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Age-Related Changes to the Production of Linguistic Prosody

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AGE-RELATED CHANGES TO THE PRODUCTION OF LINGUISTIC PROSODY

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This work is dedicated to those who have inspired me to pursue goals I never thought possible and to push past my perceived limits. My family, who has never erred from encouraging words. My committee, who has provided critical support and guidance. Most importantly, this work is dedicated to Jessica Huber, who always believed that I would (and will continue) to succeed. To those above and those I have failed to mention, you have my deepest gratitude.

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ABSTRACT

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The production of speech prosody (the rhythm, pausing, and intonation associated with natural speech) is critical to effective communication. The current study investigated the impact of age-related changes to physiology and cognition in relation to the production of two types of linguistic prosody: lexical stress and the disambiguation of syntactically ambiguous utterances. Analyses of the acoustic correlates of stress: speech intensity (or sound-pressure level; SPL), fundamental frequency (F0), key word/phrase duration, and pause duration revealed that both young and older adults effectively use these acoustic features to signal linguistic prosody, although the relative weighting of cues differed by group. Differences in F0 were attributed to age-related physiological changes in the laryngeal subsystem. Group differences in duration were attributed to age-related slowing, relative task complexity, and the cognitive-linguistic load of these respective tasks. The current study provides normative acoustic data for older adults informing the interpretation of clinical findings as well as research pertaining to dysprosody as the result of disease processes.

1. INTRODUCTION

1.1 Introduction

The appropriate comprehension and production of speech prosody is critical to effective communication (Cruttenden, 1997; Price, Ostendorf, Schattuck-Hufnagel, & Fong, 1991). Speech prosody supplements the meaning of an utterance, not by what is said but by how it is said, such that even lexically identical utterances can have multiple meanings. The appropriate production of speech prosody is essential to a natural quality that listeners associate with speech (Klatt, 1987). Speech prosody accomplished by altering suprasegmental aspects of speech production, including pitch, duration, and loudness. Studies of comprehension have shown that older adults benefit as much as young adults from linguistic prosodic cues (Cohen & Faulkner, 1986; Wingfield, Lindfield & Goodglass, 1997), but evidence from the perceptual side suggests that young and older adults may weight these cues differently (Dupuis & Pichora-Fuller, 2010). Few studies, however, have focused on changes to the production of prosody with typical aging.

There are two broad categories of prosody associated with speech. *Affective* (or *emotional*) prosody represents the emotional content of an utterance. *Linguistic* prosody represents a broad category of mechanisms used to clarify linguistic content or define the function of an utterance. Studies of prosody production in typically aging individuals have focused more on affective prosody than linguistic prosody. The focus of this study is to investigate mechanisms of linguistic prosody and compare the abilities of young and older adults to produce two types of linguistic prosody: lexical stress and ambiguous sentence production.

Types of linguistic prosody may take the form of *stress,* such as *lexical and contrastive* stress. Lexical stress distinguishes words based on relative syllable stress within the word (e.g., “REcord” the noun vs. “reCORD” the verb). Contrastive stress allows for the focus of a sentence to be identified, generally highlighting new information in the sentence (e.g., “No, the RED ball” when incorrectly handed a green ball).

Other mechanisms of linguistic prosody, such as sentence intonation, may differentiate the function of an utterance (e.g., *question-statement contrasts*). For example, the phrase "You need more" can be question or statement depending upon the inflection of one's voice even when the two phrases are lexically identical. Linguistic prosody may also be used to *disambiguate ambiguous sentences*, establishing the syntactic frame of an utterance and clarifying syntactic structures. An example sentence could include "The man hit the fellow with the guitar", in which a man could be using the guitar as an implement to hit the fellow or the man could be hitting a fellow who possesses a guitar.

These types of linguistic prosody are subserved by a variety of cues, and the types of cues that predominate tend to differ by prosodic goal. For example, question-statement contrasts rely primarily on variations of pitch (Cruttenden, 1997), while word and pause duration cues are more salient when disambiguating ambiguous sentences (Snedeker & Trueswell, 2003; Tauber, James, & Noble, 2010). Furthermore, these perceptual cues have measurable, physical correlates. What is perceived as pitch can be objectively measured as the mean fundamental frequency (F0) or the range of F0 across a unit of production, such as a sentence. Duration refers to length of time, as either the duration of the production of key words, syllables, pauses that occur within an utterance. Loudness refers to relative intensity of speech across an utterance, measured via sound pressure level (SPL).

Age-related changes to physiology or cognition may affect the production of these physical correlates (Kahane, 1981; Stine & Wingfield, 1987). Fundamental frequency (F0) and intensity are determined by a complex series of physiological mechanisms involving both the respiratory and laryngeal speech subsystems. Changes to respiratory and laryngeal physiology with typical aging may explain why some prosodic mechanisms may change with age. Cognitive factors such as working memory and cognitive slowing also change with typical aging, and may impact elements of prosody, particularly word and pause durations. A more detailed review of age-related changes to physiology and cognition follows.

1.1.1 Physiological Underpinnings for Intensity and Pausing

The coordination of the respiratory system with other speech subsystems is critical to the successful production of prosody. The interaction of the respiratory and laryngeal systems primarily determines speech loudness. Additionally, pausing behavior and the modulation of word or phrase durations involves adjustments to respiratory pressures. Thus, physiologic impairments of the respiratory system may affect a speaker's ability to produce changes to loudness and pausing required for appropriate stress marking.

Age-related changes to respiratory and laryngeal physiology affect how older adults breathe during speech. Early studies of speech breathing revealed that older adults initiated speech at higher lung volumes than young adults during reading and extemporaneous speech tasks (Hoit & Hixon, 1987; Hoit, Hixon, Altman, & Morgan, 1989). Older adults also expended a greater percentage of lung volume per breath group compared to young adults (Hoit & Hixon, 1987; Hoit et al., 1989). These age-related differences were attributed to a reduced economy of laryngeal airstream valving in older adults (Hoit & Hixon, 1987; Hoit et al., 1989). Hoit and colleagues concluded that older men and women breathe to higher lung volumes and expend more air in order to compensate for age-related changes to laryngeal physiology, such as decreased glottic closure, that impair their ability to build adequate subglottal pressure for speech (Hoit & Hixon, 1987; Hoit et al., 1989; Kahane, 1981).

Several studies have examined the effects of age-related changes to laryngeal physiology on laryngeal airway resistance, an indirect measure of subglottal pressure, offering mixed support for the impaired laryngeal valving hypothesis suggested by Hoit and colleagues (Hoit & Hixon, 1987; Hoit et al., 1989). One study determined that men experience a significant decline in laryngeal airway resistance from ages 65 to 75, while another study determined that women did not demonstrate any significant age-related change (Melcon, Hoit, & Hixon, 1989; Hoit & Hixon, 1992). Impaired laryngeal airstream valving may partially explain differences in speech breathing patterns between young and older adults. This hypothesis, however, does not account for age-related changes to respiratory physiology that affect respiratory support for speech (Kahane, 1981; Hoit & Hixon, 1987; Hoit et al., 1989).

Huber (2008) examined the effects of age-related changes to respiratory physiology on speech breathing and found similar results to Hoit and Hixon (Hoit and Hixon, 1987; Hoit et al, 1989). When instructed to speak at a comfortable loudness, older adults initiated and terminated speech at higher lung volumes than young adults (Huber, 2008). Older adults also demonstrated a significantly greater increase in the percentage of lung volume expended per utterance as utterance length increased (Huber 2008). Huber (2008) attributed these differences to reduced recoil pressure in the lungs as a result of age-related changes to respiratory physiology, such as increased pulmonary compliance, decreased chest wall compliance, and decreased respiratory muscle strength. According to Huber (2008), older adults initiate and terminate speech at higher lung volumes in order to achieve greater recoil pressure. When cued to increase loudness, older adults used different respiratory mechanisms than young adults. However, regardless of respiratory configuration, there were no significant differences in SPL between age groups for the comfortable or loud conditions, suggesting that older adults are able to increase loudness as effectively as young adults (Huber, 2008).

Age-related changes to respiratory physiology may affect the ability to modulate respiratory pressures and pausing behavior that are necessary to produce prosodic stress. Huber, Darling, Francis, and Zhang (2012) compared the utterance length and breath pausing patterns of young and older adults during a reading task in a broader study on the effects of Parkinson's disease on breath pausing patterns. Older adults produced shorter utterances than young adults during the task, consistent with previous reports by studies on respiratory support for speech (Hoit & Hixon, 1987; Huber, 2008). Huber et al. (2012) also revealed that older adults produced more breaths at minor syntactic boundaries (e.g., after a dependent clause) than major syntactic boundaries (e.g., after an independent clause) as compared young adults. Though these results could have been attributed to age-related declines in working memory, the authors propose that it more likely reflects age- related changes to respiratory physiology, such as decreased expiratory muscle strength. Older adults speak in shorter utterances and produce a greater number of breaths at minor syntactic boundaries to ensure that they continue to breathe at a location related to syntax, rather than speak until they are forced to breathe at a location unrelated to syntax (Huber et al., 2012). This is a functional adaptation that preserves the prosodic patterns in their speech and the intelligibility of their message.

In summary, older adults may experience age-related changes to respiratory and laryngeal physiology that affect the respiratory configuration they use to modulate speech loudness, pausing patterns, and the duration of key words or phrases for prosody. To compensate for these changes, older adults generally breathe to higher lung volumes and expend a greater percentage of lung volume per utterance than young adults (Hoit & Hixon, 1987; Hoit et al., 1989; Huber, 2008; Huber & Spruill, 2008). In terms of pausing behavior, older adults produce shorter utterances and a greater number of pauses at minor than major syntactic boundaries in order to compensate for age-related changes to respiratory physiology (Huber et al., 2012). Data suggest that the respiratory systems of older adults are more easily taxed than those of young adults by tasks such as modulating loudness (Huber, 2008; Huber & Spruill, 2008). Despite increased effort, older adults achieve similar SPL levels for comfortable and loud speech during reading tasks and extemporaneous speech (Huber, 2008; Huber & Spruill, 2008). What is unknown is whether the changes to respiratory or laryngeal function compromise the ability of older adults to modulate intensity and pausing for the purposes of prosodic mechanisms.

1.1.2 Physiological Underpinnings for F0

The vibration of the vocal folds in the larynx acts as the sound source for speech and is the determinate of F0. It is likely that physiological changes in the laryngeal system due to aging result in changes to F0 and the amount of F0 range a speaker can produce.

Previous studies have reported reductions in F0 for women as they age (Stathopoulos et al., 2011; Nishio & Niimi, 2008). Stathopoulos et al (2011) reported that female subjects demonstrated a less steep decline at younger ages and steeper decline at older ages in F0 (Stathopoulos et al., 2011). A study by Nishio and Niimi (2008) reported similar results regarding female subjects, identifying a significant decrease in F0 as early as the third decade of life (ages 19-29). Each study attributed these changes, in part, to a thickening of the vocal folds in women as the result of the hormonal environment (Nishio & Niimi, 2008; Stathopoulos et al., 2011). Nishio and Niimi (2008) comment that the age-related decline in F0 of female subjects cannot be exclusively attributed to post-menopausal changes to the vocal folds, as significant differences emerged in female subjects as early as ages 19-29 and 30-39. Decreased F0 starting as early as age 20 could influence the comparison of F0-related measures between young women and older women in the current study. These findings support the hypothesis that F0 declines as women age, regardless of speaking task, due to a combination of physiological and hormonal factors.

Whereas the results regarding F0 in aging women are largely consistent, results regarding aging men are not. Aging men appear to demonstrate more variable trends in F0 across studies than aging women, though F0 increase among men is more commonly reported. Ramig and Ringel (1983) found no significant difference in F0 between young and older men during reading tasks or extemporaneous speech. Similarly, Nisho and Niimi (2008) reported that male subjects demonstrated a weakly positive correlation between age and F0 with no significant differences observed between age groups. Alternatively, Stathopoulos et al. (2011) reported that male subjects demonstrated a decrease in F0 from ages 4-50, followed by a steady increase from age 50+ (Stathopoulos et al., 2011), likely due to a thinning of the vocal folds in men as a result of a change in the hormonal environment.

