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# A Comparison of Speech Onset Latencies Between Persons Who Stutter and Persons Who Do Not Stutter Across Varied Phonological Priming Conditions

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THESIS APPROVAL

The abstract and thesis of Brian Joseph Riffel for the Master of Science in Speech Communication: Speech and Hearing Science were presented July 10, 1997, and accepted by the thesis committee and the department.

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# ABSTRACT

An abstract of the thesis of Brian Joseph Riffel for the Master of Science in Speech Communication: Speech and Hearing Science presented on July 10, 1997.

Title: A Comparison of Speech Onset Latencies Between Persons Who Stutter and Persons Who Do Not Stutter Across Varied Phonological Priming Conditions

A recent theory of stuttering, the "Covert Repair Hypothesis of Disfluencies" (Kolk & Postma, in press; Postma & Kolk, 1992, 1993), accounts for the difference between persons who stutter (PWS) and persons who do not stutter (PWNS) by concluding that PWS are slower than PWNS in their phonological encoding abilities. This belief is supported through experimental studies by Bosshardt (1990) and Postma et al (1990), both of which found PWS to be slower than PWNS in silent reading tasks. In addition, Wijnen and Boers (1994) found that PWS demonstrate longer speech onset latencies than PWNS at baseline, but then approximate the times of PWNS upon "phonological priming." They interpreted their results to indicate that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p.1).

The purpose of the present study was to test the covert repair hypothesis, as it is applied to the difference between PWS and PWNS, while eliminating some of the potential biases found in earlier studies. The research question for this study was: "Is there a significant difference in speech onset latencies between PWS and PWNS across three

conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target?"

Six PWS ages 27 to 47 were recruited from both the Portland State University Speech and Hearing Clinic and a stuttering support group that meets on campus. All PWS were native speakers of English and diagnosed as a PWS by an ASHA certified speech-language pathologist (SLP). In addition, all PWS still considered themselves to be a PWS through self-report/interview. Only one of the six PWS was currently receiving treatment.

The control group consisted of 20 PWNS ages 18 to 37 recruited from Portland State University. All PWNS were native speakers of English.

All subjects performed a picture naming task designed to measure speech onset latencies across varied phonological priming contexts. Subjects were tested individually by being seated in front of a computer monitor and naming line drawings of common objects as they appeared on the screen. Subjects were asked to name the pictures as quickly and as accurately as possible. The task consisted of 504 experimental trials, presented in two blocks of 252 trials.

Following completion of the task, all naming errors, apparatus malfunctions, and extreme outliers were omitted prior to statistical analysis. Mean speech onset latencies of the two groups were then compared. Statistical analysis was performed using a one between and two within mixed factor ANOVA. Results showed no significant differences in speech onset latencies between the two groups at the .05 alpha level across the varied phonological priming conditions.

# A COMPARISON OF SPEECH ONSET LATENCIES BETWEEN PERSONS WHO STUTTER AND PERSONS WHO DO NOT STUTTER ACROSS VARIED PHONOLOGICAL PRIMING CONDITIONS

by

BRIAN JOSEPH RIFFEL

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
SPEECH COMMUNICATION:
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Portland State University
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# CHAPTER I
# INTRODUCTION

Several theories attempt to explain stuttering by incorporating the differences between persons who stutter (PWS) and persons who do not stutter (PWNS). This appears to be a logical approach, in that several studies have shown mean differences to exist between PWS and PWNS in various areas. Among the areas in which differences have been documented are speech and language development, central auditory functioning, sensory motor performance, and general intelligence. Despite the documentation of these differences, a complete theory of stuttering has yet to withstand experimental testing and become widely accepted.

One of the more recent theories which attempts to explain the existence of stuttering is the "Covert Repair Hypothesis of Disfluencies" (Kolk & Postma, in press; Postma & Kolk, 1992, 1993). The covert repair hypothesis states that disfluencies, which can be described as disruptions in the speech flow of both PWS and PWNS, are the "side effects" of interruptions in speech planning. It is hypothesized that as individuals speak, they monitor their speech plan. If errors in the plan are detected, the speaker attempts to covertly correct the error before its overt appearance. Even if the error is corrected prior to production, it is believed that this "covert repair" disrupts the fluency of the speech output. In applying this hypothesis to the difference between PWS and PWNS, Postma and Kolk believe that PWS are slower in their phonological encoding abilities. This slower speech planning leads to more errors in the phonemic plans of PWS. Stuttering is viewed as the "'normal' repair reaction to an abnormal phonetic plan" (Kolk & Postma, p.16).

The covert repair hypothesis has received some experimental support in recent literature. Wijnen and Boers (1994) compared speech onset latencies of PWS and PWNS across three conditions and concluded that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p. 1). Additional support for this theory has come from studies by Bosshardt (1990) and Postma et al. (1990), both of which found PWS to be slower than PWNS in silent reading tasks, suggesting that speech planning is slower in PWS.

Despite this empirical support, none of the previous studies have performed a pure measure of the phonological encoding process. In addition, Wijnen and Boers (1994) encountered an extremely high error rate during production, thereby calling their results into question.

The proposed study will test the covert repair hypothesis as it is applied to the difference between PWS and PWNS while eliminating some of the potential biases found in earlier studies. The research question for the proposed study is: "Is there a significant difference in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target?" If PWS are slower than PWNS in their phonological encoding abilities, differences should be detected between the two groups in speech onset latencies. This is because phonological encoding is a component of speech onset. Priming refers to the process of pre-activating the internal phonological representation of a word prior to naming of the target. This is accomplished by having the subject name a different picture (prime) prior to naming the target. Presenting a prime that shares the same CV (e.g. "coat/comb") or VC (e.g. "sun/gun") should, in effect, "highlight" the shared portion. If the "(stressed) vowel" is a point of particular difficulty in PWS, relative differences in speech onset latencies between the two groups should be detected across the various phonological priming conditions.

