ABSTRACT

Title of Thesis: A COMPARISON OF LEXICAL ACCESS IN ADULTS WHO

DO AND DO NOT STUTTER

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Previous work has postulated that a deficit in lexicalization may be an underlying cause of a stuttering disorder (Prins, Main, & Wampler, 1997; Wingate, 1988). This study investigates the time course of lexicalization of nouns and verbs in adults who stutter. A generalized phoneme monitoring (GPM) paradigm was used. Both populations showed a significant effect of word class (verbs yielded slower and less accurate monitoring than nouns), as well as phoneme position (word medial/final phonemes yielded slower and less accurate monitoring than word initial phonemes). Few significant differences were found between groups, although the experimental group showed poorer performance in all conditions, with the exception of null trials, where the experimental group actually out-performed the control group. The trends provide some level of support for the notion that people who stutter have a deficit in lexicalization, although the effect is mitigated by the lack of significance.

A COMPARISON OF LEXICAL ACCESS IN ADULTS WHO DO AND DO NOT

STUTTER

by

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I. INTRODUCTION

We explore lexicalization of nouns and verbs and the differences in lexicalization abilities which may exist between people who do (PWS) and do not stutter (PWNS). We examine these abilities using a phoneme monitoring paradigm. First, we will provide background information on linguistic processing in people who stutter, and describe some atypicalities which have been noted in people who stutter as compared to people who are typically fluent. We then explain the phoneme monitoring paradigm, and why it may be particularly well suited to experiments involving people who stutter before moving to a description of the current study and its findings.

Stuttering is a disorder that disrupts smooth, forward-moving speech, and is characterized by physical tenseness, repetitions, and blockages (Bloodstein & Bernstein Ratner, 2008). Many of the disfluencies produced by people who stutter (PWS) appear similar to the normal disfluencies produced by all speakers, though true stuttering-like-disfluencies (SLDs) can reflect physical tension and be accompanied by non-speech related symptoms, such as inappropriate loss of eye-contact and facial tics (Manning, 2010). Most PWS begin to stutter in early childhood (around 3 years old) and approximately 80% outgrow their stuttering by kindergarten or first grade. However, stuttering can persist into adulthood and become a severe quality-of-life issue for a small percentage (~0.75%) of the general population (Yairi & Ambrose, 2013).

Etiological Models of Stuttering

Theories about potential etiologies of stuttering cover a wide range of possibilities. Older theories postulated that PWS had some sort of physiological abnormality involving the tongue or the larynx. These theories gave way to the idea that stuttering was caused by emotional trauma, though both of these schools of thought are now discredited (Bloodstein & Bernstein Ratner, 2008). Among plausible current theories of stuttering, there are motor theories, language theories, and multifactorial theories (which encompass both motor and language aspects). Motor theories suggest that PWS are unable to properly sequence and execute the movements required for speech because of aberrant central coordination of motor gestures (e.g., Max, Guenther, Gracco, Ghosh, & Wallace, 2004). Language theories suggest that stuttering is caused, at least in part, by impaired language skills in PWS (e.g., Howell, 2004).

One prominent multifactorial theory of stuttering is the Dynamic-Multifactorial Model (Smith & Kelly, 1997; Smith, 1990). In the Dynamic-Multifactorial Model (DMM), stuttering is the byproduct of the complex interactions of a number of different factors, such as language abilities, motor planning abilities, and a number of psycho-social or environmental factors such as stress. Each individual has some number of these contributing factors, and, when enough contributing factors are present, and also are interacting in a certain manner, the individual begins to stutter. It is, therefore, possible to have contributing factors for stuttering, but not stutter. One possible factor which may contribute to stuttering onset and persistence is deficient linguistic ability involving some aspect of the language encoding process.

Because the DMM covers all possible contributing factors to dysfluency, other theories of stuttering with more narrow focuses can be subsumed beneath it. The EXPLAN model of stuttering states that fluency failure arises because different segments of speech take different amounts of time to plan and execute (Howell & Au-Yeung, 2002). The linguistic formulator develops what a person wants to say (the PLAN), and then the speech-motor systems execute this plan (EX). According to EXPLAN, the PLAN and EX phases of speech production happen simultaneously and independently. Some segments are more difficult to plan than others, but, in a typical speaker, these are still dealt with in a timely manner, causing no delay in execution, with fluent speech as the result. However, in people who stutter, segments that are more difficult to plan can cause the system to become backed-up, resulting in delays in communication between the planning and motor mechanisms, culminating in disfluent speech. According to EXPLAN, this back-up typically occurs when a segment which takes a relatively long time to plan is immediately preceded by a segment which takes a relatively short time to plan. In this event, the EXPLAN model states that the person who stutters will simply become stuck on the last bit of information that was successfully programmed and executed (Howell & Au-Yeung, 2002). EXPLAN is typically explained in terms of content and function words, postulating that function words, being shorter (in English) and much more commonly used, are faster to plan, and then when followed up by a content word, which takes longer to plan, a stuttering event occurs. However, this is not the only way to interpret the theory, as we will show later in discussion.

Language Abilities in PWS

Understanding language abilities in PWS is important because stuttering occurs during the use of oral language. Therefore, it is critical to understand language abilities of PWS when performing any examination of stuttering/PWS (Hall, Wagovich, & Bernstein Ratner, 2007). These differences must be taken into account and considered as a component of the stuttering disorder, unless proven otherwise, as they may provide insight as to the underlying etiology of stuttering and specifically when in the process of language production PWS face difficulty.

A large body of work has compared linguistic capabilities of people who stutter and people who do not stutter (PWNS). This research should be divided into research with adults and research with child participants, because patterns of stuttering are often different in adults and children, possibly because of the extensive psycho-social influences on stuttering that emerge and change over time.

Adult Research

There are significant differences in brain anatomy and activity of PWS during speech as compared to PWNS. Anatomically, PWNS typically show a larger right than left prefrontal lobe, and a larger left than right occipital lobe. These asymmetries are not found in PWS (Foundas, Corey, Angeles, Bollich, Crabtree-Hartman, & Heilman, 2003). PWNS tend to lateralize almost all speech and language activity to the left hemisphere of the brain, whereas PWS show lateralization that is much more evenly distributed across hemispheres, or, in some cases, even right hemisphere lateralization (Chang, Kenney, Loucks, & Ludlow, 2009). Such differences in cortical structure and function could

result in less efficient language processing in PWS, particularly in situations which result in higher cognitive loads.

There is evidence that the atypical cortical representation and processing of language in PWS can contribute to behavioral differences in motor function during language generation. Kleinow and Smith (2000) used the spatiotemporal index (STI) to show evidence of syntactic difficulties in adults who stutter (AWS). The STI quantifies the stability of motor movements during speech. The speech motor stability of adults who do not stutter (AWNS) was not affected by increasing the syntactic complexity of target phrases. However, the speech motor stability of the stuttering participants significantly decreased as the stimuli became increasingly syntactically complex. Increases in stimulus length, without an increase in syntactic complexity, did not impact the speech motor stability of either group. These results fit with the results of other studies (i.e., Bosshardt, 2002, and Smits-Bandstra & De Nil, 2009), showing that PWS have greater difficulty with higher linguistic and/or cognitive loads.

Language processing is atypical in PWS.

PWS show atypical language processing profiles and abilities as compared to PWNS, possibly as a result of the differences in cortical function and structure discussed previously. Event-related brain potentials (ERPs) in PWS have been the subject of a significant amount of research in recent years (e.g., Weber-Fox, Spencer, Spruill, & Smith, 2004; Weber-Fox & Hampton, 2008; Cuadrado & Weber-Fox, 2003; Weber-Fox, Wray, & Arnold, 2013). ERPs are electrical responses caused by the synchronized firing of various clusters of neurons as the brain processes information. ERPs can reflect specific responses to linguistic processing challenges (Weber-Fox et al., 2004). In

particular, two ERP responses, known as N400 and P600, have been noted as atypical in PWS. The N400 corresponds to the neural activity that accompanies detection of semantic anomalies in a sentence. The P600 reflects neurological response to syntactic anomalies, such as a violation in verb agreement (Weber-Fox et al., 2004). The time-course of these ERP values is delayed in PWS, and the amplitude of the P600 value shows that there is increased right hemisphere activation in PWS. These temporal windows are associated with lexical and syntactic analyses (Weber-Fox et al., 2004), and suggest areas of deficit potentially responsible for stuttering behaviors.

Child Research

Recent advances have allowed neuroimaging work to be done with young children who stutter, to increase the probability that cortical profiles in PWS are more likely to reflect underlying deficits that give rise to stuttering, rather than reflecting changes in brain function caused by adaptation to stuttering. Chang & Zhu (2013) found that the auditory-motor and basal ganglia-thalamocortical networks of CWS aged 3-9 years develop differently than in their normally fluent peers. Specifically, CWS were found to have reduced connectivity in neural networks that are required for normal timing of self-paced movements, such as speech (Chang & Zhu, 2013). Disfluent speech may result from reduced ability to plan and execute speech motor movements.

Atypical language processing begins in childhood

While Chang's results do not speak to possible involvement of language processing areas in stuttering, ERP findings in adults have now also been duplicated in children, and show that, in preschool-age children, atypical lateralization of

speech/language functions emerges very soon post-onset of stuttering. The study also noted the same atypical N400 latencies and P600 amplitude which had previously been shown in adults (Weber-Fox, Wray, & Arnold, 2013). As with the adult studies, results suggest that CWS experience more difficulty than CWNS with lexical and syntactic processes. Interestingly, many of the CWS participants showed differences in neural functions mediating language processing but typical language test performance (Weber-Fox et al., 2013).

Motor studies have also been conducted with child participants. MacPherson and Smith (2013) found that motor stability of CWNS decreases with increases in syntactic complexity. In CWS, motor stability did not decrease as syntactic complexity increased; however, there was a much higher level of instability in CWS even when given simple sentences, and this high level remained constant as the sentences became more complex. Critically, many CWS could not execute the language tasks, suggesting weaker language skills (MacPherson & Smith, 2013).