It is possible that the health of the men in these studies may explain the different findings. Ramig and Ringel (1983) found an effect of age and estimated physiological condition (good vs. poor) on F0 found only during a sustained phonation task. Specifically, older men in good physiological condition produced sustained vowels at a significantly higher F0 than older men in poor physiological condition (Ramig & Ringel, 1983). No other age group (young or middle-age) exhibited a significant difference in F0 as an effect of physiological condition (Ramig & Ringel, 1983). This age and physical condition effect could contribute to the variability and increase observed in F0 across studies of older men. Further, it should be noted that the results of Nishio and Niimi (2008) are confounded by the inclusion of smokers as participants. It is unclear how these changes affect F0 during extemporaneous speech, but it is likely that F0 is affected to some extent regardless of speaking task in men due to a combination of physiological and hormonal factors.

In addition to mean F0 change, studies of aging speakers have examined F0 variability, often measured by F0 SD and F0 range. F0 variability (F0 SD) is the change in F0 stability during phonation. F0 variability differs from F0 range, or the range of F0 values that individuals are able to produce and actively control. For example, the F0 range of a question may be greater than an uninflected statement, as the impetus to rise at the end of a question may result in more F0 change than the fall at the end of a statement. So the overall range of F0s used in a question may be larger than a statement. F0 range and variability are critical to the effective production of sentence intonation, and a discussion of age-related changes to these measures is warranted.

Older adults have demonstrated higher F0 variability than young adults. Linville (1988) found that male and female elderly speakers produced sustained vowels with consistently higher F0 SD than young female speakers. In another study, Stathopoulos et al. (2011) identified similar age-related F0 variability trends during a sustained vowel phonation task, citing a decrease in F0 SD from ages 4-30 and an increase in F0 SD past age 30 sexing both men and women. Neither study drew a direct correlation between F0 variability and age-related physiological change. The extent to which increased F0 variability with aging affects the production of prosody is also has not been investigated.

Studies have reported conflicting results regarding the F0 range of older adults, likely as a result of task differences. Several studies found a reduced F0 range in older adults during a sustained vowel and monosyllabic word production task (Ptacek et al., 1966; Endres et al., 1971). A problem with these results is the tasks did not necessitate a change in intonation to convey meaning. Conversely, McGlone and Hollient (1963) measured the vocal pitch changes of women and found no significant difference in the F0 range of young and older women during a single reading of the rainbow passage. Older men, however, demonstrated a general trend toward greater F0 range than young men while reading aloud (Mysak, 1959). Benjamin (1981) observed that older adults produced a significantly greater F0 range than young adults during a reading of the rainbow passage, consistent with Mysak (1959). The data on reading more accurately represent the use of F0 range to produce prosody during normal speech. In summary, these data suggest that older adults (men more so than women) have a greater F0 range than young adults during reading and extemporaneous speech tasks.

Age-related changes to the physiology of the muscles, cartilages, and joints associated with pitch change can be used to explain the observed impact of aging on F0 range. To raise pitch, we elongate the vocal folds, reducing the mass per unit length, allowing them to vibrate at a higher frequency. The ability to elongate the vocal folds is attributed primarily to internal structures of the larynx, specifically the cricothyroid muscle, ligament, and joint. Age-related changes that increase the mobility of these internal structures would consequently increase F0 range.

Kahane (1981) discussed several age-related changes to laryngeal tissues as an effect of aging. There may be a loosening of the cricoarytenoid joint capsule, resulting in a reduction in articulatory support for the cricoid and arytenoid cartilages with a consequent increase in the mobility of the attached structures. Increased mobility would allow older adults to shorten or elongate their vocal folds to a greater extent than young adults, increasing F0 range by achieving higher and/or lower frequencies. This, however, could make it more difficult for older adults to actively achieve or maintain a specific F0, consistent with reports of increased F0 variability. Kahane (1981, 1983) notes that ossification and calcification of the laryngeal cartilages and muscular atrophy of the vocal folds could also limit movement, thereby restricting F0 range.

In summary, despite the co-occurrence of age-related changes that could potentially both increase and decrease mobility of laryngeal structures necessary for pitch change, data from F0 range support the hypothesis of a net increase in mobility as the result of aging. Thus, older adults produce a greater F0 range than young adults during reading and extemporaneous speech tasks, although they may not be able to achieve or control changes in F0 as effectively.

1.1.3 The Role of Working Memory

Working memory is a form of short-term memory that enables an individual to simultaneously store and process information while consciously maintaining task-relevant goals or strategies (Baddeley, 1986). Age-related declines in working memory have been documented by a variety of studies based on the dominant view of working memory as described by Baddeley (1986). Tasks that require greater cognitive processing appear to exacerbate these age-related differences (Salthouse, 1994). For example, parsing syntactically simple sentences is unlikely to reveal age-related differences in working memory, as the need to simultaneously store and process information to complete the task is relatively low (Kemper & Mitzner, 2003). A paragraph reading task, however, would more likely utilize working memory and reveal age-related differences, as the reader must simultaneously process elements of language and store them for subsequent use (e.g., recognizing words, forming words them into phrases and clauses, inferring referents for pronouns, etc.; Kemper & Mitzner, 2003). Age-related declines in working memory also appear to be attenuated by environmental and contextual support, which effectively limit the amount of information that must be simultaneously stored and processed (Craik, 1986).

Studies have yet to address whether declines in working memory play a role in age-related changes to the comprehension and production of linguistic prosody. Studies of aging and memory report that young adults perform well on tasks designed to challenge working memory, such as word-by-word and paragraph reading comprehension tasks (Connelly et al., 1991). Older adults consistently require a greater amount of reading time than young adults, attributed to difficulty simultaneously storing and processing the content of text as a result of decreased working memory (Connelly et al., 1991). Older adults also demonstrate relatively greater difficulty encoding and later accessing information acquired while reading (Connelly et al., 1991), though Kemtes and Kempter (1997; 1999) dispute working memory as the sole contributor to age-related differences in reading comprehension. Interestingly, data from studies regarding the contribution of decreased working memory to difficulty with complex syntactic processing have been mixed (Kemtes & Kemper, 1997; 1999). It appears that information processing is most prominently affected by declines in working memory, and tasks with increased processing demands will likely be affected to the greatest extent (Salthouse & Babcock, 1991).

Given that the production of linguistic prosody requires various degrees of processing resources depending on the specific task, age-related differences in working memory have clear implications for the current study. Working memory allows the speaker to retain relevant information they wish to convey while simultaneously formulating the language and prosodic features to convey it. It is likely that age-related differences in working memory will be more robust for more cognitively complex applications of linguistic prosody, similar to trends that have been demonstrated in syntactic parsing and reading comprehension tasks (Salthouse, 1994). Speakers also utilize working memory to maintain a goal (e.g., communicate the intended message with the appropriate prosodic features) and to apply and monitor the strategies they choose to achieve that goal while completing a task. The inability to maintain a goal or apply strategies to complete a task may result in the neutralization of the prosodic features.

Age-related differences in working memory are anticipated to affect the prosodic tasks in the current study. For example, the disambiguation of sentences recruits working memory, as the speaker must simultaneously generate and retain two distinct meanings from lexically identical sentences. Older adults may have difficulty understanding and generating multiple meanings, resulting in hesitant production with a generalized increase in the duration of words or pauses in the utterance. Older adults are still expected to signal the meaning of syntactically ambiguous sentences by implementing pausing patterns and increasing the duration of key words proportionally to non-key words, as demonstrated in a study of syntactic prosody by Tauber et al. (2010). A failure to maintain task-related goals, strategies, or to retain pertinent information may be a detriment to the production of lexical stress but to a lesser extent than sentence disambiguation. However, the production of lexical stress is not expected to rely heavily on working memory and deficits in working memory are not expected to drive significant group differences. Changes to prosody in any task would only be expected if the task is cognitively taxing enough to overburden working memory.

1.1.4 The Role of Inhibition

Inhibition assists communicators by diminishing the intrusion of irrelevant or inappropriate thoughts that detract from the completion of more important or pertinent tasks (Kemper & Mitzner, 2003; Hasher & Zacks 1988). The ability to inhibit or suppress this information declines with typical aging (Hasher & Zacks, 1988). Young adults are more likely than older adults to inhibit distracting or misleading information from their working memory and to inhibit responses until the appropriateness of said responses can be assessed. Young adults are thought to be less distractible than older adults due to better inhibitory skills (Connelly et al., 1991). Similar to decreased working memory with aging, decreased inhibition interferes with the ability to achieve goals on multiple levels (Hasher & Zacks, 1988). Hasher and Zacks (1988) present a model in which inhibition serves as a gateway to information stored in working memory. As inhibition decreases, the amount of less-relevant information that enters and burdens the already taxed working memory of older adults increases (Hasher & Zacks, 1988). More important, however, is the role of inhibition in preventing the immediate use of probable responses before the appropriateness of said response can be assessed (Kemper &

Mitzner, 2003; Hasher & Zacks, 1988). These outcomes have implications for the production of prosody by older adults in the current study.

Older adults may compensate for decreased inhibition by using various strategies. Older adults may find ways to increase the amount of time they have to sort competing information as the result of reduced inhibition (Connelly et al., 1991). One potential strategy includes the active formulation and modification of the response during speech, which would be reflected by increased duration measures in speaking tasks. This hypothesis is consistent with age-related slowing and is observable across a range of behavioral studies (Bucur, Madden, Spaniol, Provenzale, Cabeza, White, & Huettel, 2008). Older adults may also have difficulty selecting the most likely interpretation of information while formulating an appropriate response. As a result, older adults may opt for a more neutral interpretation, and in turn produce a neutral response. In the current study, this may manifest as the neutralization of prosodic features. Decreased inhibition may be deleterious in both tasks.

1.1.5 The Role of Processing Speed

The phenomenon of "age-related slowing" is pervasive in the aging and cognition literature (McCabe & Hartman, 2008; Salthouse 1992). Age-related slowing is thought to be a generalized, linear decrease in processing speed experienced by older adults as the result of neurological aging. Aspects of processing and reasoning are affected by age-related slowing to a greater extent than skills that rely primarily on accumulated knowledge, such as semantic priming. Age-related slowing is thought to be the root cause of increased reaction times in older adults.

Generally, age-related slowing is expected to manifest as increased duration measures for tasks that require increased cognitive processing. While lexical stress task require cognitive resources affected by age-related slowing, the duration of these prosodic contrasts are so relatively short that significant effects of age-related slowing are unexpected. Ambiguous sentence contrasts require the speaker to plan and produce prosodic features that span the length of an utterance, allowing for greater significance of the effects of age-related slowing. In fact, one study of syntax and prosody production in ambiguous sentences has attributed increased duration of key words in older adults to age-related slowing (Tauber et al., 2010). However, age-related slowing is not expected to limit the ability to use duration as a parameter to differentiate meaning across tasks by older adults.

1.1.6 Aging and Affective Prosody

The appropriate comprehension and production of affective prosody reveals the emotional state of the speaker to the listener, such that utterances with the same linguistic content can have separate meanings. Speakers can convey many emotions when communicating a message through variations of F0, duration, and intensity across an utterance. In this way, the speaker supplements the linguistic content of the utterance with emotional content that can convey additional meaning.

Affective prosody uses perceptual cues and physical correlates similar to mechanisms of linguistic prosody (Scherer, 2003). Though the production of affective prosody is not the focus of the current study, information regarding the ability to produce the physical correlates of the perceptual cues associated with mechanisms of affective prosody will inform our hypotheses about linguistic prosody.

Differences between young and older adults have been found in the ability to identify affective prosodic cues in speech (Orbelo, Testa, & Ross, 2003). These differences may be attributable to the interplay of factors involved in speech comprehension (e.g., cognition, audition, etc.) and/or the emotionally neutral, artificial nature of the tasks used in studies of affective prosody comprehension (Dupuis & Pichora-Fuller, 2010). A recent study demonstrates that older adults are able to comprehend and produce affective prosody as effectively as young adults, though older adults read and repeat entire sentences with affective prosody over a greater period of time (Dupuis & Pichora-Fuller, 2010).

While studies replicating these results are limited, this single study benefits from well-controlled methodology and the use of acoustic analyses to support its findings. As a result of these findings, we hypothesized that age-related slowing will lead to a general increase in duration measures for older adults when producing linguistic prosody, though most prominently for the disambiguation of syntactically ambiguous utterances. Furthermore, this study reports that older adults are able to vary parameters of F0 and intensity as effectively as young adults during reading and repetition tasks. It is important to recognize that older adults have demonstrated the capability to vary these parameters accordingly, albeit using a form of prosody distinct from linguistic prosody. This may suggest that there will be no differences in F0 and intensity for linguistic prosody tasks.