## Definitions

The following terms have been used extensively throughout this text. Definitions have been provided to assist in the comprehension of this thesis.

Stuttering: "disruption in the fluency of verbal expression, which is characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable" (Wingate, 1964, p. 488).

Disfluencies: disruptions in the flow of speech; "stuttered disfluencies" are characterized by the one syllable variety referred to in the definition of stuttering, whereas "nonstuttered disfluencies" are the "normal" speech disruptions, such as rephrasing an utterance, pausing, interjection of "uh" or "um," etc.

PWS: person(s) who stutter(s)

PWNS: person(s) who do(es) not stutter

CWS: child(ren) who stutter(s)

CWNS: child(ren) who do(es) not stutter

Sound/Syllable Repetitions: e.g. "p-p-p-pizza"/"ba-ba-basketball"

Sound/Syllable Prolongations: e.g. "mmmmy dog..."/"baaaasketball"

Prime: "a word or phoneme presented to a speaker that increases the activation level of the internal representation of that item and facilitates subsequent processing of that item... within spreading activation theories, it is assumed that priming causes an item to reach threshold faster, because activation begins at a higher initial activation level" (Kolk & Postma, pp. 19-20).

Connectionist: model of spoken language consisting of "nodes" representing semantic concepts, words, and phonemes organized into connected hierarchical tiers; activation spreads through this network and determines which items at each level will be selected for the utterance.

Activation: name given to the "excited state" which travels bi-directionally in the connectionist network determining selections.

Selection: process of "choosing" semantic concepts, words, and phonemes in a connectionist model through heightened activation.

# CHAPTER II

# REVIEW OF THE LITERATURE

## Definition of Stuttering

Van Riper (1982) proposed that "stuttering occurs when the forward flow of speech is interrupted by a motorically disrupted sound, syllable, or word or by the speaker's reactions thereto" (p.15). He stresses the latter part of his definition as a critical feature because avoidance and struggle behaviors not only interrupt the speech flow, but also help to distinguish between disfluencies of persons who stutter (PWS) and persons who do not stutter (PWNS). Inclusion of this distinction between PWS and PWNS is a strength of Van Riper's definition. Also, for purposes of the proposed study, it is important to reemphasize that Van Riper qualifies only sound, syllable, or word disruptions as spoken aspects of stuttering.

Wingate (1964) defined stuttering as:

> (a) Disruption in the fluency of verbal expression, which is (b) characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable. These disruptions (c) usually occur frequently or are marked in character and (d) are not readily controllable. (p. 488)

Wingate's definition expands upon Van Riper's by being more detailed. Specifically, an important distinction Wingate makes is that the affected speech element is a maximum of one syllable in length, which helps to further differentiate between stuttered disfluencies and normal disfluencies. A major criticism of Wingate's (1964) definition is that he perhaps overstates it by saying "one or the other, or both, of these kernel characteristics [repetitions and prolongations] are found in *all* cases of stuttering." (p.487)

Wingate's insistence that repetitions and/or prolongations are always a part of stuttering is the main source of disagreement between his view and that of Perkins (1990), who leads a relatively recent movement in the quest for a definition of stuttering. Rather than focusing on what the listener perceives, Perkins has proposed defining stuttering from the perspective of the speaker as a speech production disorder. According to Perkins, "Stuttering is the involuntary disruption of a continuing attempt to produce a spoken utterance." (p. 376) Although this position is controversial, it has been supported by experimental research on at least one occasion (Moore & Perkins, 1990). However, one must be careful not to interpret this definition as saying that listeners are unable to identify stuttering. Perkins (1990) states, "My position is not that stuttering, typically, cannot be detected." (p. 375) In fact, he goes on to say "I would have little quarrel with Wingate's standard definition if by it he meant that syllable repetitions and prolongations are what the listener is most likely to hear when a speaker experiences stuttering." (p. 375)

Although consensus has yet to be reached with respect to a definition for stuttering, it is apparent that sound/syllable repetitions and prolongations, the focus of the proposed research, are generally accepted as the most prominent perceptual features of stuttering. The proposed study will attempt to lend support to recent research which has possibly discovered an explanation for the occurrence of sound/syllable repetitions and prolongations in the speech of PWS.

Theories of Stuttering

The initial trend in stuttering research was to view stuttering through the "Medical Model" as being the result of some physical/chemical breakdown or an inherited characteristic, either of which led to failure in the speech system. One of the earliest proposals as to the cause of stuttering was the "Theory of Cerebral Dominance (Orton & Travis, 1929). The ability to produce coordinated speech was believed to lie in the hemispheres of the cerebral cortex. Therefore, a disruption in speech was attributed to a problem in these cortical hemispheres. Specifically, stuttering was thought to be a result of insufficient cerebral dominance. Although this theory experienced some initial favor, it has since failed to gain acceptance or experimental support.

Johnson (1955) proposed one of the most influential theories of stuttering as part of a trend which shifted away from the Medical Model and began to view stuttering as a learned behavior which could be manipulated. His "Diagnosogenic Theory" blamed parents' labeling of a child's normal disfluencies as "stuttering" for providing the underlying cause of stuttering. He believed that the parents' initial "diagnosis" or labeling of stuttering and the accompanying emotional reaction caused anxiety in the child which produced and/or maintained stuttering behavior. Although evidence currently exists which distinguishes between children who stutter (CWS) versus children who are normally disfluent, this theory still carries influence which, unfortunately, can lead to ineffective treatment and unnecessary parental guilt.