Atypical language abilities may result from atypical processing

Findings from a recent meta-analysis of 22 studies that reported participants' standardized test scores and language sample measures show that CWS scored significantly lower on tests of overall language, as well as on tests of receptive and expressive vocabulary, and spontaneous mean length of utterance (MLU) (Ntourou, Conture, & Lipsey, 2011). This is consistent with other findings, such as those by Bajaj, Hodson, and Schommer-Aikins (2004), which showed that CWS have significantly poorer performance on tasks involving grammaticality judgments of syntactically and semantically anomalous sentences. Lexical access may also differ between CWS and

CWNS. Pellowski and Conture (2005) showed that semantic priming in a picture naming task led to faster speech reaction times (SRTs), as predicted, in CWNS, but in CWS, semantic priming actually led to slower SRTs.

Processing and use of verb forms have been specifically described as atypical in CWS. Wagovich and Bernstein Ratner (2007) noted that CWS produced a smaller variety of verbs than CWNS, though the CWS also produced less language overall than the CWNS, which impacted the size of the effect noted. Another study noted that, when using past-tense verbs, CWS and CWNS make a similar number of errors, but the errors of CWS are more likely to reflect double-marking of tense on verbs (i.e., *ranned* for *ran*), and that CWS are more likely to use irregular verbs than CWNS. There are several possible reasons for increased use of irregular verbs. One is that CWS have less diverse vocabularies than CWNS, so they use irregular verbs, which are often higher frequency verbs (such as 'to be'), even more often than is typical. Another possible reason is that CWS may rely on verbs which can be accessed in lexical memory, rather than verbs which must undergo morphological affixation (Bauman, Hall, Wagovich, Weber-Fox, & Bernstein Ratner, 2012).   All of these findings regarding the language abilities of CWS, when taken together, could indicate that they experience difficulties in their language planning/production process (Ntourou et al., 2011).

Lexicalization in PWS

Lexicalization is one area of the language planning/production process which is often cited as a potential cause of a moment of speaker disfluency (Postma & Kolk, 1993; Wingate, 1988). Lexicalization can be divided into two main stages. In the first stage (L1), an item is selected and grammatically encoded based on its semantic and syntactic

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properties. In the second stage (L2), phonological encoding occurs (Levelt, Schriefers, Voberg, Meyer, Pechmann, & Havinga, 1991). Wingate (1988) suggests that difficulty in lexicalization affects the ability of a PWS to assemble the phrase synchronously. Specifically, the delay during L1 lexicalization ends up causing a prosodic breakdown, evident in the fact that PWS experience the most difficulty on word initial sounds or a syllable with primary stress. Wingate suggests that PWS have a "fault line" at the onset of the primarily-stressed syllable, which is passed over by PWNS, resulting in correct expression of syllable stress, but causes difficulties in PWS, stemming from the initial delay during L1 lexicalization (Wingate, 1988). Prins, Main, & Wampler (1997) (discussed in more detail later) also showed, using a picture naming paradigm, that impairments can occur in the L1 phase, as well as in the beginning of the L2 phase. Some studies of lexicalization (such as Prins et al. 1997) examined a range of grammatical classes, and differences have been found in the lexicalization of specific parts of speech.

Grammatical class differences in typical speakers

A large literature has examined pathways of lexical access for different grammatical classes. This work has employed many different methodologies, including behavioral, electrophysiological, neuropsychological, transcranial magnetic stimulation, and brain imaging (see 2013 review by Crepaldi, Berlingeri, Cattinelli, Borghese, Luzzatti, & Paulesu). Individually, studies have produced a wide array of results, some of which also suggest that many different areas of the brain may be responsible for processing of nouns or verbs, a concept that the review eventually rejected, after finding inconsistencies among findings.   However, there is evidence that the same parts of the

brain may still process nouns and verbs differently. For example, Berlingeri, Crepaldi, Roberti, Scialfa, Luzzatti, & Paulesu (2008) had 12 participants perform a grammatical-class switching task (GCST). In this task, the participants were presented with either a noun or a verb and asked to retrieve the corresponding verb or noun (the original study was conducted in Italian, using nouns/verbs such as *applauso—applaudire* [applause—to applaud]). The participants also performed a standard picture naming task. These tasks revealed both physiological and behavioral differences between generation of nouns and verbs. Specifically, the grammatical class which elicited the longer reaction time in either task (verbs in picture naming and nouns in GCST), also showed a greater activation of the left inferior frontal gyrus for that task (Berlingeri et al. 2008).

Other studies using behavioral paradigms have also found differences between access of nouns and verbs. Szekely, D'Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, & Bates (2005) found significant differences in action and object naming profiles across a wide range of variables. Response time profiles for action naming were found to be significantly slower than those for object naming. A disadvantage for action naming was also found, even after all other variables such as picture properties, word properties, name agreement, and complexity were controlled. Effects were also found within the classes of nouns and verbs. For example, the authors found that higher-frequency objects elicit faster naming latencies, but higher-frequency verbs actually elicit slower naming latencies. From this, the authors drew the conclusion that the actual process of mapping between pictures and the name for their concepts differs for actions and objects.

Overall, while there is not full consensus that noun and verb processing are localized to specific areas, there is considerable evidence that the processes are nonetheless different. One possible driving force behind these processing differences are the semantic differences between nouns and verbs. Verbs require various numbers of arguments (a mandatory subject, obligatory and optional object[s]), which must be attached in certain ways. Because of this, it has been postulated that verb lexicalization is a more complicated process, which must begin before speech onset and which may even cause a slight delay in speech onset (Lindsley, 1976). A more complicated lexicalization process could then explain the behavioral and physiological differences noted between nouns and verbs.

Verb Processing in PWS

Both children and adults who stutter have shown atypical profiles in verb processing and use (for example Prins et al, 1997; Bernstein, 1981; Wagovich & Bernstein Ratner, 2007). One possible explanation is that PWS experience particular difficulties in the lexical access stage of verb production. While people generally have more difficulty with verbs than nouns (as shown in Szekely et al, 2005), it is possible that this difference is even greater in PWS. For example, PWS show longer latency periods during a picture naming task, presumably because of increased difficulty with verbs (Prins et al, 1997). Specifically, the difference in latencies between PWS and PWNS was six times greater during verb naming than during noun naming, and, during a task in which participants had to give two-word responses, the extra delay for producing the verb in the two-word response accounted for the difference between the groups entirely.

As mentioned earlier, CWS show increased difficulty with verbs as well. CWS are more likely to stutter on a verb than on any other part of speech (Bernstein, 1981), produce a smaller variety of verbs than CWNS (Wagovich & Bernstein Ratner, 2007), and use more irregular verbs than CWNS, which suggests less mature verb usage skill (Bauman, et al, 2012).

One possible reason for the exaggerated verb effects shown in PWS comes from the increased semantic difficulty of verbs. Because a verb influences other parts of the sentence (the arguments), verb lexicalization must begin very early, before speech onset, and then the speaker must be able to compensate for this delay to assure fluency (Lindsley, 1976). As mentioned earlier, lexicalization is an often-implicated area of deficiency which could set the stage for a stuttering event (Wingate, 1988; Postma & Kolk, 1993; Prins et al, 1997). It is possible, then, that PWS show exaggerated verb effects due to these lexicalization difficulties.

Stuttering research and the phoneme monitoring paradigm

Stuttering research is challenging for many reasons. Problems resulting from the use of spoken language tasks are among the most common difficulties. Spoken language tasks elicit all of the facets of a stuttering disorder, including those which are psycho-social in nature, rather than strictly neurological, and are therefore inappropriate to most research designs in stuttering. Analyzing spoken tasks is also difficult because of the inter-examiner variability which is inherent to transcription of stuttered speech, such as disagreement over what constitutes a moment of disfluency, and what type of disfluency was present. For accurate research of the psycholinguistic aspects of stuttering, a non-production task is desirable. One avenue of non-speech task would be obtaining actual

neural information such as ERPs or MRI scans during language comprehension or

listening tasks (as in studies such as Cuadrado & Weber-Fox, 2003; Weber-Fox et al.,

2013; and Chang & Zhu, 2013). Such tasks can involve expensive equipment and

specialized researcher training. However, there are other, simpler non-speech tasks,

many of which are ideal for use with PWS.   This explains why so many studies have

simply concentrated on receptive skills, looking at standardized measures of receptive

language abilities and receptive vocabulary (i.e. Anderson & Conture, 2000). Still other

non-speech tasks have included metalinguistic tasks, such as grammatical judgment tasks

and phonological awareness assessments (such as in Bajaj et al., 2004)   One prominent

non-speech psycholinguistic task, which has been used in a variety of experiments over

the past 50 years, though very rarely with PWS, is the phoneme monitoring paradigm

(Hakes & Foss, 1970).

The phoneme monitoring paradigm has been used to examine many different

aspects of speech processing in typically fluent adults, though the basic premise of the

task remains the same. Participants are asked to monitor for a specific, predetermined

phoneme by pressing a button when the phoneme is present during a stimulus (Connine

& Titone, 2006). The stimulus can be auditory, in which case the participants are

expected to listen for the target sound, or it can be visual. A visual stimulus typically

does not take the form of a written word, but rather of a picture, and the participant must

determine whether or not the target phoneme appears in the word which corresponds to

the pictured referent.

One of the earliest uses of the phoneme monitoring task was by Hakes and Foss

(1970). Participants heard complex sentences with and without relative pronouns (i.e.

"the puzzle (that) the youngster (who) the tutor taught devised bewildered the mathematicians") and were then asked to monitor for a given phoneme, and also to paraphrase the sentence for content. The target phoneme could occur early (beginning the first noun), late (beginning the last verb), or not at all. Two findings were obtained. The first was that the presence of relative pronouns greatly aids sentence comprehension, as measured by shorter phoneme monitoring reaction times for targets in clauses preceded by relative pronouns, and the second (and more important for our purposes) was that phoneme monitoring proved to be a very sensitive measure of language processing difficulty.

Since then, the phoneme monitoring paradigm has been used in numerous tasks looking at a variety of abilities (see review by Connine & Titone, 1996). In their 1974 study, Shields, McHugh, and Martin examined prosody and found faster phoneme monitoring latencies for word-initial accented syllables than word-initial unaccented syllables. In semantics, studies have found faster latencies in a biased context versus a neutral context (Foss & Jenkins, 1973). In syntax, notable studies include the previously referenced example by Hakes and Foss (1970), and in comparing processing of clauses with complex verbs versus those which contained simple verbs (Hakes, 1971).