1.1.7 Linguistic Prosody

Older adults have been shown to decode linguistic prosody in tasks that require them to comprehend and recall spoken discourse (Cohen & Faulkner, 1986). Further, older adults demonstrate increased difficulty comprehending and recalling speech when elements of linguistic prosody are removed (Wingfield et al., 1989, 2000). Several studies have explored the production of individual mechanisms of linguistic prosody with typical aging using acoustic analyses. Since the age-related changes that subserve these types of prosody can vary, these mechanisms will be discussed individually.

1.1.8 Lexical Stress

Lexical stress is used to distinguish word pairs that differ only by stress placement (Cheang & Pell, 2007). For example, the word "record" can serve as a noun or verb, and the intended grammatical function of "record" in a sentence is signaled only by the relative stress of syllables within the word. Trochaic stress patterns refer to words with greater first syllable stress (strong syllable-weak syllable, hereafter SW for strong-weak) while iambic stress patterns refer to words with greater second syllable stress (weak syllable-strong syllable, hereafter WS for weak-strong). SW stress patterns (e.g., "REcord") can be used to signal the noun form of noun-verb pairs among other forms, while WS stress patterns (e.g., "reCORD") signal the verb form.

No previous study has examined changes to the production of lexical stress as a result of typical aging. Much of the current research relates specifically to disordered prosody production, or dysprosody. One particular study of dysprosody by Cheang and Pell (2007) compared the acoustic parameters of the production of noun phrases (e.g., “hot dog”) and noun compounds (e.g., “hotdog”) by older adults and individuals with Parkinson’s disease. Though the disambiguation of noun phrases and noun compounds is generally not considered lexical stress, results of this study provide insight into the basic ability to modify acoustic parameters used to produce lexical stress by older adults. The authors found that older adult controls were able to distinguish noun phrases (e.g., "hot dog") from noun compounds (e.g., "hotdog"), primarily by modulating the intensity and duration of syllables within words.

Cheang and Pell (2007) also reported findings from a contrastive stress task in which older adults served as controls. Older adults demonstrated the ability to convey contrastive stress by raising the F0 of stressed words relative to unstressed words in all positions (Cheang & Pell, 2007). Notably, absolute F0 decreased with sentence position from initial to medial to final sentence position (Cheang & Pell, 2007), consistent with falling sentence intonation. With regard to intensity, older adults were able to stress sentence-initial position key words to a greater extent than middle or final position key words, though they consistently modulated intensity throughout the task (Cheang & Pell, 2007). While these findings suggest that older adults can effectively produce lexical stress, it remains unclear if the results of this study translate to the production of lexical stress in the current study and how the production of lexical stress changes with typical aging.

Theoretically, older adults have the capacity to produce lexical stress as effectively as young adults. Stress relies on alterations to intensity and duration to a greater degree than F0 (Cho, 2006). Older adults have been shown to modulate loudness as effectively as young adults in a variety of speaking conditions (Huber, 2008; Huber & Spruill, 2008). Older adults have also demonstrated the ability to modulate the duration of key words to express other linguistic prosodic meanings as effectively as young adults, despite increased absolute duration as compared to young adults due to age-related slowing (Tauber et al., 2010). It is the expectation in the current study that older adults will modulate intensity and F0 as effectively as young adults, and that there will be no significant difference in intensity or F0 between groups. Furthermore, it is expected that older adults will vary durations between stressed and unstressed syllables to mark lexical stress as effectively as young adults, with a slight increase in overall absolute duration.

1.1.9 Ambiguous Sentences

Speakers typically use prosody to mark the intonational boundaries of speech that correspond with syntactic units (e.g., clauses, lists) to assist the listener in interpreting speech and to help in clarifying complex sentence meanings (Lieberman, 1967). Sentence disambiguation is useful in when encoding or decoding sentences that could have multiple meanings depending on the arrangement of syntactic units within the sentence. For example, the sentence "*Bobby could sled or ski and snowboard*" could have multiple meanings depending on the arrangement of syntactic units within the sentence. When spoken, syntactically ambiguous sentences can be disambiguated based on the position of a pause within the utterance. This is an intonational boundary that corresponds with a syntactic unit. Given our example, if a speaker were to say "*Bobby could sled* [pause] *or ski and snowboard*", it would indicate that Bobby has the option of sledding is exclusive from both skiing and snowboarding, which come in tandem. However, if the speaker were to say "*Bobby could sled or ski* [pause] *and snowboard*", it would indicate that that, regardless of sledding or skiing, Bobby will be allowed to snowboard.

In sentence disambiguation studies, young adults have been shown to increase the duration of key words (e.g., given the latter meaning of "*Bobby could sled or ski* [pause] *and snowboard*", "*ski*" is a key word as it precedes minor syntactic boundary marked by a pause and is essential to the intended interpretation of the ambiguous sentence (Tauber et al., 2010; Snedeker & Trueswell, 2003). In this case, the duration of production of "*ski*" is greater in "*Bobby could sled or ski* [pause] *and snowboard*" than "*Bobby could sled* [pause] *or ski and snowboard*") (Tauber et al., 2010; Snedeker & Trueswell, 2003). Young adults also consistently increase pause durations following key words to mark intonational boundaries when disambiguating syntactically ambiguous sentences (Tauber et al., 2010). Young adults were more likely to produce prosodic cues to disambiguate syntactically ambiguous sentences in interactions when the referential context is not shared by the speaker and listener, as opposed to times when they do share the referential context (Snedeker & Trueswell, 2003). Thus, young adults improve listener comprehension by pausing at syntactically appropriate locations and increasing the duration of production of key words and subsequent pauses in syntactically ambiguous sentences (Tauber et al., 2010; Snedeker & Trueswell, 2003).

Only Tauber et al. (2003), however, have reported on the ability of older adults to disambiguate syntactically ambiguous sentences, and methodological weaknesses as well as a reduced statistical power could have skewed results. The experimental paradigm in Tauber et al. (2003) required participants to read a three-page document per target sentence (a total of fifteen three-page documents) that included two separate paragraphs representing the distinct meanings of structurally ambiguous sentences. These complex stimulus items relied heavily on reading comprehension, which could interfere with the comprehension of the task and therefore the disambiguation of ambiguous sentences by the speaker. If the speaker indicated that they did not understand the meaning of the target sentence, the researchers provided the meaning for the speaker. Speaker comprehension was only assessed after both target sentences were produced, and the authors failed to address how tokens which did not match the intended meaning were considered. In addition, only four of the fifteen target sentences imbedded in paragraphs were structurally ambiguous, while five of the fifteen lexically ambiguous sentences and six of the fifteen were "filler sentences" which were not analyzed. This distribution of target sentences significantly reduced the statistical power of the ambiguous sentence trials. The current study will address these weaknesses by: A) Increasing the number of relevant trials to improve statistical power, and B) Decrease both reading requirements by utilizing photographs to establish the distinct meanings of ambiguous sentences. Objective measures of duration and subjective listener ratings of disambiguated sentences did coincide with one another, suggesting that older adults accurately and effectively marked intonational boundaries using syntactic prosody (Tauber et al., 2010).

In general, older adults appear to disambiguate syntactically ambiguous sentences as effectively as young adults. Older adults have demonstrated patterns of increased key word duration and subsequent pause duration when disambiguating syntactically ambiguous sentences, similar to that of young adults (Tauber et al., 2003). It is expected that older adults will mark intonational boundaries and disambiguate syntactically ambiguous sentences by increasing the duration of the production of key words and subsequent pauses in the current study as effectively as young adults. Older adults are also expected to produce key words, phrases, and pauses of significantly greater duration as compared to young adults.

1.2 Purpose

The purpose of this study is to identify age-related differences in the production of two mechanisms of linguistic prosody (lexical stress and the disambiguation of syntactically ambiguous utterances). Currently, there is a paucity of data regarding how typical aging affects linguistic prosody. Given the propensity for prosody to be impaired in diseases common in older adults (stroke, Parkinson's disease, etc.), it is critical to understand how typical aging affects prosody in order to distinguish disease-related changes. Further, given the task-specific nature of prosody, it is important to collect data in a variety of tasks and contexts to understand the spectrum of age-related prosodic changes. Lastly, prosody offers a theoretically interesting model for the study of how changes to physiology and cognition interplay in speech change in older adults. This study seeks to contribute to the base of information regarding the production of prosody by older adults and to reveal age-related differences in linguistic prosody production through comparison between young and older adults. The following hypotheses were made:

- In the lexical stress task: 1) Older adults will mark stressed syllables by modulating intensity, duration, and F0 as effectively as young adults, and 2) Older adults will produce syllables with a slight increase in absolute duration as compared to young adults.
- In the disambiguation of syntactically ambiguous sentences:1) Older adults will modulate intensity, duration, and F0 as effectively as young adults, and 2) Older adults will produce key words/phrases and pauses with a significant increase in absolute duration as compared to young adults.

2. METHODS

2.1 Participants

Ten young adults (age 18-30) and ten older adults (age 65 or older) participated in the current study. Each age group consisted of 5 male and 5 female speakers. All participants were native speakers of English and spoke a North American Standard English dialect. Participants had normal speech and language as determined from conversational interchange. Participants reported no history of voice or respiratory problems (including asthma), neurological disease, or head or neck surgery and had been nonsmokers for the past 5 years per self-report during a phone screening. Participants also had typical hearing for their cohort as determined by a hearing screening at 20dB and 40 dB for young and older adults, respectively, at 500, 1000, and 1500 Hz bilaterally (Ventry & Weinstein, 1983).

At the time of data collection, all participants reported being free from colds, infections, and allergy symptoms. Each participant was required to have at least a 6th grade reading level as evidenced by a criterion score on the The Gray Oral Reading Test-Fourth Edition (GORT-4) (Wiederholt & Bryant, 2001). Each participant was also administered The Cognitive-Linguistic Quick Test (CLQT) (Helms-Estabrooks, 2001) to screen areas of attention, memory, executive function, language, and visuospatial skills. An overall score within age-normal limits was required to participate. Finally, participants were administered a subtest of the Test of Adolescent and Adult Language-Third Edition (TOAL-3) to ensure the age-appropriate comprehension and production of syntax.

2.2 Equipment and Data Collection

Acoustic data was recorded using a high-quality head-mounted microphone with a flat frequency response up to 20kHz in both tasks. The microphone was mounted on the participant's head while maintaining a 45-degree angle to the participant's mouth and a constant mouth-to-microphone distance of 6cm during recording. The acoustic signal was recorded via digital audio recorder (Marantz PMD-671) and a compact flash memory card. The acoustic signal was then transferred to a computer and resampled at 18kHz using Goldwave v5.5. The resampling process applied a low-pass filter at 9000Hz for anti-aliasing. Acoustic data were measured in Praat (P. Boersma & Weenink, 2010) after resampling.

2.3 Procedures

Participants were given informed consent and were tested individually. Each participant underwent a phone screening and completed a health questionnaire to rule out the exclusion criteria as listed above. Testing lasted approximately 90 minutes per session, and participants were paid $20 for their participation. Participants were instructed to listen carefully to the directions prior to each of the tasks. All speech stimuli were presented via computer as PowerPoint slides, with one speech target per slide. One example item was provided prior to each experimental task, during which the researcher provided the instructions for said task. The participant was asked to complete the example item and indicate to the researcher whether he or she understood the task and was ready to proceed. The participant was reinstructed if he or she indicated that they did not understand the task or if the researcher noted that he or she did not follow the given instructions. The participant was then asked if they understood the task and was asked to produce the same example item again. This process was repeated no more than three times for any given subject until he or she indicated understanding. The participant was also reinstructed during the task if they requested clarification. Participants were asked to complete each task using a comfortable loudness and pitch, as well as their "natural communication style." The researcher did not provide direct models of the example items to avoid influencing the speaker's responses. In addition to the two tasks which are of interest for the current study, participants provided a sample of connected speech elicited during a reading task, produced contrastive stress sentences, and completed a question-statement paradigm.

2.4 Speech Stimuli

Lexical Stress Paradigm: Participants produced noun-verb word pairs that were differentiated with the use of SW or WS stress patterns. Sentences were provided to elicit the production of stress (Appendix A). While this task represents a single, well-controlled method to elicit lexical stress in connected speech, it should be noted that the task does not capture all forms of lexical stress commonly used in the English language. Participants produced the noun and verb form of 6 words in separate sentences for a total of 12 productions. Sentences in which the noun form was elicited were termed SW sentences, while sentences in which the verb form was elicited were termed WS sentences.

Word position and sentence type were controlled in the carrier sentence of each target word. All sentences were produced as statements and all target words were the second, third, or fourth word of their respective sentence, eliminating the production of intonation contours as a variable. Presentation of stress positions were randomized and the order of sentences were counterbalanced across participants.