Adams (1990), Starkweather and Gottwald (1990) consolidated previous stuttering research findings into an etiological theory known as the "Demands and Capacities" model. "Demands" refer to environmental and/or self-imposed speaking pressures. These can include instances such as having to speak too quickly or in an uncomfortable situation, or having to produce longer and/or more complex utterances. "Capacities" refer to the speaker's cognitive, linguistic, motoric, and/or emotional abilities to produce fluent speech. Stuttering is believed to result whenever speaking "demands" exceed the speakers innate "capacities." A strength of this theory is that it accounts for the heterogeneous nature of stuttering by allowing for greater diversity in those individuals classified as PWS. Within this model, PWS may encompass a wide range of "demands" and "capacities," provided that "demands" outweigh "capacities." However, this model does not contain a provision for normal disfluencies, which seems to imply that stuttering is merely a situational occurrence that arises whenever a speaker's demands exceed their capacities, rather than a disorder unique to PWS. Adams acknowledges that the model is in the initial stages and has yet to be developed and tested.

Perkins, Kent, and Curlee (1991) have proposed the "Theory of Neuropsycholinguistic Function in Stuttering." In this theory, speech is thought to consist of linguistic and paralinguistic components which originate from different neural systems before integrating at a common output system. Fluent speech requires this integration to be "synchronous." If the integration is "dyssynchronous," the result can be either normal disfluency or stuttering, depending on both the degree of awareness as to the cause of the disruption and time pressure. Stuttering, in this theory, is defined as "disruption of speech that is experienced by the speaker as loss of control." (p. 735) Degree of control loss is then considered the measure of severity. Loss of control is thought to increase as awareness of the cause of the speech disruption decreases and time pressure to perform an utterance increases. Although this theory addresses the distinction between the *behaviors* of stuttering and normal disfluencies, it fails to distinguish between PWS and PWNS. Stuttering is described in situational terms based on external factors, rather than fundamental differences between PWS and PWNS, which seems to imply that stuttering is a transient phenomenon experienced by all speakers, rather than a disorder resulting from some difference between PWS and PWNS.

A final recent theory of stuttering, on which the current research is based, is the "Covert Repair Hypothesis of Disfluencies" (Postma & Kolk, 1992, 1993). The covert repair hypothesis states that disfluencies, which can be described as disruptions in the speech flow of both PWS and PWNS, are the "side effects" of interruptions in speech planning. These interruptions are thought to result from internal, prearticulatory error detection in, and subsequent repair of, the speech plan. In other words, as individuals speak, they monitor their speech plan. If errors in the plan are detected, the speaker attempts to covertly correct the error before its overt appearance or production. Even if the error is corrected prior to production, it is believed that this "covert repair" disrupts the fluency of the speech output.

In applying this hypothesis to the difference between PWS and PWNS, Postma and Kolk believe that PWS are slower in their phonological encoding abilities. Based on a "connectionist" or "spreading-activation" model of spoken language (Dell, 1986, 1988), this slower phonological encoding leads to more errors encoded in the phonemic plans of PWS.

In brief, a "connectionist" or "spreading-activation" model of spoken language can be thought of as an interconnected network of information "nodes" organized in hierarchical tiers of semantic concepts, words, and phonemes. The entire system is in a perpetual state of fluctuating activation or "noise," partially due to sensory input. A spoken utterance begins with heightened activation of the nodes at the semantic level that represent the "basic idea" of the intended message. Activation spreads to the word level, where the desired word nodes of the message to be spoken receive activation for selection. Upon selection of the desired words, activation then spreads to the phonological level where the phoneme nodes required for construction of the desired words receive activation for selection.

It is important to note the distinction between "activation" and "selection." In this model, it is believed that these two processes occur independently of one another. Speakers can determine speed of selection through adjustments in speech rate, but activation is beyond the speaker's control. Change in speech rate illustrates the relationship between activation and selection, in that, as a speaker talks more quickly it is more likely that speech errors will be produced. Errors represent instances when an unintended phoneme, rather than the intended phoneme, is selected to be part of the phonemic plan. This misselection is believed to result from selection having occurred prior to the target phoneme receiving activation sufficient to differentiate it from competing phonemes. Just as faster speech rate leads to increased phonological encoding errors, so too would slower activation. Phonological activation is the aspect of phonological encoding that is believed to be slower in PWS. If PWS commit more phonological encoding errors than PWNS, PWS will interrupt their speech planning more often as they detect and repair these phonological errors. These increased interruptions are believed to result in the greater number of disfluencies produced by PWS. Thus, stuttering is viewed as the "'normal' repair reaction to an abnormal phonetic plan" (Kolk & Postma, p.16).

If this assumption were true that PWS are slower than PWNS in their phonological encoding abilities, then reduction in speaking rate by PWS should lead to less stuttering. This should occur because the slower phonological encoding system is given added time to sufficiently activate the intended phonemes prior to selection, which should lead to fewer errors committed during phonological selection. It is, in fact, accepted that reduced speech rate by PWS results in less stuttering (Culatta & Rubin, 1973; Perkins et al, 1976; Postma & Kolk, 1990).