In these studies, it is assumed that the processing resources which are used for the specific task of monitoring for and identifying a phoneme are drawn from the same resources used to perform the various other computations which the experimental tasks require. Therefore, as the experimental tasks become progressively more complex, increasingly more resources are used for the higher level computations, which results in increased monitoring latencies, as progressively fewer resources are assigned to that task.

It is in this way that increased phoneme monitoring latencies are a "measuring stick",
indicative of the complexity of other computations being performed (Frauenfelder &
Segui, 1989).

In early phoneme monitoring tasks, participants monitored for phonemes in word-
initial position (such as in Hakes & Foss, 1970). This task was found to rely less on
lexical encoding and more on phoneme detection. One possible explanation for this is
that there are competing paths in the brain when asked to perform a phoneme monitoring
task. One of the paths is used purely for phonological processing and does not access the
lexical/sematic system. The other path uses information from the lexical/semantic system
to enhance the ability to monitor for the phoneme. It is thought that both paths are
activated, and then whichever pathway finishes the job first is the one which is used.
This means that for a task where all of the phonemes are word-initial, the participant may
not need to access the lexical/semantic path at all because the phonological path will
always be faster. To rectify this problem, Frauenfelder and Segui (1989) proposed a
modified version of the paradigm, which they called *generalized phoneme monitoring*
(GPM). In GPM, the phoneme for which the participant is monitoring can appear
anywhere in the target-bearing word, rather than only in the initial position. To test their
new procedure, Frauenfelder and Segui utilized a series of experiments in which they
contrasted monitoring latencies in conditions where the target-bearing word was preceded
by a semantically related word and conditions where it was not. When they performed
this experiment using a traditional phoneme monitoring task in which all of the target
sounds were word-initial, they found no effect of lexical context. This indicates that
there may not be significant lexical processing occurring during the task. However, when

they performed the same experiment using their updated GPM procedure, they found a significant effect of lexical context, indicating that lexical processing was playing a role in the participants' phoneme monitoring. Interestingly, this effect of lexical context was even noted when using the GPM procedure in target-bearing words where the target phoneme was still presented in the word-initial position. It is possible that the reliance of the participants on pre- or post-lexical processing hinges on the instructions presented to them. If the instructions state that the participant only needs to listen for word-initial phonemes, they may concentrate so much on the initial phonemes that they never access the lexical code. However, if the instructions state that the phoneme could appear anywhere in the target-bearing word, they must rely on the lexical code much more significantly, which means that the phoneme monitoring task will utilize the same process of speech production up to the point of the actual production .

A phoneme monitoring paradigm is ideally suited to examining differences in lexical access abilities. In a review of lexical access studies by Vigliocco, Vinson, Druks, Barber, & Cappa (2011), two main findings were noted. The first is that separability in the access/processing of object and action words is clearly evident. The second, and more interesting finding for the purposes of this study, is that effects of grammatical class emerge or become stronger when the experimental tasks which the participants are completing become more complex and require greater processing demands. This, then, fits very well with the underlying notion behind a phoneme monitoring paradigm: that the monitoring latencies increase as fewer resources are assigned to that task because the experimental task is becoming progressively more difficult.

Why examine phoneme monitoring in PWS?

A GPM paradigm still utilizes the lexicalization process as though speech production is going to be completed, without risking any interference that may result from the process of actually producing speech. It is for this reason that further study of the lexicalization process of PWS is merited, using a more effective paradigm, which is better suited to the specific demands of stuttering research.

The phoneme monitoring paradigm has not been used before with PWS, or at least not in the manner originally intended by Hakes and Foss. Sasisekaran et al. (2006) attempted to use a phoneme monitoring paradigm to examine phonological encoding of nouns in PWS; however, in her study, the monitoring latencies recorded were taken as a direct measurement of the amount of time it took the PWS to perform the requisite phonological encoding to monitor for each phoneme. In other words, phoneme monitoring was used as an index of the efficiency of phonological encoding by PWS and PWNS. This approach differs significantly from the original design of the phoneme monitoring paradigm, in which the monitoring latencies were not, in and of themselves, a direct measurement of phonological encoding skill. Rather, the paradigm was designed so that a second linguistic task was being performed simultaneously with the phoneme monitoring. These tasks were presumed to use the same pool of resources in the brain, and the phoneme monitoring latencies were used as a "measuring stick", which reflected the amount of resources being used by the main experimental task, which was typically syntactic or lexical (Frauenfelder & Segui, 1989). This approach to the phoneme monitoring paradigm makes it much more versatile. In the interpretation used here, the paradigm could feasibly be designed to measure any aspect of language processing.

Present Study

Differences in lexical access abilities of nouns and verbs in PWS and PWNS may shed light on linguistic factors which affect stuttering. Namely, if the latencies for PWS are significantly slower than those for PWNS, it could indicate an impairment in the L1 phase of lexicalization, which has been identified as an underlying source of disfluency (Wingate, 1988). Also, if the latencies found for verbs are even more depressed than the latencies found for nouns, it would be further evidence of a particular problem with verbs (as has been identified in such studies as Prins et al, 1997; Bernstein, 1981; Wagovich & Bernstein Ratner, 2007; Bauman et al., 2012), and provide evidence as to the origin of that difficulty. Ultimately, these difficulties reflect just one fiber of an intricate web of factors that may lead to a stuttering event, a web which potentially includes a variety of factors such as motor sequencing difficulties and psycho-social pressures. As stated in the Dynamic-Multifactorial model, no one factor can be identified as "the cause" of stuttering (Smith & Kelly, 1997), though, as evidenced above, difficulties in lexicalization seem to play an important role.

The current study proposes to use an adaptation of the phoneme monitoring procedure used by Sasisekaran, et al. (2006). This study will examine the lexical access abilities of PWS and PWNS by examining the differences in the phoneme monitoring latencies for nouns and verbs.

II. RESEARCH QUESTIONS AND HYPOTHESES

Our research questions are as follows:

What is the progression of lexicalization of nouns and verbs in PWNS and people who stutter?

a. Are there differences in the phoneme monitoring profiles of PWS and PWNS?

b. Are these differences related to either the difference in grammatical class of the word being monitored, or the position of the phoneme within the word?

c. If so, what insight does this provide into which aspects of linguistic encoding are relatively impaired in PWS?

Our hypotheses are as follows:

1a. For both groups of speakers, the progression of encoding for verbs will be significantly slower than the progression of nouns for both phoneme monitoring locations, which will be shown by an increase in monitoring latencies.

1b. There will be a delay in monitoring latencies for word medial/final phonemes due to their position in the word, but there will be no additional delay due to part of speech (that is to say, word-medial phonemes in verbs will not be disproportionately slower than word-initial phonemes in verbs, when compared to word-medial/initial phonemes in nouns).

2. PWS will show a slower progression overall than PWNS, and will show a particular disadvantage with verbs, both on word initial and word medial/final phonemes.

If Hypothesis 1 is correct, it will confirm prior work done in the field (such as that done by Szekely, et al., 2005). If Hypothesis 2 is correct, it will provide further behavioral evidence of processing differences between PWS and PWNS in the L1 phase of lexicalization, as was suggested by Wingate (1988) and demonstrated by Prins et al, 1997, albeit using a paradigm that is not as well suited to PWS as a phoneme monitoring paradigm. It will also provide further evidence suggesting that PWS have particular difficulty with verbs, providing more information about areas of potential language weaknesses in PWS, and possibly even identifying a language weakness which can be targeted during therapy to improve efficiency of lexical retrieval.

III. METHODS

Participants

Fifteen PWS were recruited from a variety of sources, including the University of Maryland, College Park campus, local area/local therapy groups, and the National Stuttering Association (NSA) yearly convention. After recruiting PWS, PWNS were recruited for a control group. PWNS were recruited to match for age (within five years), gender, handedness, and education (within two years), so that the PWS and PWNS groups matched as closely as possible, with the exception of a negative history of fluency or language disorder by the PWNS. All participants were monolingual, native speakers of English with no other significant cognitive or linguistic disorders/conditions, as reported by a self-history questionnaire (such as dyslexia, Autism Spectrum Disorder, Specific Language Impairment, etc.) The self-history questionnaire also included questions about stuttering history, education, and socio-economic status (Appendix A). Participants were compensated for their time with a 10 dollar gift card, or volunteered as part of an undergraduate course requirement.

Stuttering Participants

Stuttering participants included eight females and seven males, ranging in age from 22 to 58 years of age ($M = 40.53$ years). Three of the stuttering participants were left-handed. Education levels ranged from high-school graduates to Ph.Ds (range 12 to 24 years, $M = 17$ years). Age of onset for stuttering symptoms ranged from three to nine years of age ($M = 5.25$ years). Ten of the stuttering participants reported a positive family history of stuttering. All participants completed the *Stuttering Severity Instrument, 4th edition (SSI-4*; Riley & Bakker, 2009). Numerical scores for stuttering

participants ranged from 2 to 25, which correspond to ratings from "below very mild" to "moderate". The average severity score was 13.7, which corresponds to a rating of "very mild".

Typically Fluent Participants

Typically fluent participants also included eight females and seven males, ranging in age from 20 to 63 years ($M = 41.46$ years). Three of the PWNS were left-handed. Education levels ranged from high-school graduates to Ph.Ds (12 to 22 years, $M = 17$ years). Two of the typically fluent participants reported a positive family history of stuttering. The *SSI-4* was administered to all participants, but no typically fluent participants demonstrated any stuttering-like disfluencies. More detailed information on all participants can be found in Appendix B.

Background testing

In addition to the *SSI-4*, all participants also completed an experimental language task (Appendix C), which included reading and writing questions from self-study reviews for the *Graduate Record Examination* and the *SAT* (found on majortests.com). This assessment served as a concurrent measure of participants' language ability, and consisted of 30 multiple choice questions of three different types: a) spot-the-ungrammaticality (six minutes to complete 12 questions), b) vocabulary fill-in-the-blank (eight minutes to complete eight questions), and c) analogies (three minutes to complete ten questions). The assessment was designed to provide high-level assessment of language abilities under relatively stringent time constraints. A similar procedure was used in Watson, Freeman, Chapman, Miller, Finitzo, Pool, and Devous (1991), to assess

higher-level language abilities than are generally assessed using tests designed to describe gross language impairments in adults.