Ambiguous Sentences Paradigm: Stimuli consisted of sentences with ambiguous prepositional phrase attachments (Appendix B). For example, in the sentence “The girl hit the boy with the fan,” the sentence could be referring to a girl hitting a boy who is holding a fan or a girl using a fan to hit a boy. Each sentence was paired with two pictures that corresponded to the two scenarios the sentence could be used to describe. Sentences in which the ambiguous prepositional phrase emphasized the action performed by the subject were termed the verb target. Sentences in which the ambiguous prepositional phrase demonstrated possession were termed the direct object target.

Snedeker and Trueswell (2003) found that when speakers are aware that a sentence is ambiguous and must be disambiguated for listeners to correctly interpret the sentence, speakers reliably use prosody to disambiguate that sentence. However, when speakers are not aware that a sentence is ambiguous and the context of the task only supports one interpretation of the sentence, speakers do not reliably use prosody to disambiguate sentences. Therefore, participants were shown the sentence and the two pictures that corresponded with it and were told that the sentence could be used to describe both pictures. The participants were then shown each picture individually and asked to produce the sentence in such a way as to describe the given picture. Ten sentences and picture sets were produced in both contexts for a total of 20 sentence productions. Presentation of sentence type was randomized and the order of the sentences was counterbalanced across participants.

2.5 Measurements

Lexical Stress Paradigm: Measurements included mean intensity, mean F0, and duration of each vowel segment in the target word using Praat (P. Boersma&Weenink,

2003). The boundaries of the segment included the points at which the first and second vowel formants were evident (as viewed on the spectrogram provided by Praat). The phonemes /r/ and /l/ were included as part of the vocalic segment. Duration of each vocalic segment was measured in seconds. The mean intensity was measured across the duration of each vocalic segment. The F0contour for each segment was manually checked for tracking errors. Erroneous F0 points were excluded from the analysis of mean F0. In the event that more than 50% of the F0points were incorrectly tracked, the mean F0measure for the segment was not made. Evident glottal fry was also excluded and was typically accompanied by tracking errors. Once errors were removed, the mean F0 was calculated across each vocalic segment.

These acoustic measures were used to calculate a Pairwise Variability Index (PVI) for each target word (Ballard et al., 2012; Ballard et al., 2010; Low, Grabe, & Nolan, 2000). The PVI calculates the difference in the acoustic parameters between the syllables in single word, and represents this difference as a ratio. A positive PVI suggests a SW stress pattern, a negative PVI suggests an WS stress pattern, and a PVI of zero indicates a neutral stress pattern. For example, the PVI_Duration formula is as follows:

$$PVI = 100 \times ((dk - dk+1) / [(dk + dk+1) / 2])$$

where *d* is the duration of the k^{th} syllable.

A percent correct value was also calculated from the above acoustic parameters. The percent correct value represented the extent to which the participant used prosodic cues to signal stress as anticipated. For each target word, the acoustic parameters of duration, intensity, and frequency between syllables were compared. These parameters were expected to be relatively greater for the first syllable in trochaic (or strong-weak) patterns, and relatively greater for the second syllable in iambic (or weak-strong) patterns. For example, if the intensity and duration were greater for the first syllable compared to the second syllable but F0 was greater in the second syllable of a trochaic word, the percent correct value would be 66.7% (or equal to 2/3). Possible percent correct values included: 0% (0/3 parameters greater in its anticipated location), 33.3% (1/3 parameters), 66.7% (2/3 parameters), and 100% (3/3 parameters).

Ambiguous Sentences Paradigm: As pausing has been found to play a large role in disambiguating syntactically ambiguous sentences (Tauber et al., 2010; Snedeker & Trueswell, 2003) and understanding syntactically complex sentences (Price et al., 1991; Shah, Baum, & Dwivedi, 2006), measurements concentrated on pausing and word duration. Measurements of the duration of key words/phrases (the verb, direct object noun, and prepositional phrase) and subsequent pauses (pauses after the verb and direct object), mean intensity, and mean F0 were made using Praat (P. Boersma & Weenink, 2003). Duration measures began at the onset of the vocalic segment (determined by the first and second vowel formants) and terminated at the final consonant or end of the vocalic segment, depending on the phonemic content of the target word or phrase. Pause duration measures were initiated at the termination of the preceding key word/phrase and were terminated at the initiation of the following key word/phrase. For example, the verb pause was initiated at the same point as the termination of the verb, and it would also be terminated at the initiation of the direct object. Pauses did not include any volitional speech or speech sounds. Intensity also began at the onset of the vowel, and terminated at either the end of vocalic segment or word/phrase as suggested by the intensity contour. The F0 contour for each segment was generated and manually checked for tracking errors. Erroneous F0 points were excluded from the analysis of mean F0. In the event that more than 50% of viable pitch points (the time where the pitch points could have been tracked, as opposed to fricatives and the pauses between words in the prepositional phrases) were incorrectly tracked, the mean F0 measure for the segment was excluded. Evident glottal fry was also excluded and was typically accompanied by tracking errors.

2.6 Statistical Analysis and Reliability

Two-factor repeated measures analyses of variance (ANOVA) were used to assess significant differences between conditions within tasks. The within factors were trochaic/iambic productions for the lexical stress task and verb/direct object target productions for the disambiguating syntactically ambiguous utterances task. The between subject factor was age, and no significant sex effects were hypothesized. Tukey HSD comparisons were used for pairwise comparisons for all significant ANOVA effects. Four participants were randomly chosen to be reanalyzed by a second individual in the laboratory to determine inter-measurer reliability. For the lexical stress task, duration, mean F0, and mean intensity for each syllable in each target word were reanalyzed. For the ambiguous sentences task, the duration, F0, and SPL of the verb, direct object, and prepositional phrase as well as the pause duration after the verb and after the direct object were reanalyzed. Inter-rater reliability was measured by t-tests. All of the t-tests (except for the mean SPL of the verb, $t=0.021$) indicated no significant differences suggesting that the measures were reliable. However, the difference in the mean SPL of the verb (0.05) was very small, and correlation was high (r=.9989).

3. RESULTS

3.1 Lexical Stress

Table 1 provides a summary of the results of the ANOVAs completed on the data from the lexical stress task. Table 2 provides the means and standard errors for the two groups by stress pattern on the dependent variables from the lexical stress task.

3.1.1 Intensity (SPL)

For PVI_SPL, there was a significant effect of stress pattern but no significant group or group by stress pattern effects (see Table 1). PVI_SPL was significantly higher for the SW pattern as compared to the WS pattern(see Figure 1). For mean SPL in the first syllable, there was a significant stress pattern effect, but no significant group or group by stress pattern effects (see Table 1). SPL was significantly higher in the first syllable when it was stressed (SW pattern) as compared to the when it was not stressed (WS pattern; see Table 2 and Figure 2). For mean SPL in the second syllable, there was a significant stress pattern effect, but no significant group or group by stress pattern effects. SPL was significantly lower in the first syllable when it was not stressed (SW pattern) as compared to the when it was stressed (WS pattern) (see Table 2)

Table 1: Statistical Summary for the Lexical Stress Task (p<=0.006)

Measure	**Group (df = 1)**		**Stress Pattern (df = 1)**		**Stress Pattern X Group (df = 1)**	
	F	***p***	***F***	***p***	***F***	***p***
1st Syllable SPL	0.126	.7266	83.230	<.0001*	0.001	.9712
1st Syllable F0	0.119	.7336	17.564	<.0001*	9.394	<.0025*
1st Syllable Duration	1.165	.2953	40.606	<.0001*	3.846	.0512
2nd Syllable SPL	0.1054	.7492	85.240	<.0001*	0.8331	.3624
2nd Syllable F0	0.317	.5806	11.423	<.0009*	9.650	<.0022*
2nd Syllable Duration	0.140	.7131	39.133	<.0001*	2.195	.1399
PVI SPL	0.1685	.6864	19.605	<.0001*	1.137	0.2876
PVI F0	1.772	.2010	45.730	<.0001*	20.195	<.0001*
PVI Duration	6.253	.0220	216.772	<.0001*	.001	.9712

Note. F0 = fundamental frequency | SPL = Sound Pressure Level | *indicates significance

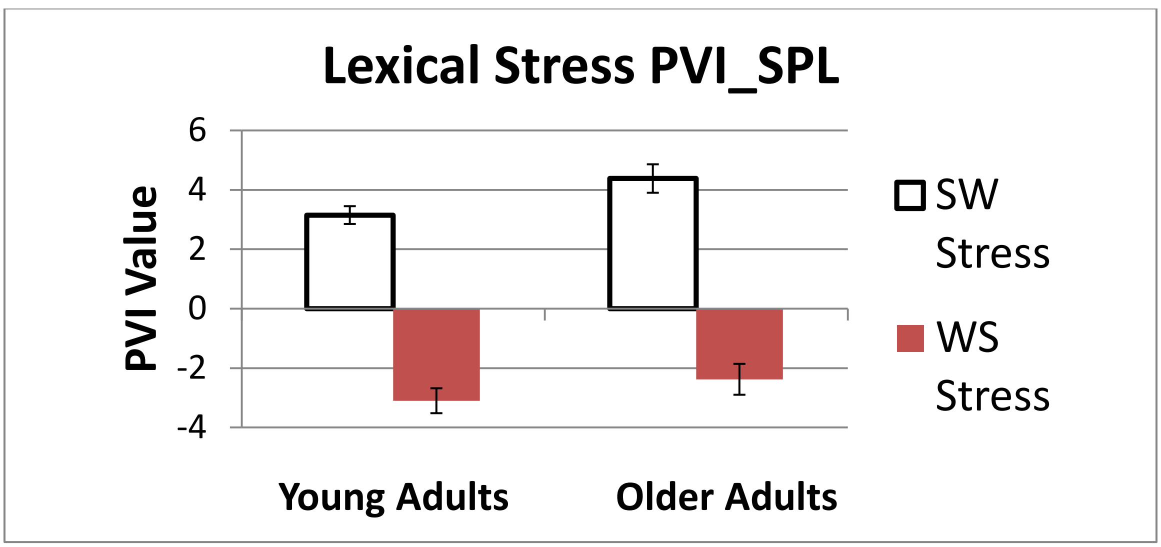

Figure 1: PVI_SPL Means by Age for Lexical Stress

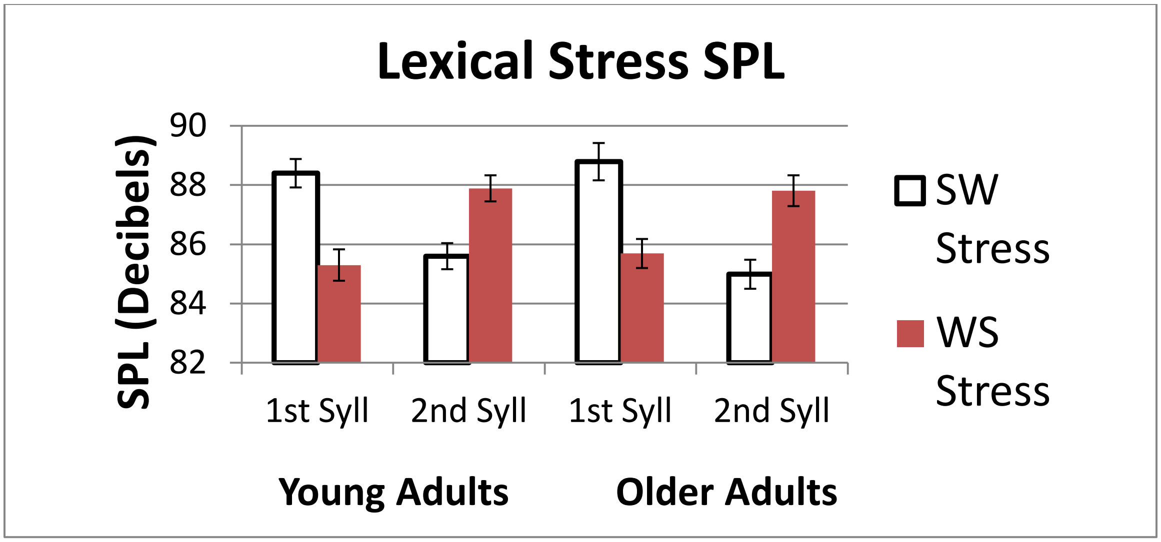

Figure 2: SPL Means by Age and Stress for Lexical Stress

3.1.2 Fundamental Frequency (F0)

For PVI_F0, there was a significant effect of stress pattern and group by stress pattern but no significant group effect (see Table 1).For the stress pattern main effect, PVI_F0was significantly higher for the SW pattern as compared to the WS pattern (see Table 2 and Figure 3). The results of the group by stress pattern interaction effect were that PVI_F0 was significantly different across stress patterns for the older adults, but not for the young adults (see Table 2 and Figure 3). Further, PVI_F0 in the SW pattern was significantly greater for older adults than young adults, but there was no significant difference between the groups for the WS pattern (see Table 2 and Figure 3). For mean F0 in the first syllable, there were significant stress pattern and group by stress pattern effects, but no significant group effect (see Table 1). For the stress pattern main effect, F0 was significantly higher in the first syllable when it was stressed (SW pattern) compared to when it was not stressed (WS pattern; see Table 2 and Figure 4). The results of the group by stress pattern interaction effect were that older adults had asignificantly higher F0 for the first syllable in the SW pattern as compared to the WS pattern, but there were no significant differences across the stress patterns for the young adults (see Table 2 and Figure 4). For mean F0 in the second syllable, there were significant stress pattern and group by stress pattern effects, but no significant group effect (see Table 1).For the stress pattern main effect, mean F0 was significantly lower in the second syllable when it was not stressed (SW pattern) as compared to the when it was stressed (WS pattern; see Table 2 and Figure 4). The results of the group by stress pattern interaction effect were that older adults had a significantly lower second syllable F0 in the SW pattern as compared to the WS pattern, but there were no significant differences across stress patterns for young adults (see Table 2 and Figure 4). There were no significant differences between young and older adults in mean F0 for either syllable.