Additional support for the covert repair hypothesis comes from evidence in the literature which supports the existence of a prearticulatory editing component in speech production. In his analyses of speech repairs, Levelt (1983) actually coined the phrase "covert repair," which he defined as speech events containing either an interruption plus an editing term (e.g., "I want to, uh, go to bed") or an interruption followed by a retracing of one or more words (e.g., "I want to, I want to go to bed"). Presence of "editing terms" in speech is believed to be an indication that internal editing of the speech plan is occurring. Levelt (1983) also cited the speed with which speakers can correct errors as further proof that editing occurs at the prearticulatory level. In addition to Levelt's findings, Garnsey and Dell (1984) review the literature supporting prearticulatory editing in terms of output biases in speech errors and psychophysiological indicators. With respect to output biases, for example, several studies have shown that errors of sound exchanges tend to create words rather than non-words. This abundance of meaningful speech errors is attributed to the existence of an internal editor which is more likely to detect obvious errors, such as non-words. For psychophysiological evidence, Motley, Camden, & Baars (1982) found heightened galvanic skin response (GSR) when a speaker was producing two-word phrases which would create sexual taboo words if their initial consonants were exchanged (e.g., hit shed - shit head, tool kit - cool tit). In addition, errors tended to be "safe" or nontaboo, such as *hit head* or *cool kit,* rather than *shit shed, shit head, cool tit,* or *tool tit.* This increased GSR was interpreted as a response to the internal formulation and editing of the taboo word. Finally, Postma and Kolk (1992) demonstrated that speakers continued to correct themselves frequently even when auditory feedback was reduced through the use of white noise. Although auditory feedback was probably not completely eliminated, particularly with respect to bone conduction, they believe it reasonable to assume that persistence of self-repairing under noise was, to a large extent, a result of internal editing. These studies support the existence of a prearticulatory editing component in speech production, which is one of the central foundations of the covert repair hypothesis.

PWS vs. PWNS

In addition to potential differences in speech planning between PWS and PWNS, it is important to consider other potential differences between PWS and PWNS for purposes of both experimental design and interpretation of results. Andrews, Craig, Feyer, Hoddinott, Howie, and Neilson (1983) provide a review of differences between PWS and PWNS as part of their comprehensive review of stuttering literature. Differences were reported within the following categories: intelligence, speech and language development, central auditory functioning, and sensory-motor performance.

Four studies reviewed by Andrews et al. (1983) which compare CWS (mean age 10) with CWNS found CWS to score significantly (half a standard deviation) lower on intelligence tests, with this difference being evident in both verbal and nonverbal tests. Accordingly, CWS were shown to be approximately six months delayed educationally. Intelligence testing, however, is controversial and beyond the scope of this study. In addition, these studies compared children, whereas our study will be comparing adults. Admittedly, between group differences may exist, in the proposed study, relative to intelligence. However, it is likely that the use of adults perceived to be of comparable intelligence levels will make potential between group differences in intelligence negligible. In addition, the nature of the experimental task is believed to further reduce the potential role of intelligence.

Of seven studies reviewed by Andrews et al. (1983) which addressed speech and language development, six supported the finding that CWS are approximately six months delayed in achieving their speech milestones. Nippold (1990), however, points out potential problems with these results, such as small differences between PWS and PWNS, as well as lack of control for intelligence, family patterns, and gender as contributing factors. She cautions readers to question the validity of these studies on the basis of most data having been collected through the subjective method of parental interview.

Eight studies reviewed by Andrews et al. (1983) reported that CWS do not perform as well as CWNS on certain language tests, although effects of intelligence were not controlled. Again, Nippold (1990) challenges findings involving syntax and morphology, semantics, and word finding as being inconsistent. She does concede that some PWS may have greater difficulty in the areas of semantics and word finding.

However, rather than suggesting major deficits in these areas, she attributes differences in semantic abilities to the variability which exists among CWS and believes assessment of word finding skills to be complicated by stuttering behaviors of avoidance, circumlocution, hesitation, and blocking.

Seven studies reviewed by Andrews et al. (1983) showed CWS to possess three times greater risk of articulation disorders than CWNS. Louko, Edwards, and Conture (1990) reviewed the stuttering literature and found the percentage of CWS and also exhibit articulation problems to range from 16% to 67-96%, with most studies reporting between 20% and 40%, while the percentage of individuals in the general population with articulation or phonological disorders is 2-6%. Results of their study confirmed these figures. Upon comparing a group of CWS with a group of CWNS, 40% (12 of 30) of CWS exhibited disordered phonology, as opposed to 7% (2 of 30) of CWNS. Clearly, there is evidence supporting a relationship between stuttering and articulation or phonological disorders. However, relative to the proposed study, we believe that use of adults as subjects, rather than children, will eliminate potential problems associated with articulation, as well as the previously mentioned speech and language development.

Studies of central auditory function reviewed by Andrews et al. (1983) found PWS to have difficulties with stimulus recognition/recall in complex auditory tasks. Again, it is believed that the nature of the proposed experimental task, voice reaction to visual stimuli, will make potential between group differences in central auditory function negligible.

Finally, in studies of sensory-motor performance, several deficits were reported by Andrews et al. (1983) in PWS. In 17 studies measuring voice reaction time in response to auditory stimuli, 11 reported PWS to be slower. In seven examinations of voice reaction time to visual stimuli, five found PWS to be slower. Six studies reported PWS to be slower in manual reaction to auditory stimuli. However, Andrews and his associates attribute some of these negative findings to inadequate power resulting from small sample sizes. In addition, the authors performed three sets of studies measuring manual and voicing reaction to pure tones, as well as an auditory discrimination task, and onset/offset of voicing in response to a tone. In none of these three studies were the authors able to find a significant reaction time deficit in PWS. As stated previously, the task required in the proposed study is that of voice reaction time to visual stimuli. The literature is inconclusive with respect to potential reaction time differences between PWS and PWNS. Part of the motivation behind the proposed study is to examine this potential between-group difference.