Stimuli

Noun and verb stimuli sets (15 each) (Appendix D) came from the International Picture Naming Project (IPNP) (Szekely et al, 2005), and consisted of line drawings of nouns and verbs. Normative data are provided for number of phonemes, word frequency, naming agreement, age of acquisition, and picture complexity, and the stimuli were matched across all of these categories.

Word frequency was measured using the English Lexicon Project (ELP). The ELP uses the Hyperspace Analogue to Language (HAL) values to compute word frequency, based on American English norms. HAL values are drawn from a corpus of roughly 131 million words (Balota, Yap, Cortese, Hutchison, Kessler, Loftis, Neely, Nelson, Simpson, & Treiman, 2007).

Naming agreement was measured as a percentage provided by Szekely et al (2005). In these lists, the participants' responses were divided into four categories. The first category is the percentage of participants who gave the exact expected name. The second category is the percentage of participants who gave some morphological variant of the target. The third category is the percentage of participants who gave a synonym, and the fourth category is the percentage of participants who gave an incorrect response. The four categories add up to 100%. For this study, the first two categories were added together to create a measurement of lemma frequency for each item.

Age of acquisition and picture complexity were also taken from the norms

provided by Szekely et al (2005). Age of acquisition was based on a scale where a 1

means that the word is acquired at 8-16 months old, a 2 means that the word is acquired

between 17 and 30 months, and a 3 means that the word is acquired above 30 months.

Picture complexity was based on an objective scale which uses the file size of pictures

stored in a .jpg format, where a larger file size means that the picture is more visually

complex.

Number of syllables was matched across groups, as was use of consonant clusters.

These stimuli included some homophonous nouns and verbs, although only verbs that are

used as nouns less than 25% of the time, and nouns used as verbs less than 25% of the

time were included (Kim & Thompson, 2000).

Procedure

Prior to beginning the experimental task, participants were presented with all of

the pictures used in the experiment and were given the names expected for each picture.

Participants were instructed that the phoneme for which they were monitoring could

appear anywhere within the word to ensure lexical/semantic involvement (Frauenfelder &

Segui, 1989). Each word was used as an experimental word (in which the target

phoneme actually appeared) and as a filler word (in which the target phoneme did not

appear) to prevent the participant from responding prematurely on the assumption that all

words contained a target phoneme (as done by Sasisekaran et al., 2006). Therefore, each

word was presented four times: once with a target phoneme in the initial position, once

with a target phoneme in the non-initial position, and twice as a filler word. For the non-

initial position, the target phoneme was the second consonant sound to appear in the

word. The experiment was presented in eight blocks, each of which contained 15 stimulus words, either all of the nouns or all of the verbs. Word order was pseudo-randomized in each block, any stimulus was presented only once per block, and block order was randomized for each participant. Each block contained eight experimental items and seven fillers, or vice versa, and the number of positive-responses in which the phoneme is in the initial position was equal to the number of positive-responses in which the phoneme is in a non-initial position.

The experiment was presented on a laptop computer and designed using the program DMDX (Forster & Forster, 1999). Participants completed the experiment while seated comfortably at a laptop computer. During the task, a target phoneme for which the participant monitored was presented for 1000 milliseconds, followed by a picture for 3000 milliseconds. The participant responded by pressing keys corresponding to 'yes' or 'no' as quickly as possible. Right-handed participants responded using two adjacent keys which could be easily pressed using two fingers on the right hand, and left handed participants responded using two adjacent keys which could be easily pressed using two fingers on the left hand. The next stimulus was presented after a response, or after the 3000 millisecond presentation window concluded, if no response was given in that time. Prior to the experiment, six practice items (three nouns and three verbs) were presented using words which did not appear during the experiment. Participants were instructed to monitor for the target phoneme throughout the target-bearing word, and also to monitor for a sound, rather than making judgments based on letters in the word's written form (which was not displayed). If the participant did not understand the task after the

instructions and practice items, the instructions and practice items were repeated until the participant demonstrated understanding of the task.

Instrumentation

The DMDX program recorded the response times of each participant. Response times were defined as the time, in milliseconds, from the beginning of the presentation of the picture to a response given by the participant. Participants were seated at a laptop computer, which had a SteelSeries 6GV2 keyboard attached to it.

Dependent Variables

Two dependent variables were considered: the accuracy of the responses given (whether or not the participant correctly determines if the phoneme was present in the word), and the response latency.

Data Analysis

Multiple balanced design ANOVAs were used to analyze the data. Using both accuracy and response latency as response variables (in separate analyses), ANOVAs were conducted that used phoneme position and group as factor variables, as well as ANOVAs which used part-of-speech and group as factor variables. When examining accuracy, all responses were included for each participant. When examining reaction times and word position, only experimental trials were used, and significant outliers (responses more than two standard deviations above or below the mean) were excluded from analysis of reaction times. Null trials (in which the target phoneme did not appear in the word) were used for some analyses, as specifically mentioned in results.

IV. RESULTS

Language Test Scores

Mean language test score for the PWS group was 17.60 (range = 5-28, SD = 6.08). Mean language test score for the PWNS group was somewhat higher at 20.73 (range = 12-28, SD = 4.23). A two-tailed, two sample t-test showed that the difference between the two groups was not significant, $t(28) = 1.64$, $p = 0.1126$. The language test was then divided into three sections, by type of question, and each individual section was also analyzed. Section 1 included 12 "spot-the-ungrammaticality" type questions. PWS mean score was 5.33 (range = 1-10, SD = 2.41). PWNS mean score was 6.46 (range = 4-10, SD = 2.03). A two-tailed, two sample t-test showed this difference was not significant, $t(28) = 1.39$, $p = 0.1747$. Section 2 of the language test included eight vocabulary fill-in-the-blank questions. PWS mean score was 4.67 (range = 0-8, SD = 2.64). PWNS mean score was 6.20 (range = 4-8, SD = 1.52). A two-tailed, two sample t-test showed this difference was not significant, $t(28) = 1.95$, $p = 0.0611$. Section 3 of the language test consisted of 10 analogies. PWS mean score was 7.60 (range = 4-10, SD = 1.92). PWNS mean score was 8.07 (range = 3-10, SD = 1.98). A two-tailed, two sample t-test showed this difference was not significant, $t(28) = 0.66$, $p = 0.5176$. Thus, although differences between PWS and PWNS were not significant, PWS scored lower than PWNS on all subtests as well as overall, with the largest difference shown in lexical completion.

Accuracy on phoneme monitoring

Accuracy was computed as the number of total correct trials, out of 120 (including null trials). PWS mean score was 105.33 (range = 83-115, SD = 9.64).

PWNS mean score was 108.20 (range = 88-119, SD = 7.84. A two-tailed, two sample t-test showed that this difference was not significant (t(28) = 0.89, p = 0.3794). Accuracy data, which are reported as proportions, were also examined by part of speech and phoneme position. Across both groups, verbs were less accurate than nouns. PWS Noun ACC M = 0.86, (range = 0.58 – 0.96, SD = 0.11); PWS Verb ACC M = 0.84 (range = 0.62 – 0.97, SD = 0.10); PWNS Noun ACC M = 0.90 (range = 0.73 – 1.0, SD = 0.07); PWNS Verb ACC M = 0.88 (range = 0.60 – 0.97, SD = 0.10). Medial-position phonemes were less accurate than initial-position phonemes. PWS Initial ACC M = 0.94 (range = 0.80 – 1.0, SD = 0.06); PWS Medial ACC M = 0.66 (range = 0.07 – 0.86, SD = 0.23); PWNS Initial ACC M = 0.95 (range = 0.77 – 1.0, SD = 0.06); PWNS Medial ACC M = 0.80 (range = 0.32 – 0.97, SD = 0.16). Null responses were examined and actually found to have a significantly higher accuracy rate than word medial responses. PWS Null ACC M = 0.95 (range = 0.88 – 1.0, SD = 0.04); PWNS Null ACC M = 0.93 (range = 0.80 – 1.0, SD = 0.04). For correct judgement of null targets, PWS performed somewhat better than PWNS, although this difference was not significant, t(28) = -1.46, p = 0.15.

Excluding null responses, an Analysis of Variance (ANOVA) testing only nouns, with accuracy as the response variable and phoneme position and group as the factor variables revealed a highly significant effect of position (F(1, 56) = 23.36, p < 0.001), but did not show a significant effect of group (F(1, 56) = 2.23, p = 0.141), nor a significant interaction between position and group (F(1, 56) = 1.91, p = 0.172). An ANOVA testing only verbs with accuracy as the response variable and phoneme position and group as the factor variables revealed another significant effect of position (F(1, 56) = 22.93, p < 0.001), although no significant effect of group was found (F(1, 56) = 2.14, p = 0.1472),

nor was any interaction (F(1, 56) = 2.52, p = 0.118). An ANOVA with accuracy as the

response variable and part-of-speech and group as the factor variables showed a

significant effect of group (F(1, 116) = 4.03, p = 0.04), although no main effect of part of

speech (F(1, 116) = 0.37, p = 0.54) was found, nor was any interaction (F(1, 116) = 0.12,

p = 0.73).

To summarize, an overall assessment of accuracy, including experimental and

null trials, found no significant differences between the groups. Participants in both

groups performed more accurately on nouns rather than verbs, and on word-initial

phonemes as opposed to word-medial phonemes. In most analyses, PWNS also out-

performed PWS, although this profile did not reach significance. Participants in both

groups performed better on null responses than word-medial, and PWS out-performed

PWNS on null responses, though not significantly. ANOVAs with null responses

removed confirmed the effect of position for both parts of speech. An ANOVA with null

responses removed found no significant main effect of part-of-speech. Raw accuracy

data for all conditions can be found in Table 1, and are plotted in Figure 1.

Reaction Time

Average reaction times were computed using a trimmed data set. The trimmed

data set included only trials in which the participant responded with a correct answer, did

not include null trials, and also removed any trials in which the reaction time recorded

was more than two standard deviations away from the mean reaction time for that group.