Table 2: Mean Values by Age and Stress for Lexical Stress

Measure	**Young Adult**		**Older Adult**	
	SW	**WS**	**SW**	**WS**
1st Syllable SPL	88.40(.48)	85.30(.53)	88.79(.63)	85.69(.49)
2nd Syllable SPL	85.60(.44)	87.89(.44)	84.99(.49)	87.81(.52)
1st Syllable F0	159.35(6.24)	160.43(6.76)	161.57(4.09)	146.14(3.60)
2nd Syllable F0	155.25(6.69)	155.41(5.91)	138.25(4.36)	152.76(3.65)
1st Syllable Duration	.126(.011)	.061(.003)	.121(.004)	.088(.009)
2nd Syllable Duration	.110(.004)	.136(.004)	.105(.005)	.145(.007)
PVI_SPL	3.16(0.303)	-3.10(0.42)	4.38(0.48)	-2.30(0.52)
PVI_F0	4.70(1.59)	0.23(1.80)	16.88(2.68)	-5.34(1.81)
PVI_Duration	8.31(4.40)	-76.26(5.38)	16.15(5.22)	-52.24(6.09)
%Correct	67.2%(3.9%)	79.4%(3.0%)	75.6%(3.3%)	82.8%(3.4%)

Note. F0=fundamental frequency in Hz | SPL=Sound Pressure Level in dB | Duration in seconds | Mean(Standard Error)

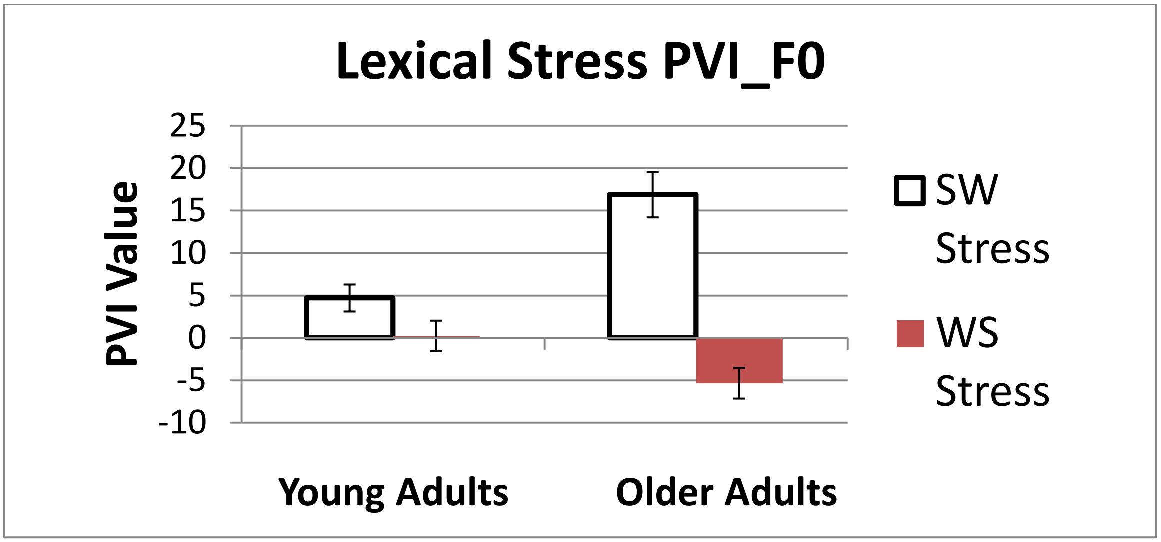

Figure 3: PVI_F0 Means by Age for Lexical Stress

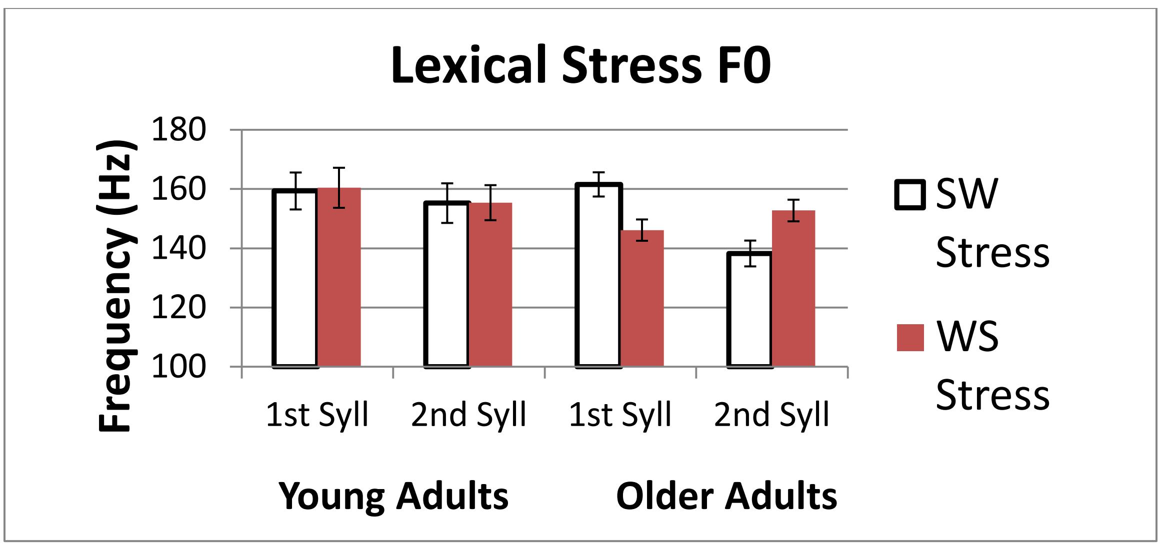

Figure 4: F0 Means by Age and Stress for Lexical Stress

3.1.3 <u>Syllable Duration</u>

For PVI_Duration, there were significant group and stress pattern effects, but no significant group by stress pattern effect (see Table 1). PVI_Duration was significantly higher for the SW pattern as compared to the WS pattern (see Table 2 and Figure 5). Young adults had more negative PVI_Duration values as compared to older adults (see Table 2 and Figure 5).For duration in the first syllable, there was a significant stress pattern effect, but no significant group or group by stress pattern effects (see Table 1). Duration was significantly higher in the first syllable when it was stressed (SW pattern) as compared to the when it was not stressed (WS pattern; see Table 2 and Figure 6). For duration in the second syllable, there was a significant stress pattern effect, but no significant group or group by stress pattern effects (see Table 1). Duration was significantly lower in the first syllable when it was not stressed (SW pattern) as compared to the when it was stressed (WS pattern; see Table 2 and Figure 6).

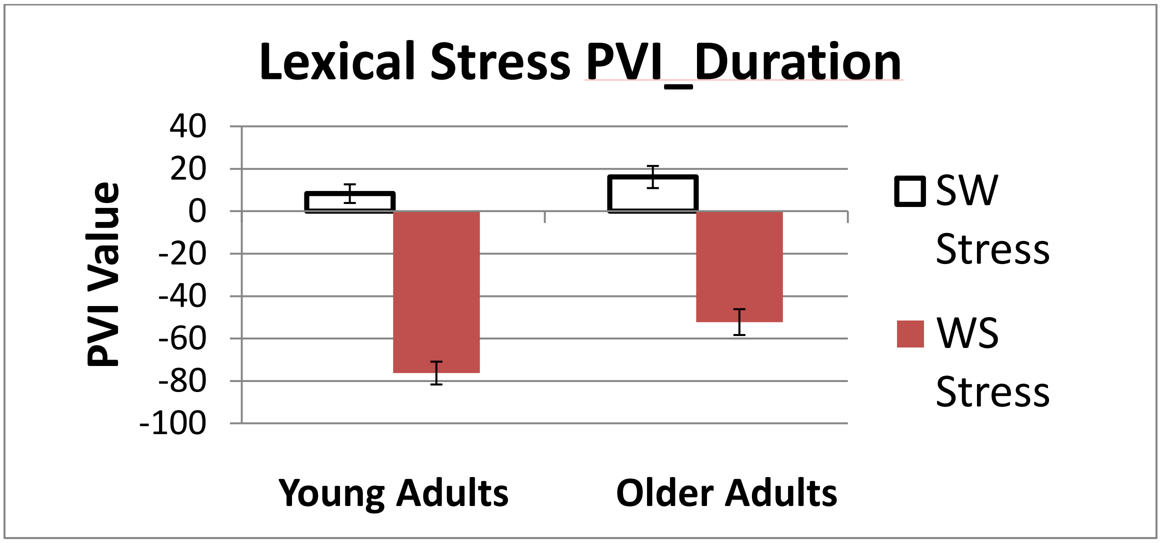

Figure 5: PVI_Duration Means by Age and Stress for Lexical Stress

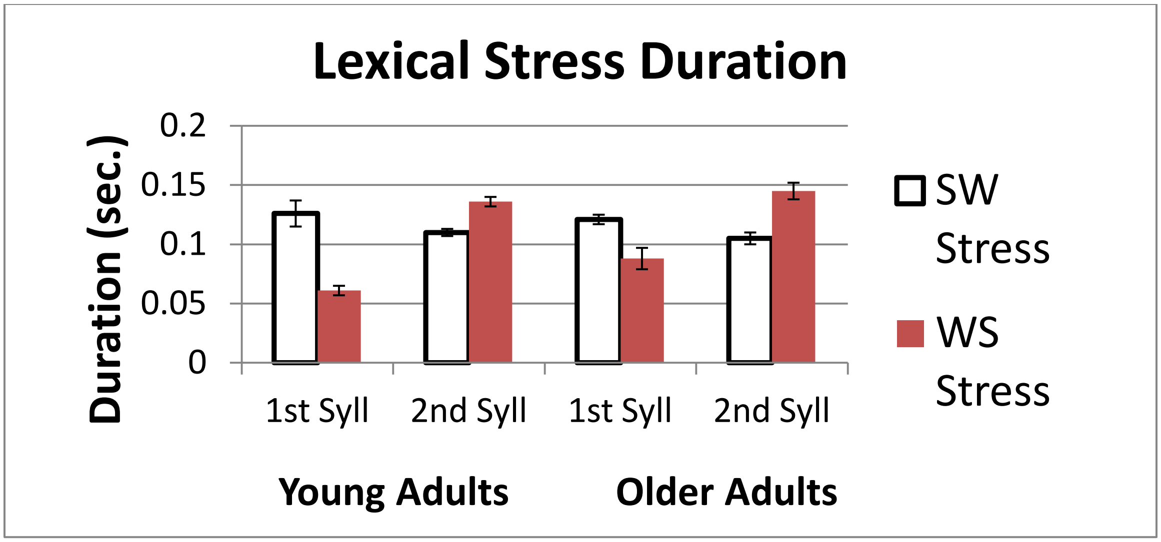

Figure 6: Duration Means by Age and Stress for Lexical Stress

3.1.4 <u>Percent Correct Value</u>

On average, older adults produced target syllables with anticipated prosodic features with greater accuracy than young adults (see Table 2 and Figure 7). Young and older adults more often produced anticipated prosodic features in WS stress patterns than SW stress patterns (see Table 2 and Figure 7).