In summary, a number of studies have attempted to illustrate differences between PWS and PWNS. Differences have been documented in the areas of speech and language development, central auditory functioning, sensory-motor performance, and general intelligence. Differences in phonological encoding, particularly with respect to internal activation of phonemes, are in the early stages of investigation and have yet to be thoroughly demonstrated. The proposed study will attempt to measure if differences in phonological encoding exist between PWS and PWNS.

Studies Related to the Covert Repair Hypothesis

Recent studies have begun to investigate the potential difference in speech planning between PWS and PWNS. Wijnen and Boers (1994) compared nine PWS to nine PWNS in a "phonological priming" experiment, utilizing a paradigm developed by Meyer (1990, 1991). Both groups were comprised of eight men and one woman ranging from 20 to 35 years of age. All PWS had been diagnosed by speech therapists and still considered themselves to be PWS. The PWS also reported that their stuttering had started between three and ten years of age. Each of the PWS had received treatment for at least one year and up to ten; some of the PWS were still receiving treatment. The PWS were instructed not to use fluency-enhancing techniques (e.g. reduction of speaking rate, easy-onset, prolongation) and, when asked following the experiment, they confirmed that the nature of the task prevented the use of fluency-enhancing measures. Finally, of the nine PWS, three each were classified as severe, moderate, and mild, based on a subjective rating of fluency during a short interview prior to the experiment.

For the experimental task, subjects were required to produce, as quickly as possible, one of five possible response words based on the visual presentation of a corresponding semantically-related cue word. Indirect phonological priming was attempted by specifying the response words under three conditions: heterogeneous, in which the five possible responses were phonemically unrelated, and two homogeneous cases, one in which the five response words shared the same initial consonant (C-prime: e.g. "cat"/"cup") and one in which the five response words shared both the same initial consonant and subsequent vowel (CV-prime: e.g. "cat"/"cap"). While the PWNS demonstrated shorter speech onset latencies with each increase in the size of the prime, most PWS did not show reduction in speech onset until the CV-prime was given. The authors interpreted these results as an indication that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p. 1) and argue that repetition or prolongation of initial syllables is the result of attempting to produce the syllable prior to specification of the vowel in the articulatory plan.

Whereas Postma and Kolk believe phonological encoding merely to be slower in PWS as compared to PWNS, Wijnen and Boers specify the syllable nucleus/vowel as a point of particular difficulty. A potential criticism of the Wijnen and Boers interpretation is that the nucleus should be examined independent of the onset prior to identifying it as the location of the impairment. A question that the proposed study will address is the effect of priming the rhyme (VC) of a one syllable word (CVC) without priming the initial consonant/onset (e.g."sun"/"gun") , in order to gain a greater understanding of the role played specifically by the nucleus. The rationale given by Wijnen and Boers for their experiment is if they could influence phonological encoding to reduce the specific problem, the behavior of PWS would approximate that of individuals who do not stutter, but if they interfered without affecting the specific problem no positive effect would be obtained. One could argue, however, that lack of effect with the C-prime may have been due to degree of impairment, rather than location, and it was simply a case of requiring a larger prime.

A more critical difference between the Wijnen and Boers study and the proposed study lies in the task. The proposed task provides a relatively direct measure of the effect of a phonologically-related prime on the encoding process. Unlike the task of Wijnen and Boers, in which subjects are required to repeatedly reactivate the phonological representations of responses, the proposed study measures the influence of a prime on the target in discrete trials based on a single activation. This difference between tasks also reduces the potential for strategic planning or guessing which exists in the Wijnen and Boers task due to the subjects learning all possible responses and the relationship between potential responses before being required to produce the responses.

Other studies have addressed differences between PWS and PWNS during speed of activation tasks. Bosshardt (1990) and Postma, Kolk, and Povel (1990), both found PWS to be slower than PWNS in silent reading tasks, suggesting that speech planning is slower in PWS. More recently, Bosshardt & Fransen (1996) addressed the question of which specific premotor process(es), phonological encoding, lexical access, and/or semantic coding, are responsible for the slower performance of PWS as compared to PWNS. Specifically, they conducted a study to compare speed of premotor processes in PWS versus PWNS during a silent reading task. An experimental group of 14 PWS was matched with 14 PWNS based on educational level and estimated daily reading time.

Subjects were presented with a visual cue word. Following reception of the cue word, subjects controlled the visual presentation of prose text on a word-by-word basis. Subjects read the prose text silently while monitoring for a target word which was identical to, rhymed with, or was categorically related to the cue word. The text was either normal prose, syntactically correct but semantically abnormal, or random in word order, so as to study the influence of syntax on monitoring time. The experimenters measured speed of phonological encoding as the difference between identical and rhyme monitoring and speed of semantic coding as the difference between identical and categorical monitoring. Only the difference between identical and category was found to be significant between groups. This confirmed the authors' expectation that PWS exhibit slower semantic coding. Results did not support the belief that PWS are slower in phonological encoding.