Across both groups, verb reaction times were slower than noun reaction times. PWS

Noun RT *M* = 1024.40 (range = 595.74 – 1345.80, SD = 189.44); PWS Verb RT *M* =

1122.77 (range = 880.04 – 1434.29, SD = 165.40); PWNS Noun RT *M* = 973.28 (range =

808.67 – 1215.09, SD = 129.60); PWNS Verb RT M = 1068.21 (range = 792.31 –

1396.94, SD = 161.72). Reaction times for word-medial phonemes were slower than

reaction times for word-initial phonemes. PWS Initial RT M = 950.23 (range = 703.15 –

1237.74, SD = 154.43); PWS Medial RT M = 1174.42 (range = 861.06 – 1524.54, SD =

195.71); PWNS Initial RT M = 905.29 (range = 720.94 – 1294.61, SD = 154.04); PWNS

Medial RT M = 1069.17 (range = 835.61 – 1375.41, SD = 147.44). Reaction times for

null trials were also computed, and actually found to be quicker than reaction times for

word-medial trials for the PWS. PWS Null RT M = 1096.11 (range = 732.07 – 1514.26,

SD = 187.12); PWNS Null RT M = 1087.77 (range = 844.93 – 1393.38, SD = 147.84).

However, this difference was not significant, $t(28) = 1.12$, $p = 0.2722$. An ANOVA

testing only nouns with latency as the response variable and phoneme position and group

as factor variables revealed a significant effect of position ($F(1, 56) = 11.14$, $p = 0.001$),

but did not show a significant effect of group ($F(1, 56) = 2.78$, $p = 0.101$), nor a

significant interaction between position and group ($F(1, 56) = 0.23$, $p = 0.635$). An

ANOVA examining only verbs with latency as the response variable and phoneme

position and group as factor variables yielded a significant effect of position ($F(1,56) =$

24.87, $p < 0.001$), but, again, did not show a significant effect of group ($F(1, 56) = 2.45$, p

$= 0.123$), nor a significant interaction between position and group ($F(1, 56) = 0.66$, $p =$

0.419). An ANOVA with latency as the response variable and part-of-speech and group

as the factor variables showed a significant main effect of part-of-speech ($F(1, 116) =$

5.24, $p = 0.02$) as well as a significant main effect of group ($F(1, 116) = 4.05$, $p = 0.05$),

though no interaction between the two ($F(1, 116) = 0.00$, $p = 0.97$).

To summarize, PWNS showed quicker reaction times across all conditions (excluding null trials) than PWS. For both groups, nouns took less time to access than verbs, and phonemes in the initial position were encoded more quickly than phonemes in the medial position. Null trials yielded faster reaction times for PWS than PWNS, and were the only condition to do so, although the difference was not significant. ANOVAs for both parts of speech showed a significant effect of phoneme-position, but no significant effect of group, nor any interaction between the two. An ANOVA with latency as the response variable and part-of-speech and group as the factor variables showed a significant main effect of part-of-speech, as well as a significant main effect of group, though no interaction between the two. Raw latency data can be found in Table 1, and are plotted in Figure 2.

Accuracy and language test scores were significantly correlated ($r(28) = 0.46$, p < 0.01). However reaction time and language test scores were not significantly correlated ($r(28) = 0.25$, p = 0.2531). This indicates that accuracy may be linked to having better language skills in general, regardless of which group a participant was part (although this is negligible, since group differences in accuracy were not significant), but reaction time differences cannot be attributed to having better language abilities overall. In general, participants with higher language test scores also had significantly higher PM accuracy scores and showed a trend toward faster reaction times.

Figure 1.

Mean ACC by Condition

Figure 2.

Mean Response Latencies by Condition
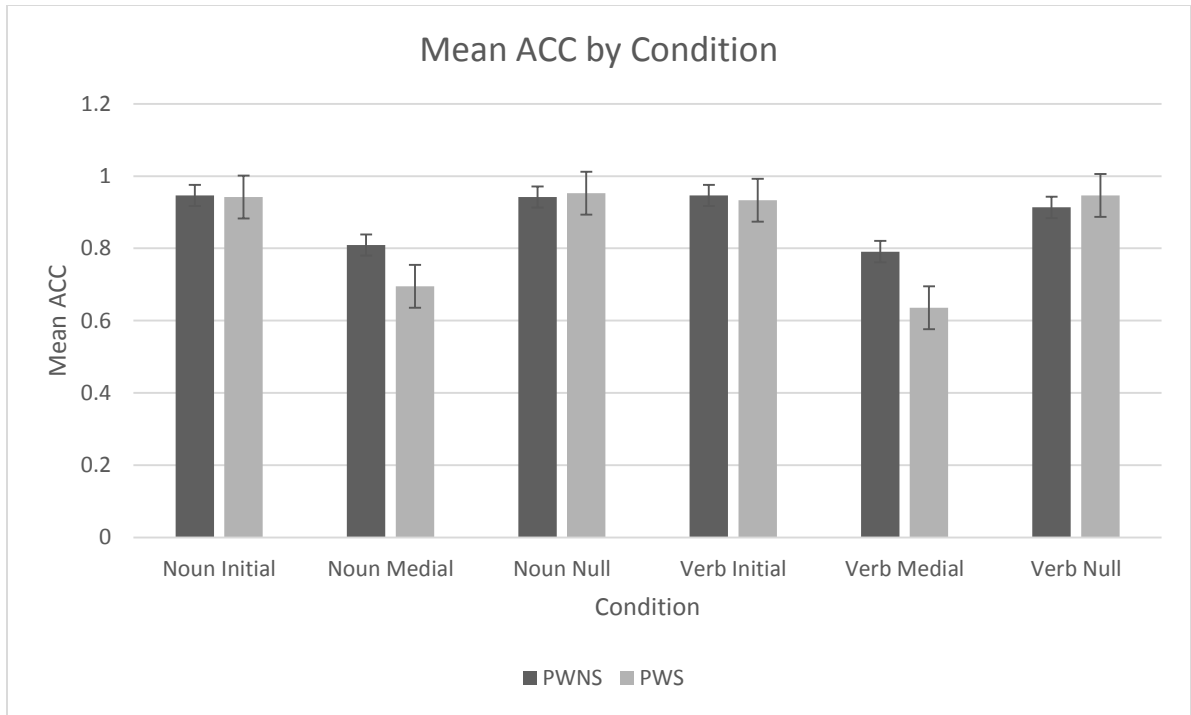
32
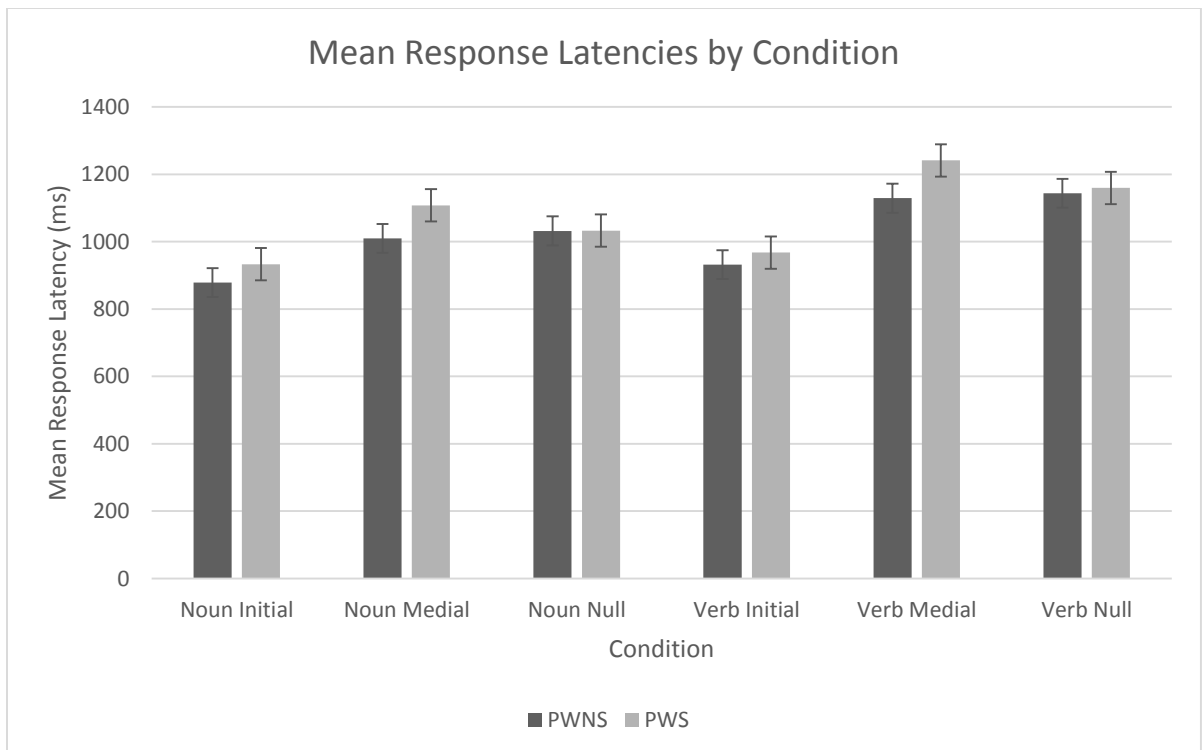
Table 1. Descriptive Statistics

Group	Noun/Verb	Initial/Medial/Null	Mean ACC	Mean Latency	Median Latency	SD of Latency	SE of Latency	Min Latency	Max Latency
PWNS	Noun	Initial	0.95	878.46	850.58	150.45	38.85	693.74	1229.07
PWNS	Noun	Medial	0.81	1009.43	1022.53	137.04	35.38	837.19	1271.36
PWNS	Noun	Null	0.94	1031.94	992.88	142.00	36.66	848.97	1299.20
PWNS	Verb	Initial	0.95	932.12	899.94	172.26	44.48	702.03	1360.14
PWNS	Verb	Medial	0.79	1128.90	1080.79	184.86	47.73	834.03	1530.14
PWNS	Verb	Null	0.91	1143.60	1118.41	161.01	41.57	840.89	1487.55
PWS	Noun	Initial	0.94	932.91	898.24	160.23	41.37	658.27	1231.99
PWS	Noun	Medial	0.70	1107.66	1161.35	242.34	62.57	505.92	1450.15
PWS	Noun	Null	0.95	1032.64	1010.91	202.27	52.23	623.02	1498.13
PWS	Verb	Initial	0.93	967.55	946.68	158.40	40.90	747.69	1314.91
PWS	Verb	Medial	0.64	1241.18	1231.69	210.99	54.48	940.69	1777.16
PWS	Verb	Null	0.94	1159.59	1182.89	179.21	46.27	841.11	1530.38

Speed/Accuracy Tradeoff and Inverse Efficiency Scores

Multiple correlations were performed to look for speed/accuracy tradeoffs in various conditions. Looking only between groups at all responses (not separating nouns/verbs or phoneme position), PWS showed no significant correlation between speed and accuracy ($r(14) = 0.17$, p = 0.55). PWNS showed an expected and highly significant negative correlation between speed and accuracy (r(14) = -0.88, p < 0.001).