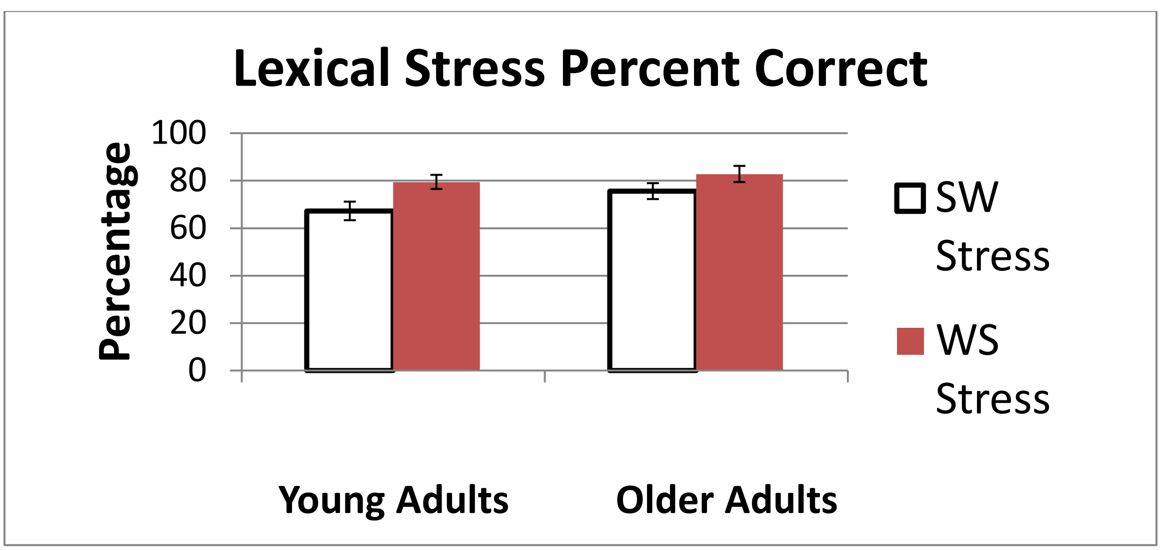

Figure 7: Percent Correct Means by Age and Stress for Lexical Stress

3.2 Ambiguous Sentences

Table 3 provides a summary of the results of the ANOVAs completed on the data from the disambiguating ambiguous sentences task. Table 4 provides the means and standard errors for the two groups separated by target on the dependent variables from the disambiguating ambiguous sentences task.

3.2.1 Intensity (SPL)

There were no significant group, pause target, or group by pause target effects for verb and direct object SPL. For prepositional phrase SPL, there was a significant pause target effect but no significant group or group by pause target effects (see Table 4). SPL was significantly higher in the prepositional phrase when the target was the direct object as compared to when the target was the verb (see Table 4 and Figure 8).

Table 3: Statistical Summary for Ambiguous Sentences(p<=0.006)

Measure	**Group (df = 1)**		**Target (df = 1)**		**Target X Group (df = 1)**	
	F	***p***	***F***	***p***	***F***	***p***
Verb SPL	0.988	.3335	0.036	.8507	0.910	.3406
Verb F0	0.268	.6113	0.749	.3875	0.3408	.5597
Verb Duration	2.273	.1490	0.201	.6545	0.106	.7451
Verb Pause Duration	0.229	.6381	0.808	.3694	0.003	.9535
Direct Object SPL	0.791	.3856	2.287	.1313	1.145	.2854
Direct Object F0	0.338	.5684	1.336	.2486	1.704	.1926
Direct Object Duration	9.4456	.0065	2.240	.1353	1.503	.2210
Direct Object Pause Duration	0.234	.6347	1.829	.1771	0.204	.6519
Prepositional Phrase SPL	1.222	.2835	23.319	<.0001*	1.698	.1933

Table 3 Continued

Prepositional Phrase F0	0.063	.8043	6.323	.0126	0.448	.5041
Prepositional Phrase Duration	17.245	.0006*	8.4914	.0038*	0.0592	.8079

Note. F0 = fundamental frequency | SPL = Sound Pressure Level | *indicates significance

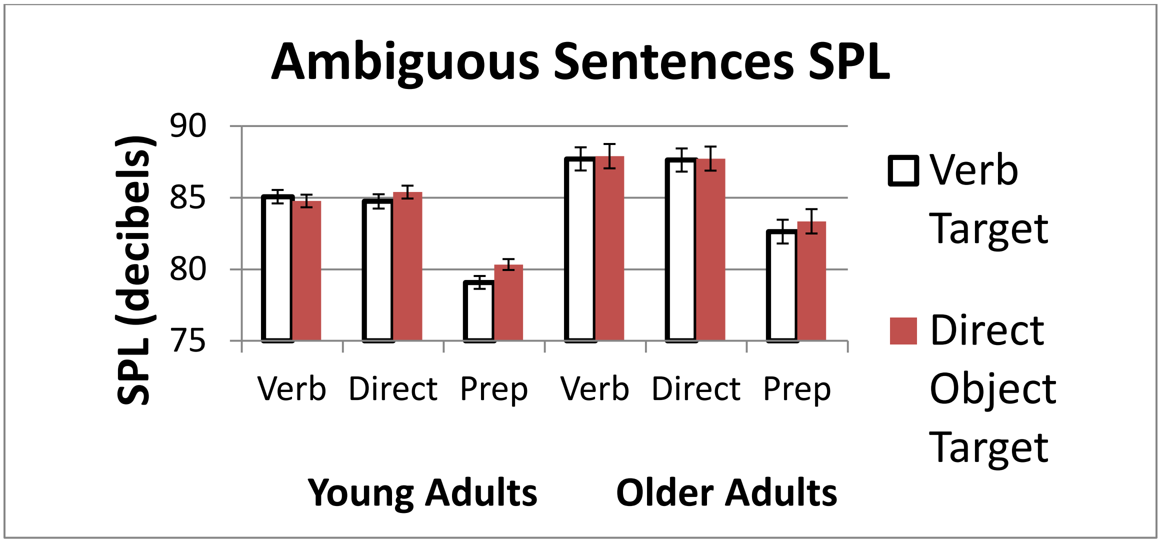

Figure 8: SPL Means by Age and Target for Ambiguous Sentences
Note. Direct = Direct Object | Prep = Prepositional Phrase

3.2.2 <u>Fundamental Frequency (F0)</u>

There were no significant group, pause target, or group by pause target effects for verb and direct object F0. For prepositional phrase F0, there was a significant pause target effect but no significant group or group by pause target effects (see Table 4). F0 was significantly higher in the prepositional phrase when the target was the direct object as compared to when the target was the verb (see Figure 9).

Table 4: Mean Values by Age and Target for Ambiguous Sentences

Measure	Young Adult		Older Adult	
	Verb	Direct Object	Verb	Direct Object
Verb SPL	85.07(.47)	84.77(.44)	87.71(.81)	87.90(.85)
Direct Object SPL	84.74(.51)	85.39(.45)	87.62(.81)	87.72(.84)
Prep Phrase SPL	79.08(.45)	80.33(.38)	82.63(.83)	83.35(.85)
Verb F0	163.88(4.60)	166.47(4.90)	154.52(3.97)	155.53(3.70)
Direct Object F0	146.84(4.67)	146.53(4.31)	133.90(3.30)	135.15(2.91)
Prep Phrase F0	134.02(3.23)	135.38(4.22)	124.70(3.24)	127.90(3.20)
Verb Duration	.301(.018)	.296(.017)	.327(.02)	.324(.008)
Direct Object Duration	.255(.006)	.277(.008)	.318(.009)	.320(.008)
Prep Phrase Duration	.781(.016)	.830(.015)	.891(.017)	.948(.025)
Verb Pause Duration	.048(.006)	.043(.005)	.053(.008)	.047(.006)
Direct Object Pause Duration	.056(.011)	.038(.010)	.040(.013)	.032(.009)

Note. F0=fundamental frequency in Hz | SPL=Sound Pressure Level in dB | Duration in seconds | Mean(Standard Error)

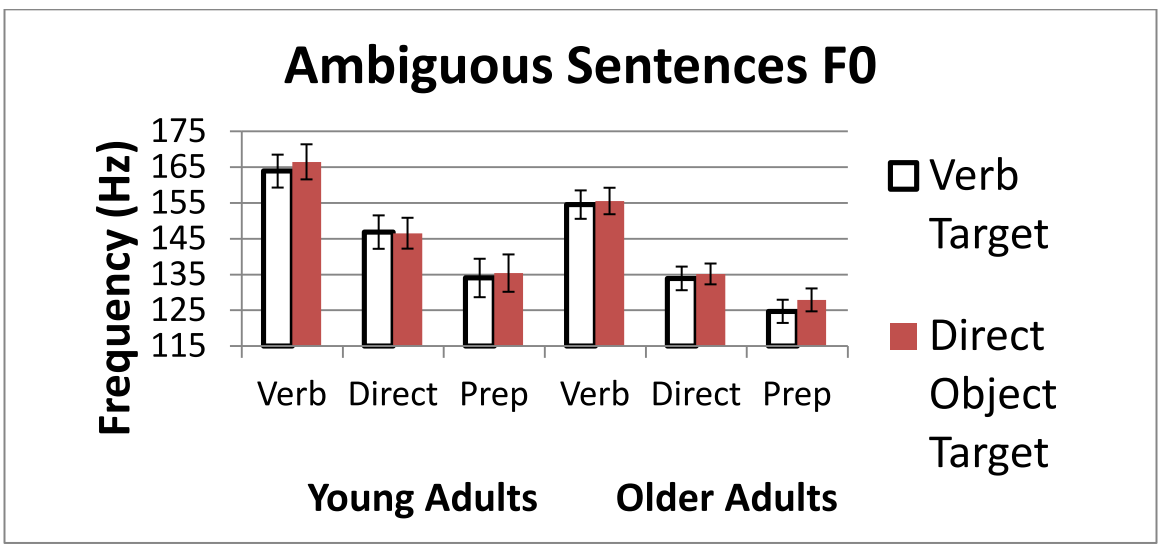

Figure 9: F0 Means by Age and Target for Ambiguous Sentences
Note. Direct = Direct Object | Prep = Prepositional Phrase

3.2.3 Word and Phrase Duration

There were no significant group, target, or group by target effects for verb duration (see Table 3). For direct object duration, there was a significant effect of group but no significant effects of target or group by target (see Table 4). Older adults produced direct objects of significantly greater duration than young adults (see Table 4 and Figure 10). For prepositional phrase duration, there were significant effects of group and target, but no significant effect of group by target (see Table 4). Older adults produced prepositional phrases of greater duration as compared to young adults (see Table 4 and Figure 11). Prepositional phrases were also of significantly greater duration when the target was the direct object as compared to when the target was the verb (see Table 4 and Figure 11).