## Summary

The review of the literature indicates that there are potential differences between PWS and PWNS. These differences may include intelligence, speech and language development, central auditory functioning, and sensory-motor performance (Andrews et al., 1983); and speech planning/phonological encoding (Kolk & Postma, in press; Postma & Kolk, 1992, 1993; Wijnen & Boers, 1994). Several theories have been proposed which incorporate differences between PWS and PWNS in attempt to explain how stuttering occurs. Currently, no theory has been able to completely account for stuttering. A recent theory, the covert repair hypothesis of disfluencies, seeks to explain differences between PWS and PWNS by claiming that PWS are slower in their phonological encoding abilities (Postma & Kolk, 1993). Experimental procedures by Wijnen and Boers (1994), Bosshardt (1990), and Postma et al. (1990) support the covert repair hypothesis. The studies by Bosshardt (1990) and Postma et al. (1990), however, do not employ a speaking task. Wijnen and Boers (1994) attribute the difference between PWS and PWNS to the syllable nucleus without testing the nucleus independent of the onset. In addition, the relatively high error rate of 21% calls into question whether or not the task was being performed properly. The proposed study will attempt to add support to the covert repair hypothesis while eliminating some of the potential biases found in the Wijnen and Boers (1994) study. The research question proposed for this study is: "Is there a significant difference in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target?" Based on the current literature, the experimental hypothesis would support finding significant differences across conditions between PWS and PWNS. The null hypothesis is that no significant differences exist across conditions between PWS and PWNS.

# CHAPTER III

# METHOD

## Subjects

Six PWS ages 27 to 47 were recruited from both the Portland State University Speech and Hearing Clinic and a stuttering support group that meets on campus. All PWS were native speakers of English and diagnosed as a PWS by an ASHA certified speech-language pathologist (SLP). In addition, all PWS still considered themselves to be a PWS through self-report/interview. PWS were also asked to rate/report their severity of stuttering. It was deemed unnecessary to perform a formal evaluation of severity because PWS were not being selected on the basis of severity. Also, because the task itself was lengthy, time required of the subjects was kept to a minimum. Whether or not a subject has received or is receiving speech intervention and, if so, for how long, was considered irrelevant because the task required of the subjects, responding as quickly as possible, was assumed to prevent the use of fluency-enhancing techniques, such as reduction of speaking rate, easy-onset, or prolongation. Profiles of the six PWS follow in TABLE 1.

The control group consisted of 20 PWNS ages 18 to 37 recruited from a Portland State University undergraduate voice and diction class taught by this author. Data gathered from these control subjects had been used for a previous study on which this author served as research assistant. All PWNS were native speakers of English. All participants were free of apparent or reported mental, visual, and language deficiencies.

Table 1

PROFILES OF PWS

| Subject # | Age | Education | Gender | Severity | Treatment? |
|---|---|---|---|---|---|
| 1 | 27 | Grade 16 | Female | Mild | Not Currently |
| 2 | 47 | Grade 18 | Male | Mild | Not Currently |
| 3 | 29 | Grade 18 | Male | Mild-Mod. | Not Currently |
| 4 | 41 | Grade 18 | Male | Mild | Not Currently |
| 5 | 38 | Grade 18 | Male | Mild-Mod. | Not Currently |
| 6 | 40 | Grade 10 | Male | Moderate | Currently |

## Stimuli

The experimental stimuli consisted of 72 line drawings depicting common objects from Snodgrass and Vanderwart (1980) and several different picture books of line drawings. The pictures were digitized for computer presentation and enlarged to approximate size uniformity. The names of the pictured objects were all monosyllabic words of the form CVC. The 72 stimuli consisted of 18 pairs of words that share the same onset and nucleus, but have different codas (Onset-Related stimuli; e.g., "coat"/"comb") and 18 pairs of words that share the same nucleus and coda, but have different onsets (Rhyme-Related stimuli; e.g., "sun"/"gun").

## Design

The experimental design consisted of two within-subject factors: Prime Type (Related or Unrelated) and Prime Location (Onset-Related and Rhyme-Related). Stimuli consisted of 18 pairs of onset-related stimuli and 18 pairs of rhyme-related stimuli, for a total of 36 related prime-target pairs. Two stimulus sets were constructed in such a manner that the stimuli comprising the prime-target pairs were reversed across sets (e.g., set 1: "coat"-"comb", set 2: "comb"-"coat"). The unrelated prime-target pairs were constructed in the following manner. The 72 stimuli, which comprise 36 related pairs, were divided into 9 groups consisting of 2 pairs of onset-related and 2 pairs of rhyme-related stimuli. Within each of the 9 groups, in addition to appearing as both a related prime and target with the other member of the pair, each stimulus item appeared as an unrelated prime with each of the other six stimulus items from the group in one set and target in the other set. This yielded 24 unrelated pairs per group across the two stimulus sets, resulting in a total of 216 unrelated pairs from 9 groups in each of two stimulus sets, for a total of 432 unrelated pairs. Combined with the 72 related pairs, the result was 252 trials per stimulus set, or 504 total trials for the experiment.

Apparatus

Stimuli were presented on a Macintosh Classic located in the basement of Neuberger Hall. A custom software program written using PsyScope controlled the presentation and timing of the stimuli. Connected to the Macintosh Classic for collecting naming latencies to the targets were a Shure SM 57 microphone and a Carnegie-Mellon University button box containing a voice activated relay and a crystal oscillator that produced measurements to within +/- 1 ms. Sensitivity of the microphone was adjustable to compensate for voice intensity differences between subjects.

Procedure

Each subject was tested individually. The subject was seated approximately two feet in front of the computer monitor in a dimly lit room. Because it was critical that subjects correctly name the primes and targets, they were first shown each of the 72 pictures with the corresponding name written below the picture. Presentation of the pictures with names was arranged such that no two successive pictures/names were semantically or phonologically related. Also, the spacing between the related primes and targets was maximized to prevent subjects from observing the relationships. Subjects were asked to look at each picture and read the name aloud. The experimenter pushed the spacebar to control the onset of each picture-name display. The experimenter then presented the pictures in the same order without the names, in order to verify that the subject had learned the names of the pictures. Subjects would not have been allowed to proceed to the experimental portion until they demonstrated ability to name the pictures correctly, however, none of the subjects experienced difficulty learning the picture names.