Examining nouns and verbs separately, PWS again showed no significant correlation between speed and accuracy for nouns ($r(14) = 0.34$, p = 0.21), nor for verbs ($r(14) = -0.09$, p = 0.74). These correlations trend in opposite directions, although the correlation for verbs is marginal. For PWNS, nouns showed a highly significant negative correlation ($r(14) = -0.85$, p < 0.001), and verbs also showed a highly significant negative correlation ($r(14) = -0.82$, p < 0.001).

Examining phoneme position separately, PWS showed no significant correlation between speed and accuracy for phonemes in the initial position ($r(14) = 0.19$, p = 0.49), nor for phonemes in the medial position ($r(14) = -0.03$, p = 0.92), nor for null trials ($r(14) = 0.10$, p = 0.71). PWNS showed highly significant negative correlations for phonemes in the initial position ($r(14) = -0.82$, p < 0.001), phonemes in the medial position ($r(14) = -0.83$, p < 0.001), and for null trials ($r(14) = -0.77$, p < 0.001).

The Inverse Efficiency Score (IES) (Townsend & Ashby, 1978; Bruyer & Brysbaert, 2011) is a statistical measure which combines speed and error. It is calculated by dividing reaction time by the proportion of correct responses. Because reaction latencies are expressed in milliseconds, and the latencies are being divided by a

proportion, the resulting value is also expressed in milliseconds, with smaller numbers indicating greater efficiency on the task (Bruyer & Brysbaert, 2011).

PWS showed an IES of 1197.08 ms for nouns and 1360.43 ms for verbs. PWNS showed an IES of 1097.91 ms for nouns and 1250.27 ms for verbs. These differences were not significant for nouns ($t(28) = -1.15$, p $= 0.19$), nor were they significant for verbs ($t(28) = -0.89$, p $= 0.38$).

For phoneme position, PWNS mean IES was 970.28 ms for phonemes in the initial position. PWS mean IES was 1015.25 ms for phonemes in the initial position. This difference was not significant ($t(28) = -0.59$, p $= 0.56$). For medial phonemes, PWNS mean IES was 1486.81 ms, PWS mean IES was 2645.16 ms. This difference was not significant ($t(28) = -1.47$, p $= 0.15$). For null trials, PWNS mean IES was 1181.70 ms, PWS mean IES was 1155.02, indicating that the PWS were slightly more efficient on the null trials, though the difference was not significant ($t(28) = 0.35$, p $= 0.73$).

To summarize, PWNS showed a higher level of efficiency for both parts of speech and also for phonemes in the initial or medial/final position, though never significantly higher than that of PWS. However, PWS showed a non-significantly higher level of efficiency for null trials.

V. DISCUSSION/CONCLUSIONS

The primary goal of this study was to compare the time-course of noun and verb lexicalization in people who do and do not stutter. Lexicalization is an area of speech production and processing which has been implicated in the past as being deficient in people who stutter, and a potential contributing factor to disfluency (Postma & Kolk, 1993; Wingate, 1988). A major secondary goal of this study was to examine any differences found in the time-course of lexicalization of nouns and verbs, since studies examining noun and verb processing in typical speakers have shown that the processes differ (Szekely, et al., 2005), and it has been postulated that verb production is a more complicated process than noun production (Lindsley, 1976). Investigating nouns and verbs is particularly interesting when also comparing people who do and do not stutter, as verb processing in people who do and do not stutter has been shown to be atypical in both adults and children (Prins et al., 1997; Bernstein, 1981). Other goals of this study included early-stage development of a language test more suited to finding higher-level differences in the abilities of adults who do and do not stutter, and also demonstrating the use of the phoneme monitoring paradigm in stuttering research.

Phoneme monitoring paradigm

To our knowledge, this is the first study in which a phoneme monitoring paradigm has been used with PWS as originally designed by Hakes and Foss. Sasisekaran et al. (2006) used phoneme monitoring latencies as direct indices of phonological encoding skill. In the GPM task, the monitoring latencies are not direct measurements of anything, but rather a "yardstick", by which one can measure the relative difficulty of other concomitant language processing tasks (Frauenfelder & Segui, 1989).

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This study used the generalized phoneme monitoring paradigm updated by Frauenfelder & Segui (1989); common artifacts that occur with phoneme monitoring testing have been well-documented (Connine & Titone, 1996). The biggest potential artifact of prior PM tasks- whether participants' responses are developed at the pre-lexical or lexical level- is an issue that was resolved with the advent of the generalized phoneme monitoring paradigm (Frauenfelder & Segui, 1989). The GPM has been used relatively infrequently in the past ~40 years, and it has been used extremely infrequently to compare atypical and typical speakers. However, this study has demonstrated both the viability and the versatility of the paradigm.

Lexicalization

Nouns and Verbs

Across both groups, lexicalization of verbs was significantly slower than lexicalization of nouns. This is consistent with previous work (such as Szekely et al., 2005), and supports Hypothesis 1a. This effect cannot be attributed to name agreement, number of phonemes, syllable structure, age of acquisition, picture complexity, or word frequency, as none of these factors varied significantly between noun and verb stimuli. A frequently-advanced reason for this effect is that verbs are simply more semantically complex than nouns, resulting in a more complex lexicalization process which must begin before speech onset, and even causes a slight delay in speech onset (Lindsley, 1976). Additionally, because verbs require more grammatical class information than nouns, Levelt et al.'s (1991) proposal that retrieval of grammatical class information is part of the lexicalization process could explain why verb lexicalization times were slower in this study, as well as others (i.e. Szekely et al., 2005) than noun lexicalization times.

Response latencies for PWS were slower than PWNS when monitoring for phonemes in both nouns and verbs, and the IES showed that PWS were less efficient than PWNS, although this difference was not significant. These trends provide some support for Hypothesis 2. These trends are in agreement with the results seen in similar studies, such as that of Prins, Main, and Wampler (1997) and Sasisekaran et al. (2006). The trends suggest that lexicalization or phonological encoding may indeed be impaired in some way in PWS. Such a deficit could then trigger stuttering-like disfluencies during speech. This explanation would greatly strengthen a language-based theory of stuttering, and could significantly contribute to a multimodal theory of stuttering, such as the Dynamic-Multifactorial Model (Smith & Kelly, 1997).

The extra layer of difficulty in lexicalizing verbs also appears to have had an effect on participant accuracy. Both groups showed lower accuracy for trials in which the stimulus item was a verb, although the difference between nouns and verbs was not significant. PWS also showed lower accuracy for both nouns and verbs than PWNS, but, again, this difference was not significant. Still, while none of the differences found between PWS and PWNS were significant, it is worth noting that all of the differences discussed so far were consistent in identifying less strong performance by PWS.

Phoneme Position

Both groups showed significantly slower monitoring latencies for phonemes in the medial position than for phonemes in the initial position, indicating an increase in the amount of time it takes to encode phonemes in non-initial positions. This supports Hypothesis 1b, and is consistent with previous research (Sasisekaran et al., 2006). Both groups also showed significantly lower accuracy when monitoring for a phoneme in the

medial position than when monitoring for a phoneme in the initial position. No significant effect of group was found with regard to phoneme position, although, in all cases, PWS averaged slower monitoring latencies and poorer accuracy, as well as poorer efficiency scores. Again, these trends provide some support for Hypothesis 2.

The deficits displayed by PWS, although not significant, can be explained using the EXPLAN model of stuttering (Howell & Au-Yeung, 2002). Howell & Au-Yeung explain EXPLAN in terms of content and function words, however, they acknowledge that this is not the only context in which the theory can be interpreted. In the context of this study, a possible explanation is that a word-initial phoneme is easier to plan than the remainder of the word, and, when this occurs, a back-up occurs within the word itself, rather than across a word boundary, as postulated by Howell & Au-Yeung (2002). In typical speakers, this pattern is not significant enough to result in fluency breakdown. If PWS have particular difficulty with verbs, the additional semantic demands inherent to verb production would increase the stress on the system, and could induce stress across word boundaries, since the nouns preceding the verbs would be significantly easier to produce. The idea that speakers may become stuck within a single word and also across a word boundary, is supported by Levelt's model of speech production (Levelt, Roelofs, & Meyer, 1999). In the Weaver++ model, after a word's lemma is retrieved, morphological, metrical, and segmental information then must be retrieved. Segmental information is retrieved last, because of phrasal resyllabification. For example, if a word ends in a consonant cluster, and the next word begins with a vowel, the final consonant of the first word may be resyllabified (i.e., 'escort us' becomes '*es-cor-tus')* (Levelt et al., 1999). However, the necessary phonemes must simultaneously available. If the initial

phonemes are much easier to plan than the medial phonemes, then a backup could be caused which prevents timely planning of individual words, and, when segmentation occurs, prevents timely planning of entire phrases.

Interestingly, an analysis of response times on null trials for each group showed that for PWS, responses to null trials were actually faster than responses to trials with the phoneme in the word-medial position, although not significantly so. This pattern did not hold for PWNS. PWS were also more efficient (as demonstrated by IES) than PWNS (although not significantly) when completing null trials. These results suggest that PWS have an easier time determining that a phoneme does not exist in a word at all, as opposed to determining that it exists. This can also be interpreted through the EXPLAN model. If people who stutter experience increased difficulty in planning the later portion of a word, as the EXPLAN model would suggest, perhaps they have a subconscious "default setting" going into each trial, in which they assume that the phoneme for which they are monitoring will not occur in any position other than initially. This assumption would essentially be based on the fact that the PWS will have difficulty planning much further into the word than the initial phoneme, because of the delay suggested by the EXPLAN model, so they are quicker to resort to a negative decision when put under experimental stress. However, because PWNS do not experience the extra difficulty in monitoring for a sound in a medial position, they are able to more quickly identify when a sound occurs in the medial position, and do not feel as though they have to resort to a quicker negative decision.