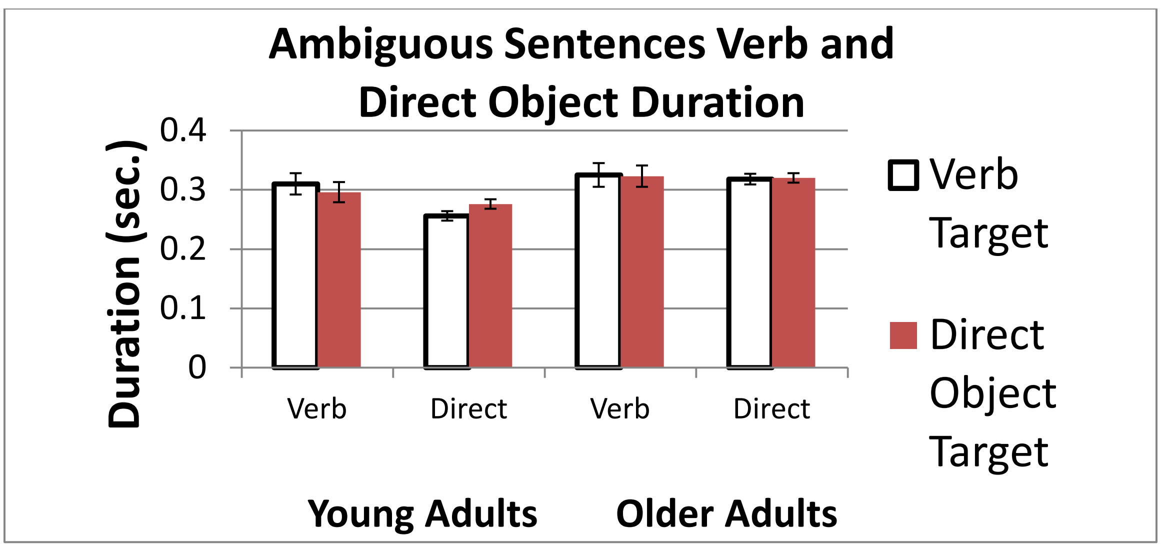

Figure 10: Verb and DO Duration Means by Age and Target for Ambiguous Sentences
Note. Direct = Direct Object | DO = Direct Object

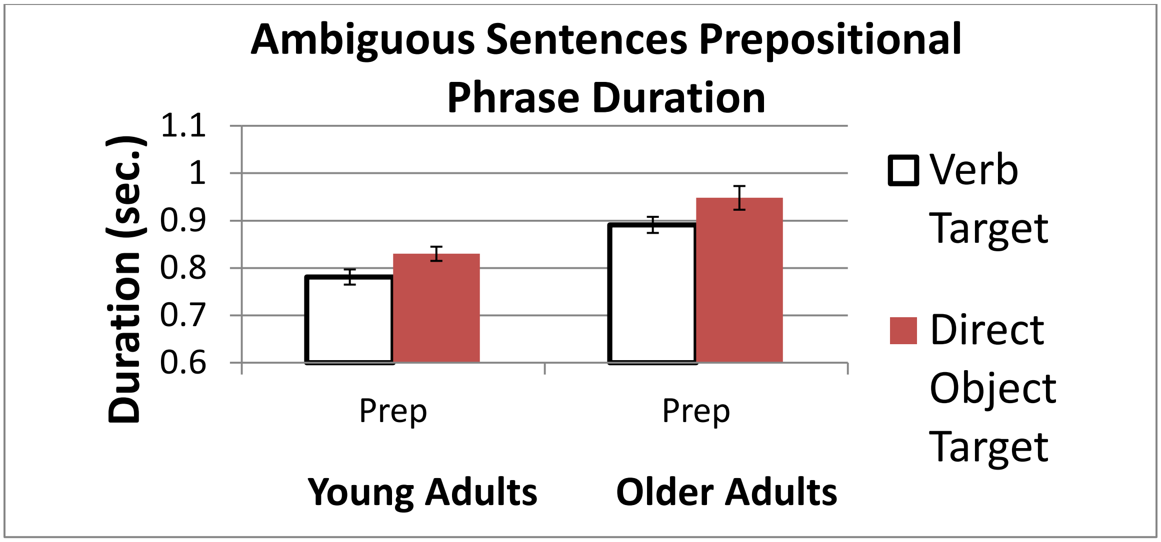

Figure 11: PP Duration Means by Age and Target for Ambiguous Sentences
Note. Prep = Prepositional Phrase | PP = Prepositional Phrase

3.2.4 Pause Duration

There were no significant group, target, or group by target effects for verb pause or direct object pause durations (see Table 4 and Figure 12).

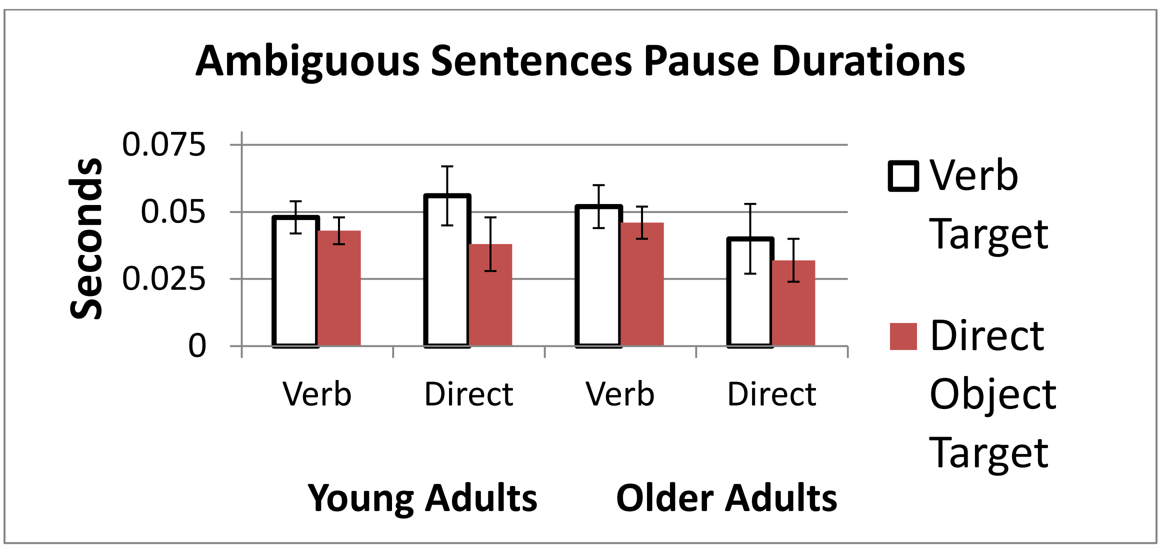

Figure 12: Pause Duration Means by Age and Target for Ambiguous Sentences
Note. Direct = Direct Object

. 4. DISCUSSION

4.1 Discussion of Lexical Stress Task

In the current study I sought to identify age-related differences in the production of lexical stress by older and young adults through acoustic analyses of SPL, F0, and the duration of vocalic segments in syllables. It was hypothesized that both young and older adults would effectively signal lexical stress by significantly altering the acoustic features of SPL, F0, and syllable duration, and that older adults would produce vocalic segments of slightly greater duration than young adults regardless of syllable position or stress pattern. The data largely supported these hypotheses. First, a discussion of SPL and F0 will be used to illustrate the impact of age-related physiological changes on the production of lexical stress. A discussion of syllable duration will then be used to illustrate the impact of age-related cognitive changes on the production of lexical stress.

4.1.1 Physiological Changes and Lexical Stress

As expected, both age groups utilized SPL to differentiate the first and second syllables of SW and WS stress patterns. First syllable mean SPL was significantly higher in the SW than the WS stress patterns, while first syllable SPL was significantly lower in the WS than the SW stress patterns. Thus, as expected, stressed syllables were produced with higher SPL than unstressed syllables. Mean PVI_SPL supported the interpretation that both groups used SPL to cue stress according to the expected patterns since it was significantly higher in the SW than WS stress patterns.

SPL stress pattern effects illustrate that young and older adults modulate SPL significantly to signal lexical stress, a finding which is in support of the first lexical stress hypothesis. This was the expectation in the current study, as children and young adults have previously demonstrated the ability to contrast SPL in the production of SW and WS stress patterns (Schwartz, Petinou, Goffman, Lazowski, & Cartusciello, 1996). Older adults have demonstrated similar capabilities, consistent with the SPL findings from the syllable-level stress task of Cheang and Pell (2007).

If present, SPL group effects would have suggested an impact of age-related physiological changes in the respiratory and laryngeal subsystems, the interaction of which is assumed to drive SPL. The lack of SPL group effects is in support of the second lexical stress hypothesis, as no significant difference implies that older adults do not habitually produce lexical stress with any greater or lesser SPL than young adults. Again, this was expected given previous studies which report that older adults are able to modulate SPL in a variety of loudness conditions, albeit with potentially increased effort (Huber, 2008).

Now turning to F0, there were no F0 group effects, although there were stress pattern and group by stress pattern effects. Older adults utilized F0 to a significantly greater extent than young adults when differentiating SW and WS stress patterns, specifically for SW stress pattern contrasts. Contrary to expectations, young adults did not demonstrate a similar pattern, and made only minimal contrasts between first syllable mean F0 and second syllable mean F0 for SW and WS stress patterns and there was no significant change across the syllables in mean PVI_F0.For older adults, mean PVI_F0 was significantly higher in SW than WS stress patterns, and significantly greater than young adult mean PVI_F0 in SW stress pattern.

F0 effects illustrate that older adults contrast F0 to signal SW and WS stress patterns to a significantly greater degree than young adults, a finding which was not expected in the current study. In fact, it appears that young adults did not effectively disambiguate SW and WS stress patterns through alterations of F0.This is contrary to the first lexical stress hypothesis, which assumes that young and older adults would both significantly alter F0 to produce lexical stress. Further, the older adult data in the present study are in contrast with a previous study in which older adults demonstrated a lack of significant F0 contrast between targets in syllable-level stress tasks (Cheang and Pell, 2007).

If present, F0 group effects would have suggested an impact of age-related physiological changes in the laryngeal subsystems, the principal driver of F0. The lack of significant group effects is consistent with previous studies (Mysak, 1959).

One explanation for the significantly increased contrast of F0 in lexical stress by older adults may be that age-related physiological changes in the laryngeal subsystem facilitate F0 change. Stiffening or hardening of laryngeal tissues may contribute to restricted F0 range, while decreased tension in other key tissues and a loosening of articulatory cartilages may contribute to increased F0 range. Older adults may find it easier to contrast F0 than young adults, because of the loosening of tissues. It is thought that the effect of decreased tension and loosening outweighs the stiffening of other tissues; thus, older adults may have more difficulty voluntarily controlling F0.Older adults may overly change F0 due to difficulties controlling their laryngeal tension.

Alternatively, the phenomenon of cue trading in the production of all forms of stress can account for the stress pattern differences in F0 and is well-documented in prosody literature (Hayes, 1995). Specific to task and experimental paradigm, groups vary in the acoustic parameters used to signal stress. Lexical stress is also notorious for individual cue weighting, even within groups (Hayes, 1995). The results suggest that young adults tended to produce lexical stress by modulating other parameters (such as SPL and duration) to a greater extent than F0. Older adults differed from this pattern, stressing F0 in addition to SPL and duration.

4.1.2 Cognitive Changes and Lexical Stress

As mentioned previously, duration is the acoustic correlate of speech assumed to be impacted primarily by age-related changes to cognition. Both young and older adults utilized duration to differentiate the first and second syllables of SW and WS stress patterns, which was the expectation in the current study. First syllable duration was significantly greater in SW than WS stress patterns. Mean PVI_Duration was significantly different between SW and WS stress patterns for both young and older adults. Duration stress pattern effects illustrate that young and older adults modulate duration significantly to signal lexical stress, a finding which is in support of the first lexical stress hypothesis. This was the expectation in the current study, as young adults have previously demonstrated significant duration contrasts for SW and WS stress patterns (Goffman, Heisler, & Chakraborty, 2006). Older adults have demonstrated similar capabilities, consistent with the duration findings from the syllable-level stress task of Cheang and Pell (2007).

Young adult mean PVI_Duration was lower than older adults in SW and WS stress patterns, although the mean difference were much higher for the WS syllables. These data suggest that young adults used duration more than older adults as a cue for WS patterns. The canonicity of SW and WS syllable stress can help to explain why duration was used to contrast WS stress to a greater extent than SW stress, and more so by young adults than older adults. Young adults have previously demonstrated greater temporal contrast for WS than SW stress in the more difficult, noncanonical WS stress pattern (Goffman et al., 2006). This pattern was replicated by young adults in the current study, and by older adults to an extent. Both young and older adults contrasted syllable duration to signal WS stress to a greater degree than SW stress. This may also be an effect of cue trading. While young adults primarily used duration and SPL, older adults appeared to rely on all three acoustic features. This may decreased the relative importance of duration contrasts for older adults as compared to young adults.

If present, duration group effects would have suggested an impact of age-related cognitive changes. The lack of group differences may be due to the relatively light cognitive-linguistic load required to produce lexical stress in sentences.

It is also pertinent to discuss the percent correct measure in relation to the acoustic features described above. Both groups demonstrated a greater accuracy in the anticipated production of WS stress than SW stress. These results provide some insight in the theories proposed above.

The percent correct measure assumes that all three acoustic features will be greater in one syllable than the other for a given stress pattern. A percent greater than 66% suggests that two cues were moving in the expected direction. Means above 66% for all groups and stress patterns indicates that, on average, speakers used at least two convergent cues. Accuracy is greater for WS stress in both groups, which may be accounted for by the relative weight of the second syllable in WS stress as compared to SW stress (Prince, 1980). The measure will naturally reflect higher accuracy for WS stress than SW stress, the latter of which has more distributed stress across syllables (as evidenced by PVI values that range from zero to positive for SW stress).The finding that older adults use all three acoustic features to signal lexical stress, as opposed to the primary reliance on SPL and duration young adults, is supported by this finding. A measure that is dependent on all acoustic measures would reflect higher scores for those who choose to use all acoustic correlates of stress (older adults), as opposed to those who trade cues (young adults).

