the variables. As Spanish was a consistent L2 in this investigation, further studies could compare other languages to see if speech breathing is consistent among all languages or if language is a variable that causes differing results. Overall, previous studies on speech breathing could be duplicated with a bilingual population to bring more knowledge to the field of bilingual speech breathing.

Significance in Speech-Language Pathology

The field of speech-language pathology is diverse with many specializations. This study combines the specializations of bilingualism and speech respiration and has implications within both. By furthering this science, clinicians will be better equipped with available knowledge on how individuals who are bilingual breath during speech. When assigned to a client who is bilingual and who may have experienced an injury causing respiratory difficulties, clinicians will now know how this population typically breaths during speech. This information will lead to future studies on clinical practices for helping these patients return to their typical speech breathing. It is possible this study could apply to a wide variety of patients within the bilingual community. This may include those who are bilingual with aphasia, apraxia, cleft lip and palate, dysarthria, tracheostomy and ventilator dependence. This thesis is a pilot study that could pave the way to future work in the field of speech-language pathology that could have an impact on bilingual, respiratory speech therapy.

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Appendix A: Research Participant Information

XX-XXXX – ***Respiratory differences in spontaneous and scripted speech among bilingual adults***

History Screening:

Participant number: _____ Date of birth: ________________

1. Do you currently smoke?	Yes	No
2. Do you suffer from chronic respiratory infections?	Yes	No
3. Have you ever been diagnosed with a breathing disorder? (e.g., asthma, emphysema, chronic bronchitis)	Yes	No
5. Are you currently suffering from symptoms of the flu, a cold or sinus infection?	Yes	No
8. Have you ever been diagnosed with, or treated for, a voice disorder?	Yes	No
10. Do you suffer from any chronic health conditions?	Yes	No

-If yes, please explain below

Appendix B: Reading Passages

The Rainbow Passage

When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

La Oveja

La oveja es un animal hervívoro. Se alimenta de yerba. Habita en todos los climas. Es un animal manso y resistente. Se mueve constantemente, pero es dócil a la voz del pastor y se deja guiar por los perros. Todo es útil en la oveja. La lana sirve para fabricar vestidos, mantas, y alfombras. La piel se usa para abrigos y objetos de adorno. Su carne es sabrosa y con su leche se hacen quesos.