While our results are compatible with a language-based model of stuttering such as EXPLAN, we do not mean to ignore deficits in motor-planning and execution in PWS,

for which there is significant evidence (i.e., Kleinow & Smith, 2000). One of the most interesting aspects of a multi-factorial theory of stuttering such as the Dynamic-Multifactorial Model (Smith & Kelly, 1997), is that it does encompass all possible contributing factors, including linguistic-neurological, motor-neurological, and even psycho-social. Inasmuch as this study found a potential level of linguistic encoding deficit in people who stutter, the DMM explains very persuasively how such deficits might compromise the motor encoding of speech in PWS.

Future Research Directions

There are a variety of directions in which this research could continue in the future. The most basic of these would be to repeat this study to verify the results, and try to increase the sample size. Sample size could be increased by making the tasks able to be administered remotely. DMDX can be programmed to be administered remotely, so that the participant downloads the files from a drop-box online, completes the tests, and the results are automatically emailed to a DMDX server. The language testing could then be administered via an online survey system. This it would significantly increase the access to potential participants (Forster & Forster, 2003).

Making this study more difficult may also be a worthwhile future research direction. Most of the words used in this study were single-syllable words, with a relatively early age of acquisition. It is possible that these words did not provide a high enough level of difficulty to result in enough stress on the language processing system in the experimental participants to induce significant differences in performance. One way to make the task more difficult would be to decrease the amount of time given for each trial before the trial automatically times out, although this may result in an unacceptably

high number of trials which automatically time out. Using more complicated, multi-syllabic words could also make the task more difficult and potentially induce group differences, although more complex words may also be more difficult to match across all of the necessary categories to ensure that the word groups are similar enough to show valid results. Adding a speaking task could also increase the level of difficulty. If the difficulties experienced by PWS are the result of asynchronous planning and execution, as is suggested by the EXPLAN theory (Howell & Au-Yeung, 2002), then it is possible that the experimental task must include both of these processes to fully illustrate the scope of any deficiencies in PWS. However, including both of these processes in the same task makes it more difficult to interpret the results, as it would not be possible to determine at what stage any difficulty was occurring.

Other future directions for this research include different uses of the phoneme monitoring paradigm. The phoneme monitoring paradigm is extremely versatile, but is not very commonly used in research, and is very rarely used with PWS. However, because the phoneme monitoring paradigm is so versatile, it could feasibly be used to test many other areas of language processing and production which are thought to be potential areas of deficit in PWS. For example, atypical syntactic processing has been cited as a potential source of stuttering-like disfluencies (Cuadrado & Weber-Fox, 2003), and is also an area that has been researched using phoneme-monitoring paradigms since their inception (Hakes & Foss, 1970; Hakes, 1971). Other significant areas of stuttering research include prosody, particularly involving differences between stressed and unstressed syllables (Wingate, 1988; Prins, Hubbard, & Krause, 1991; Natke, Grosser, Sandrieser, & Kalveram, 2002; Packman, Onslow, Richard, & van Doorn, 1996;

Hubbard, 1998), which is also an area of previous examination in non-stuttering populations using a phoneme monitoring paradigm (Pitt & Samuel, 1990).

The language test used in this study also bears further examination. Language test results in this study must be interpreted carefully, as the task was experimental, and was not normed across a large sample of participants. Still, the results were consistent with much of the prior research with both adults (Newman & Bernstein Ratner, 2007; Pellowski, 2011) and children (Ntourou et al., 2011). However, as pointed out by Ntourou et al (2011), the scores achieved by PWS do not necessarily point to the conclusion that language abilities in PWS are "disordered" in the traditional sense of the word. This distinction between being "disordered" and being *subtly different* is critical. Simple logic dictates that if the language abilities of a given population are not clinically disordered, then use of tests designed to diagnose clinical disorders is probably not useful in assessing language skills in an experimental sample. Therefore, to understand fully the nature of the subtle differences in language capabilities that may exist between people who do and do not stutter, it is useful to develop experimental challenges to assess language knowledge and use. Our task, composed of three different types of SAT and GRE questions, and with fairly stringent time limits set on each section, was designed to provide an adequate level of language challenge. A customized language test was especially necessary in light of the fact that many of the stuttering participants had completed college or post-graduate degrees. Three types of question were chosen which assessed areas in which a deficit has previously been associated with a stuttering disorder, such as syntactic abilities (Cuadrado & Weber-Fox, 2003), vocabulary and word-finding

abilities (Pellowski, 2011), and ability to perform concomitant cognitive processes (Bosshardt, 2002).

Further research should be performed in an attempt to create and validate a language test that is appropriate to be used for the purpose of examining the more subtle differences which appear to exist between adults who do and do not stutter. Types of questions should be chosen which assess specific aspects of language that have been implicated as possibly deficient in people who stutter. Time limits should also be considered. The test used in this study used what initially seemed to be quite stringent time limits, though, over the course of the study, it seemed that most of the participants finished with ample time. In general, the test should be designed keeping in mind that it must stress the language processing system enough to induce noticeable breakdown.

Conclusions

This study was conceived to provide further evidence of differences in lexicalization between people who do and do not stutter, similar to the differences seen in studies such as Prins, Main, and Wampler (1997). While few significant differences were found, all of the trends seen supported the previous research done in the area. The study examined not only differences between people who do and do not stutter, but also differences in the time-course of lexicalization between nouns and verbs, and between word-initial and word-medial/final phonemes. Differences between nouns and verbs is a particularly under-researched area, in sore need of contributions to breadth of knowledge. Possibly the greatest contribution made by this study is the demonstration of the use of the phoneme monitoring paradigm, and how it can be used, with its original intent, to make comparisons between people who do and do not stutter. This raises a wide variety

of potential follow-up studies, all of which could be completed using the same, well-proven, simple, non-invasive paradigm.

Appendix A. Background Questionnaire

Background Questionnaire

1. What is your full name?

2. Are you a person who stutters?

3. Does anybody else in your family stutter, and who?

4. When did you begin to stutter (approximate age in years)?

5. Do you have any other speech/learning disorders?

6. Do you have any other relevant medical disorders?

7. How many years of education do you have?

8. Please estimate your high school/college GPA.

9. What is your current job?

10. Please report an estimate of your family's combined annual income.

    a. Under $20,000

    b. Between $20,000 and $40,000

    c. Between $40,000 and $70,000

    d. Between $70,000 and $100,000

e. Between $100,000 and $150,000

f. Greater than $150,000

Appendix B. Participant Information

PWNS

Participant	Group	Gender	Age (Years)	Handedness	Stutter	Family History	AoO (years)	Education (years)	GPA (of highest Ed Lvl)	Income	SSI Score	Severity
C003	PWNS	Female	20	Right	No	No	n/a	13	3.0	4	0	None
C004	PWNS	Female	57	Right	No	No	n/a	16	3.5	2	0	None
C019	PWNS	Female	49	Right	No	Yes	n/a	12	3.5	6	0	None
C032	PWNS	Female	28	Right	No	No	n/a	21	3.8	3	0	None
C033	PWNS	Male	63	Right	No	No	n/a	22	3.8	6	0	None
C034	PWNS	Female	47	Right	No	No	n/a	19	3.1	6	0	None
C035	PWNS	Male	46	Right	No	No	n/a	16	2.8	6	0	None
C036	PWNS	Male	33	Left	No	No	n/a	20	3.9	5	0	None
C037	PWNS	Male	49	Right	No	No	n/a	17	3	6	0	None
C038	PWNS	Male	52	Right	No	No	n/a	17	3.5	6	0	None
C040	PWNS	Female	25	Right	No	Yes	n/a	18	3.5	5	0	None
C041	PWNS	Male	24	Right	No	No	n/a	18	3.8	2	0	None
C042	PWNS	Female	50	Right	No	No	n/a	22	3.3	5	0	none
C043	PWNS	Female	54	Left	No	No	n/a	16	3.8	5	0	none
C045	PWNS	Male	25	Left	No	No	n/a	17	3.65	5	0	none

$M = 41.46$ $M = 17.6$

PWS

Participant	Group	Gender	Age (Years)	Handedness	Stutter	Family History	AoO (years)	Education (years)	GPA (of highest Ed Lvl)	Income	SSI Score	Severity
S002	PWS	Female	49	Right	Yes	Yes	9	19	3.0	6	6	below very mild
S006	PWS	Male	49	Right	Yes	Yes	7	18	3.5	6	2	below very mild
S007	PWS	Male	24	Right	Yes	Yes	4	16	3.4	3	15	very mild
S008	PWS	Female	51	Left	Yes	No	3	18	3.5	4	25	moderate
S009	PWS	Male	55	Right	Yes	Yes	5	16	3.2	3	11	very mild
S010	PWS	Male	22	Left	Yes	No	7	16	3.9	4	5	below very mild
S011	PWS	Male	32	Left	Yes	No	5	18	3.0	2	23	moderate
S012	PWS	Female	28	Right	Yes	Yes	4	20	3.7	5	11	very mild
S013	PWS	Female	47	Right	Yes	No	6	24	3.7	5	14	very mild
S022	PWS	Female	56	Right	Yes	Yes	5	16	3.5	6	23	moderate
S023	PWS	Male	44	Right	Yes	Yes	5	16	3.7	3	12	very mild
S026	PWS	Female	46	Right	Yes	No	3	12	3.5	3	18	mild
S027	PWS	Female	23	Right	Yes	Yes	3	15	3.0	3	10	very mild
S030	PWS	Male	58	Right	Yes	Yes	7	22	3.2	6	11	very mild
S031	PWS	Female	24	Right	Yes	Yes	6	16	3.5	6	19	mild

$M = 40.53$ $M = 17.46$

$t(28) = 0.1860, p = 0.85$ $t(28) = 0.1244, p = 0.90$

Appendix C. Language Test

The following sentences test your ability to recognize
grammar and usage errors. **Each sentence contains either
a single error or no error at all. No sentence contains more
than one error.** If the sentence contains an error, select the
letter which corresponds to the part that must be changed to make the
sentence correct. If the sentence is correct, select choice E.
In choosing answers, follow the requirements of standard
written English.