4.2 Discussion of Ambiguous Sentences Task

The current study sought to identify age-related differences in the disambiguation of syntactically ambiguous sentences by young and older adults through acoustic analyses of SPL, F0, and the duration of key words/phrases and pauses in sentences. It was hypothesized that both young and older adults would effectively disambiguate ambiguous sentences by primarily through significantly altering the word/phrase duration, and pause duration, and that older adults would produce significantly greater key word/phrase and pause durations than young adults regardless of target. SPL and F0 were measured as potential secondary cues for disambiguation. The data generally supported these hypotheses, with some differences compared to previous reports of the disambiguation of ambiguous sentences by young and older adults. Similar to the discussion of lexical stress, a discussion of SPL,F0, and duration will first be used to illustrate the impact of age-related physiological changes on the disambiguation of syntactically ambiguous sentences and to compare our data to earlier studies of syntactically ambiguous sentences. A discussion of age group effects on word/phrase and pause duration will then be used to illustrate the impact of age-related cognitive changes on the disambiguation of syntactically ambiguous sentences.

4.2.1 Physiological Changes and Sentence Disambiguation

Previous studies have not examined the use of SPL change as a cue for sentence disambiguation. However, in the current study, both groups utilized prepositional phrase SPL to differentiate direct object and verb target sentences. Prepositional phrase mean SPL was significantly greater in direct object target sentences than verb target sentences for both age groups. Neither verb nor direct object mean SPL were used to disambiguate the sentences. There were also no significant group differences.SPL target effects illustrate that young and older adults modulate SPL similarly to disambiguate syntactically ambiguous sentences, a finding which supports the first ambiguous sentences hypothesis.

If present, SPL group effects would have suggested an impact of age-related physiological changes in the respiratory and laryngeal subsystems, the interaction of which is assumed to drive SPL. Age-related physiological changes do not appear to have a significant impact on the ability to modulate SPL when disambiguating ambiguous sentences.

Results of F0 are similar to those of SPL, as both age groups utilized prepositional phrase F0 to differentiate direct object and verb target sentences. Prepositional phrase mean F0 was significantly greater in direct object target sentences than verb target sentences for both age groups. Neither verb nor direct object mean F0 were used to disambiguate sentences. There were also no significant group differences. F0 pause target effects illustrate that young and older adults modulate F0 similarly to disambiguate syntactically ambiguous sentences, a finding which supports the first ambiguous sentences hypothesis.

If present, F0 group effects would have suggested an impact of age-related physiological changes in the laryngeal subsystems, the primary driver of F0. Age-related physiological changes do not appear to have a significant impact on the ability to modulate F0 when disambiguating ambiguous sentences.

Young and older adults did not use pauses or duration as clearly as expected from previous literature. Only prepositional phrase duration was significantly greater in direct object target sentences than verb target sentences. Duration target effects illustrate that young and older adults modulate duration similarly to disambiguate syntactically ambiguous sentences, a finding which partially supports the first ambiguous sentences hypothesis. The lack of significant target effects for pauses and for duration of verbs and direct objects, however, is not supportive of our hypotheses.

Instead of using direct object and verb pauses, speakers in the current study used prepositional phrase SPL, F0, and duration to differentiate direct object and verb target sentences. This is somewhat surprising, given that verbs and direct objects were the expected boundaries of intonational groups within sentences, and should have received more relative stress (Snedecker and Trueswell, 2003). A comparison of SPL and F0 measures cannot be made with Snedecker and Trueswell (2003), as these measures were not made; however, the duration effects can be compared.

Task differences between Snedecker and Trueswell (2003) and the current study may account for the differences in the results. In the current study, participants read pre-made sentences aloud, as opposed to generating their own sentences as in Snedecker and Trueswell (2003). This may have constrained speakers in the current study to use the ambiguous prepositional phrase attachment (the longest and most terminal segment of the pre-made sentence) to differentiate direct object and verb target sentences.

Turning now to pauses, no group, target, or group by target effects emerged for verb or direct object pauses. These data suggest that young and older adults used pauses similarly and did not reliably used pauses to differentiate targets. These results differ from the findings of Snedecker and Trueswell (2003), who found that young adults disambiguate syntactically ambiguous sentences via pauses after the verb) and direct object). Cruttenden (1997)reports that pausing cannot be used alone as the feature to disambiguates utterances. Specifically, pauses do not always indicate syntactic boundaries, and other factors (such as acoustic cue trading) must be considered in the formation of phrasal boundaries (Cruttenden, 1997). Unfortunately, Snedecker and Trueswell (2003) did not collect SPL or F0 data. No other study on the disambiguation of ambiguous sentences has reported SPL or F0 to the authors' knowledge.

Cue trading, driven by the constraints of the task in the current study, may account for these results. It is evident that prepositional phrase SPL, F0, and duration are being used by both groups to differentiate direct object and verb target sentences. Both age groups may have been cued to use a specific word or phrase in the sentence (as a written sentence was visually presented) rather than to insert a pause. Thus, the difference could be the result of the use of self-generated sentences as opposed to the use of pre-made sentences. The effects of cue trading are apparent, and these likely impacted the use of pauses in the current study.

It is not clear why stress was mainly present in the direct object target sentences as opposed to verb target sentences. One explanation is that the linguistic structure and canonicity of each sentence type differs, and may have impacted the participant's ability to decode and encode the separate sentence meanings. In the direct object target sentence, young and older adults were anticipated to phrase the sentence by placing a pause after the direct object: "The woman hit the man [pause] with the umbrella." In this way, the first phrase takes a "subject-verb-object" (SVO) word order and the prepositional phrase serves an adverbial function.SVO word order is one of the most syntactically simple and canonical sentence structures in the English language, and is easier to decode or encode for speakers and listeners (Lieberman, 1967). This was likely beneficial for participants in the current study. In addition, the direct object target sentence was modular, meaning that the prepositional phrase could be transplanted to the front of the sentence ("With the umbrella, the woman hit the man") and maintain meaning. This further distinguished the prepositional phrase from the SVO phrase when the encoding of the sentence meaning.

Verb target sentences do not share this canonical SVO word order phrasing. For example, "The woman hit [pause] the man with the umbrella" places the pause after the verb and before the direct object, resulting in a "Subject-Verb" phrase and an "Object-Prepositional Phrase" phrase. Not only is this phrasing non-canonical, it is also not modular. Participants may have consequently lost the benefits described above for decoding and encoding ambiguous sentences, resulting in a more prosodically neutral production of the prepositional phrase. Furthermore, Lieberman (1967)notes that the falling intonation of verb pause target sentences begins after the verb, resulting in greater relative SPL and F0 decrease for verb target sentences as opposed to direct object target sentences. In summary, speakers may have had difficulty choosing a stress target given the constraints of verb target sentences. Therefore, direct object target sentences are stressed to a relatively greater degree.

4.2.2 Cognitive Changes and Sentence Disambiguation

Similar to the lexical stress task, differences between age groups in word/phrase and pause duration were hypothesized the impact of age-related cognitive changes in the disambiguation of ambiguous sentences. Older adults produced significantly greater direct object and prepositional phrase durations than young adults, regardless of target. There were no significant target or group differences in pause durations. Duration group effects were hypothesized to suggest an impact of age-related cognitive changes, which were expected given the relative difficulty and cognitive load of disambiguating ambiguous sentence. Taken with the lack of age group effects on duration during the lexical stress task, these data demonstrate older adults produce key words and phrases of greater duration than young adults when the cognitive load of a task is high. These group differences support the second ambiguous sentence hypothesis. The duration group differences in the current study suggest that the disambiguation of syntactically ambiguous utterances is a cognitively complex task that requires a relatively large amount of cognitive resources.

The lack of a group difference for verb duration may have been a product of the task. Compared to the verb, the direct object and prepositional phrase were in a more terminal sentence position. The direct object and prepositional phrase must be stored in a cognitive buffer longer, along with the planned alterations in prosodic cues for said phrases, until they are produced. This was more cognitively taxing, and drove higher duration measures as a result. The task of reading may have exacerbated these group differences (Dupuis and Pichora-Fuller, 2003). Dupuis and Pichora-Fuller (2003) note that older adults read sentences more slowly than young adults. Direct objects and prepositional phrases may have been affected proportionally more by their later sentence position and longer durations (as compared to the single word verb).

4.3 Integrative Discussion of Findings

Age-related physiological group differences in the use of F0 for stress were apparent in the lexical stress task but not in the disambiguation of ambiguous sentences task. This supports the hypothesis that age-related changes to physiology more dramatically affect SPL and F0 in prosodic tasks with relatively brief periods of acoustic contrast. When disambiguating ambiguous sentences, the intonational contour is spread out over a broader duration and a greater number of phrases and may include multiple rise/fall patterns at various syntactic boundaries.

The disambiguation of ambiguous sentences represents a cognitively demanding task which revealed significant group differences in the duration of key words/phrases between young and older adults. When disambiguating sentences, speakers must develop a plan to utilize acoustic contrasts at syntactic boundaries and simultaneously retain that plan while coordinating the speech subsystems with those acoustic goals. This appears to become increasingly difficult as the syntactic complexity of the utterance increases. These group differences were not present in the lexical stress task. Speakers had to perform fewer cognitive functions to produce lexical stress in the experimental paradigm, thus reducing the cognitive-linguistic load on the speaker. These data suggest that the lexical stress task recruits relatively fewer cognitive resources as compared to disambiguation of syntactically ambiguous sentences.

The current study demonstrates that individual features of physiology and cognition can be tied to specific acoustic features in the production of linguistic prosody. However, physiology, cognition, and language also appear to interact when producing linguistic prosody. Cue trading serves as an example of this interaction. When certain cues are either deemed ineffective by the speaker or cannot be achieved, the speaker can utilize another cue to a greater extent. It is important to remember, however, that individual types of linguistic prosody are rarely used in isolation. As speakers, we may need to produce lexical stress while disambiguating an utterance, and that would require coordination of multiple, simultaneous acoustic contrasts. Future research should continue this line of investigation, including multiple levels of linguistic complexity in research examining the effects of aging on prosody production.

4.4 Clinical Implications

These data help to inform the interpretation of clinical findings in older adult populations. Typically aging older adults appear to vary SPL, F0, syllable duration, key word/phrase duration, and pause similarly to young adults. Age-related changes to physiology and cognition do not appear to restrict the ability to modulate these features. Older adults may require more processing time for tasks with high cognitive-linguistic loads, but this does not appear to detract from their ability to signal stress when cued. In many cases, older adults tended to utilize all three acoustic features to signal stress and in some instances, utilized an acoustic feature to a greater extent than young adults (such as the increased F0 contrast in lexical stress).

These data are also useful when interpreting the clinical findings of acoustic assessments for older adult populations when dysprosody is suspected. Disease processes of which dysprosody is a symptom (Parkinson's disease, Multiple Sclerosis) often refer to the reduced or absent ability produce or control prosodic contrasts. For example, monotonicity in individuals with Parkinson's disease refers to a reduced or absent pitch variance and a monotonous quality. The most important finding of the current study is that dysprosody is not the product of typical aging, and, when present, signals a significant change in physiology, cognition, or language. Whether or not these data can be used to detect significant differences in the production of prosodic contrasts in individuals with speech disorders remains to be tested in a clinical capacity.

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APPENDICES

Appendix A: Lexical Stress Paradigm

Target Word	Noun/Verb	Context Sentence
Contract	Noun	The new contract will keep us employed.
	Verb	Metal will contract when cooled.
Desert	Noun	The desert can be hard to cross.
	Verb	She might desert her team.
Object	Noun	There's a strange object on the table.
	Verb	The lawyer will object to this motion.
Permit	Noun	You need a permit to park here.
	Verb	You should permit her request.
Record	Noun	Here is a record of today's sales.
	Verb	She must record the new song today.
Subject	Noun	She is a subject in our study.
	Verb	He may subject you to his bad singing.

Appendix B: Ambiguous Sentences Paradigm

1. The man entertained the dog with the bandana.
2. The man pet the dog with the stick.
3. The boy tagged the girl with the jump rope.
4. The woman hit the man with the umbrella.
5. The man surprised the woman with the flower.
6. The girl chased the boy on the skateboard.
7. The woman tickled the boy with the feather.
8. The boy tripped the girl with the stick.
9. The man followed the woman on the bike.
10. The girl watched the boy with the binoculars.