When the subject had learned the names of the pictures, the experimenter presented some practice trials prior to the experimental trials. The practice trials utilized pictures that were different from the experimental trials in order to eliminate any potential bias which could arise from practicing trials which would later appear during the experimental portion. Subjects encountered the following series of events for each trial: A) fixation cross centered on the screen for 500 ms;

B) prime picture centered on the screen; C) onset of pronunciation to name the prime cleared the picture and began a 650 ms response-stimulus interval (RSI); D) target picture centered on the screen; E) onset of pronunciation to name the target cleared the picture and began a 750 ms inter-trial interval (ITI). Subjects were told to name each picture as quickly and as accurately as possible. When the subject was comfortable performing the practice trials, the 504 experimental trials were presented in 2 blocks of 252 trials. There were four breaks spread throughout each block of 252 trials to allow potential for brief rest periods of up to several seconds. Completion of the entire task, including learning and testing of the picture names, required approximately one hour and fifteen minutes.

Analysis

The dependent variable measured was response time, as measured by the timed difference between the onset of visual presentation of the target word picture and verbal initiation of the corresponding name. The independent variables manipulated were subject type (PWS vs. PWNS), prime type (related vs. unrelated), and prime location (onset vs. rhyme).

The dependent measure of response time was measured in milliseconds. Response times were tabulated by the hardware/software combination described previously and stored in a spreadsheet for future analysis. A three-way analysis of variance (subject type, prime type, and prime location) was performed to answer the research question, "Is there a difference in the speech onset latencies between PWS and PWNS across various levels of phonological priming?"

# CHAPTER IV

# RESULTS AND DISCUSSION

## RESULTS

The purpose of this study was to test the covert repair hypothesis of disfluencies, as it is applied to the difference between PWS and PWNS, by eliminating some of the potential biases found in previous studies. Specifically, the question addressed was: "Is there a significant difference in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target?" A recent study by Wijnen and Boers (1994) claims that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p. 1). If this is the case, results of this study should reflect differences between the two groups (PWS vs. PWNS) across the varied phonological priming contexts.

### Analysis

The following were eliminated prior to analysis: word naming errors, including disfluencies, and trials on which the voice-activated relay was tripped too soon, due to interjections prior to the prime/target, or too late/not at all, due to lack of vocal intensity. Word naming errors totaled 3% of trials for PWS and 2% for PWNS, while voice-activation failures occurred on 3% of trials for PWS and 1% for PWNS. The low error rates are an indication that the subjects were engaged and performing the task to the best of their abilities. In addition, any responses which produced a naming latency greater than 2.5 SDs from the overall mean for each subject were omitted prior to analysis to ensure that a small number of outlying responses would not skew the results in a false direction. These omissions totaled 2% of trials for PWS and 3% for PWNS. In all, a total of 8% of trials were eliminated for PWS and 6% for PWNS; thus, the analyses of naming latencies were based on 92% of responses from PWS and 94% from PWNS.

Mean naming latencies were computed based on overall differences between the two groups (PWS vs. PWNS), group differences relative to prime (related vs. unrelated), and group differences relative to location of prime (onset vs. rhyme). The mean naming latencies are shown in Table 2.

Table 2

MEAN NAMING LATENCIES (MSEC)

| | MEAN | STD. DEV. | STD. ERROR |
|---|---|---|---|
| GROUP | | | |
| PWNS | 676.237 | 73.838 | 5.837 |
| PWS | 684.400 | 118.765 | 17.142 |
| GROUP * PRIME | | | |
| PWNS, RELATED | 690.969 | 81.476 | 9.109 |
| PWS, RELATED | 699.304 | 140.124 | 28.603 |
| PWNS, UNRELATED | 661.505 | 62.412 | 6.978 |
| PWS, UNRELATED | 669.496 | 93.411 | 19.067 |
| GROUP * PRIME * LOCATION | | | |
| PWNS, RELATED, ONSET | 717.743 | 85.019 | 13.443 |
| PWS, RELATED, ONSET | 726.526 | 144.669 | 41.762 |
| PWNS, UNRELATED, ONSET | 674.367 | 61.463 | 9.718 |
| PWS, UNRELATED, ONSET | 675.939 | 93.726 | 27.056 |
| PWNS, RELATED, RHYME | 664.196 | 68.907 | 10.895 |
| PWS, RELATED, RHYME | 672.082 | 136.045 | 39.273 |
| PWNS, UNRELATED, RHYME | 648.643 | 61.427 | 9.712 |
| PWS, UNRELATED, RHYME | 663.054 | 96.795 | 27.942 |

Statistical analysis of these results was performed using a one between (subject type) and two within (prime type and location) mixed factor ANOVA. Results of this analysis are shown in Table 3.

Table 3

ANOVA SUMMARY

| Source | Sum of Squares/Mean Square | F-Value | P-Value |
|---|---|---|---|
| Group | 2460.447 | .050 | .8249 |
| Group * Prime | 1.085 | .001 | .9797 |
| Grp * Prime * Location | 435.432 | .793 | .3820 |

Although mean response latencies were slower for PWS than for PWNS under all conditions, the differences between groups were not statistically significant at the .05 alpha level. Overall differences in mean response latencies between the two groups produced a p-value of .8249. Between-group differences based on prime yielded a p-value of .9797. Finally, between-group differences based on prime and location produced a p-value of .3820.