You will have 6 minutes to complete the 12 questions

Sample Question:
1. My grandmother sees <u>remarkable</u> well considering <u>that</u> she has endured four
   operations on her eyes and <u>suffered from</u> vitamin deficiency <u>during</u> her childhood.
   a. Remarkable
   b. That
   c. Suffered from
   d. During
   e. No error

Answer: A. 'Remarkable' needs to be changed to 'remarkably'.

---

1. The union <u>insisted</u> on an increase in <u>their</u> <u>members'</u> starting pay, and threatened
   to call a strike if the company <u>refused to</u> meet the demand.
   a. Insisted
   b. Their
   c. Members'
   d. Refused to
   e. No error

2. Television viewers claim <u>that</u> the number of scenes <u>depicting</u> alcohol
   consumption <u>have</u> increased dramatically <u>over</u> the last decade.
   a. That
   b. Depicting
   c. Have
   d. Over
   e. No error

3. Employees with <u>less</u> personal problems <u>are</u> <u>likely</u> to be <u>more</u> productive.
   a. Less
   b. Are
   c. Likely
   d. More
   e. No error.

4. The teacher <u>sat</u> down <u>besides</u> the frightened child and tried <u>to reassure</u> him that the monster was <u>merely</u> imaginary.
    a. Sat
    b. Besides
    c. To reassure
    d. Merely
    e. No error
5. <u>Because</u> they played <u>by</u> the rules, the members of the team <u>were given</u> a standing ovation even though <u>it</u> did not win the match.
    a. Because
    b. By
    c. Were given
    d. It
    e. No error
6. We have no choice <u>but</u> to appoint <u>Mary:</u> she is the <u>best</u> of the two candidates, and there <u>is</u> no prospect of finding more applicants.
    a. But
    b. Mary:
    c. Best
    d. Is
    e. No error
7. My grandmother's legacy <u>is</u> substantial, <u>especially</u> if the value of the rare stamps <u>are</u> taken <u>into</u> consideration.
    a. Is
    b. Especially
    c. Are
    d. Into
    e. No error
8. Everyone <u>who</u> visits Singapore <u>is impressed</u> by its cleanliness, <u>which</u> is mainly a result of rigorous implementation of <u>their</u> strict laws.
    a. Who
    b. Is impressed
    c. Which
    d. Their
    e. No error
9. In <u>such</u> areas as sports, ranking of individual performance <u>is</u> relatively well accepted <u>since</u> the parameters on which the rating <u>are</u> based are generally objective.
    a. Such
    b. Is
    c. Since
    d. Are
    e. No error

10. This detailed <u>yet</u> readable biography is well researched <u>and</u> provides valuable insight <u>to</u> the facts <u>that</u> motivated the famous philosopher.

    a. Yet
    b. And
    c. To
    d. That
    e. No error

11. I have <u>nearly</u> written all the new tests <u>for</u> inclusion in the revised edition of my book, and <u>hope to finish</u> the work <u>within</u> a week.

    a. Nearly
    b. For
    c. Hope to finish
    d. Within
    e. No error

12. The students <u>have been</u> practicing for the concert <u>since</u> three weeks<u>, and</u> in that time <u>have</u> improved considerably.

    a. Have been
    b. Since
    c. , and
    d. Have
    e. No error

Answers

1. B 'the union' is not plural, so 'their' is incorrect
2. C 'the number of scenes' is singular ('the number'), so it should be a singular verb
3. A should be 'fewer', not 'less'
4. B change 'besides' to 'beside'
5. D 'the members' is plural, to 'it' should be 'they'
6. C since there are only 2 candidates, it should be 'better', not 'best'
7. C 'the value' is singular, so it should be 'is', not 'are'
8. D should not use 'they' or 'their' when the subject of the sentence is a country
9. D 'are' should be 'is' to agree with subject 'rating'
10. C 'to' should be 'into'
11. A 'nearly' should be moved to not split the verb ('have written')
12. B change 'since' to 'for'

Instructions: select the letter corresponding to the word(s) which best fill the blank(s)

You will have 8 minutes to complete 8 questions

Sample Question

1. The parliamentary session degenerated into ____ with politicians hurling ____ at each other and refusing to come to order.
   a. Mayhem – banter
   b. Disarray – pleasantries
   c. Tranquility – invectives
   d. Chaos – aphorisms
   e. Anarchy – insults

   Answer: E. Anarchy - insults

1. Today Wegener's theory is ____ ; however, he died an outsider treated with ____ by the scientific establishment.

A. unsupported - approval
B. dismissed - contempt
C. accepted - approbation
D. unchallenged - disdain
E. unrivalled - reverence

2. Each occupation has its own ____ ; bankers, lawyers and computer professionals, for example, all use among themselves language which outsiders have difficulty following.

A. merits
B. disadvantages
C. rewards
D. jargon
E. problems

3. ____ by nature, Jones spoke very little even to his own family members.

A. garrulous
B. equivocal
C. taciturn
D. arrogant
E. gregarious

4. Many people at that time believed that spices help preserve food; however, Hall found that many marketed spices were ____ bacteria, molds, and yeasts.

A. devoid of
B. teeming with
C. improved by
D. destroyed by
E. active against

5. If there is nothing to absorb the energy of sound waves, they travel on _____, but their intensity _____ as they travel further from their source.

A. erratically - mitigates
B. eternally - alleviates
C. forever - increases
D. steadily - stabilizes
E. indefinitely - diminishes

6. The intellectual flexibility inherent in a multicultural nation has been _____ in classrooms where emphasis on British-American literature has not reflected the cultural _____ of our country.

A. eradicated - unanimity
B. encouraged - aspirations
C. stifled - diversity
D. thwarted - uniformity
E. inculcated - divide

7. In the Middle Ages, the _____ of the great cathedrals did not enter into the architects' plans; almost invariably a cathedral was positioned haphazardly in _____ surroundings.

A. situation - incongruous
B. location - apt
C. ambience - salubrious
D. durability - convenient
E. majesty - grandiose

8. The crew of the air balloon _____ the sand bags to help the balloon rise over the hill.

A. capsized
B. jettisoned
C. salvaged
D. augmented
E. enumerated

Answers

1. D
2. D
3. C
4. B
5. E
6. C
7. A
8. B

Instructions: select the letter corresponding to the word which best completes the analogy

You will have 3 minutes to complete 10 questions

Sample Question

1. REAM : PAPER :: (_____) : HAY
   a. Hutch
   b. Bale
   c. Coop
   d. Quart

Answer: B. Paper is stored in a ream, hay is stored in a bale.

1. SHARD : POTTERY :: (____) : WOOD

A. acorn
B. smoke
C. chair
D. splinter

2. (____) : SPEECH :: COORDINATED : MOVEMENT

A. predictive
B. rapid
C. prophetic
D. articulate

3. SCINTILLATING : DULLNESS :: (____) : CALM

A. erudite
B. boisterous
C. cautious
D. exalted

4. ELUCIDATE : CLARITY :: ILLUMINATE : (____)

A. memory
B. problem
C. oblivion
D. light

5. PENURY : MONEY :: STARVATION : (____)

A. sustenance
B. infirmity
C. illness
D. care

6. ARCHIPELAGO : ISLAND :: CONSTELLATION : (____)

A. hamlet
B. zodiac
C. star
D. sea

7. FENESTRATION : (____) :: PORTAL : DOOR

A. mural
B. table
C. window
D. atrium

8. (____) : LENIENT :: MISER : CHARITABLE

A. philanthropist
B. virtuoso
C. hedonist
D. authoritarian

9. ALLAY : SUSPICION :: (____) : FEAR

A. plant
B. calm
C. generate
D. anger

10. BOAST : LANGUAGE :: SWAGGER : (____)

A. anger
B. gait
C. sight
D. wealth

Answers

1. D
2. D
3. B
4. D

5. A
6. C
7. C
8. D
9. B
10. B

Appendix D. Stimuli

Nouns

Word	Name Agreement (%)	Number of Phonemes	AoA	Pic. Complexity	Freq HAL	Log Freq HAL
boot	92	3	1	8857	43868	10.69
ball	100	3	1	13345	38502	10.56
guitar	98	5	3	12032	24781	10.12
hair	98	3	1	41463	42603	10.66
foot	100	3	1	7638	24212	10.09
goat	96	3	3	15302	2562	7.85
bed	100	3	3	11109	31345	10.35
kite	100	3	3	17880	2346	7.76
pear	100	3	3	18960	971	6.88
pot	73	3	3	5266	13161	9.49
leg	79	3	1	6995	17838	9.79
stool	83	4	3	10988	1234	7.12
sun	100	3	1	18102	74083	11.21
table	98	4	1	12010	56081	10.93
window	100	5	1	26944	54926	10.91
Averages	94.467	3.400	1.933	15126.067	28567.533	9.627

Verbs

Word	Name Agreement (%)	Number of Phonemes	AoA	Pic. Complexity	Freq HAL	Log Freq HAL
salute	100	5	3	15575	1321	7.19
run	100	3	1	17276	223338	12.32
juggle	96	4	3	14974	1115	7.02
jump	71	4	1	15496	26855	10.2
lick	94	3	2	18076	4418	8.39
pour	96	3	2	26916	11348	9.34
pull	79	3	1	30784	28190	10.25
type	100	3	3	19194	157464	11.97
read	100	3	1	30065	289582	12.58
dive	100	3	3	16005	8177	9.01
beg	92	3	3	17686	4583	8.43
ride	98	3	1	18780	23593	10.07
sit	96	3	2	18449	25658	10.15
surf	100	3	3	20492	5923	8.69
swim	100	4	1	16766	5116	8.54
Averages	94.800	3.333	2.000	19768.933	54445.400	9.610
	t(28) = 0.1049, p = 0.917	t(28) = 0.2686, p = 0.790	t(28) = 0.1862, p = 0.853	t (28) = 1.705, p = 0.099	t(28) = 1.06, p = 0.296	t(28) = 0.0298, p = 0.976

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