Based upon the above analysis, the null hypothesis: "No significant difference exists in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target" could not be rejected. For this group of experimental subjects there was not a significant difference in speech onset latencies between PWS and PWNS across the varied phonological priming conditions.

# DISCUSSION

Data gathered from this study was used to determine if there was a significant difference in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target. Results indicated that there is not a significant difference in mean onset latencies between the two groups.

Two factors support the results of this study. First, the small number of errors committed by the subjects is an indication that the subjects were fully-engaged and performing the task to the best of their abilities. This allows for a high level of confidence that accurate data has been obtained. Conversely, Wijnen and Boers (1994) encountered error rates of 25% for PWS and 17% for PWNS, for an overall error rate of 21%.

The task itself is also a strength of this study. Unlike the Wijnen and Boers task, in which subjects repeatedly reactivate phonologically-related responses, the task from this study measures the influence of a prime on the target in discrete trials based on a single activation. This provides a more pure measure of the effect of a phonologically-related prime on the encoding/speech process. This task difference also reduces the potential for strategic planning or guessing which is highly likely in the Wijnen and Boers task due to the subjects learning all possible responses and the relationships between potential responses prior to producing the responses. It should be noted, however, that although the task is a relative strength of this study, it is possible that none of these studies, this present study included, are sufficiently isolating phonological encoding. Speech onset latency presumably encompasses more than phonological encoding.

Calculation of mean response latencies yielded large measures of standard deviation and standard error (see Table 1). In addition, it was noted that removal of one PWS, whose times were noticeably slower than the remainder of the group, would produce different between-group results: mean response latencies would appear *faster* for PWS than for PWNS. These are indications that the sample size of PWS must be increased to obtain more meaningful results. It is interesting to note, however, that the outlying PWS is the only member of the experimental group currently receiving treatment. It is known that part of this subject's treatment stresses reduction of speech rate. Although all subjects were instructed, and periodically reminded, to perform the task as quickly and as accurately as possible, this subject may have focused more on accuracy as a result of habits recently acquired in treatment.

# CHAPTER V

## SUMMARY AND IMPLICATIONS

### SUMMARY

The research question addressed in this study was: "Is there a significant difference in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target?" The results of this study can be applied to the covert repair hypothesis of disfluencies, as it relates to the difference between PWS and PWNS.

A recent study by Wijnen and Boers (1994) claims that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p. 1). If this is the case, results of this study should reflect differences between the two groups (PWS vs. PWNS) across the varied phonological priming contexts.

Six PWS age 27 to 47 were recruited from both the Portland State University Speech and Hearing Clinic and a stuttering support group that meets on campus. All PWS were native speakers of English and diagnosed as a PWS by an ASHA certified speech-language pathologist (SLP). In addition, all PWS still considered themselves to be a PWS through self-report/interview. Only one of the six PWS was currently receiving treatment.

The control group consisted of 20 PWNS age 18 to 37 recruited from Portland State University. All PWNS were native speakers of English.

All subjects performed a picture naming task designed to measure speech onset latencies across varied phonological priming contexts. Subjects were tested individually by being seated in front of a computer monitor and naming line drawings of common objects as they appeared on the screen. Subjects were asked to name the pictures as quickly and as accurately as possible. The task consisted of 504 experimental trials, presented in two blocks of 252 trials.

Following completion of the task, all naming errors, apparatus malfunctions, and extreme outliers were omitted prior to statistical analysis. Mean speech onset latencies of the PWS were then compared to data compiled from a group of 20 PWNS age 18 and older. Statistical analysis was performed using a one between and two within mixed factor ANOVA. Results showed no significant differences in speech onset latencies between the two groups across the varied phonological priming conditions. Thus, the null hypothesis: "No significant difference exists in speech onset latencies between PWS and PWNS across three conditions in which CV, VC, or no part of a one syllable (CVC) word is primed prior to naming of the target" could not be rejected.

## IMPLICATIONS

Central to the covert repair hypothesis of disfluencies is the belief that PWS are slower than PWNS in their phonological encoding abilities (Kolk & Postma, in press; Postma & Kolk, 1992, 1993). This belief is supported by Bosshardt (1990) and Postma et al (1990), as well as Wijnen and Boers (1994). Through experimental studies, Bosshardt (1990) and

Postma et al (1990) both found PWS to be slower than PWNS in silent reading tasks, suggesting that speech planning is slower in PWS. Wijnen and Boers (1994) found PWS to demonstrate longer speech onset latencies than PWNS relative to "phonological priming" and interpreted their results to indicate that in PWS "the encoding of noninitial parts of syllables, particularly the (stressed) vowel, is delayed" (p.1). One of the purposes of this study was to prime the vowel/rhyme (VC) of a one syllable (CVC) word, independent of the initial consonant, and compare the resulting speech onset latencies to those of other location-based primes (onset-CV) and unrelated primes in order to test the significance of the role played by the (stressed) vowel. The results of this study are in opposition to these prior studies. This study showed no significant differences between groups (PWS vs. PWNS) relative to the vowel/syllable rhyme. These differing results may be due to: the experimental task, the relative severity of the PWS, and/or the sample size.

If PWS are significantly slower than PWNS in their phonological encoding abilities, that difference should be apparent in a speech production task, such as the picture naming employed by this study. This is because phonological encoding is a component of speech production. Postma and Kolk believe that the increased disfluencies of PWS, compared to PWNS, are a result of phonological encoding errors committed by a slower phonological encoding system as it attempts to maintain the same rate as that of a faster phonological encoding system (PWNS). They point to the phenomenon of slower speech rate in PWS producing fewer disfluencies as support for this claim. Assuming a difference in speed of phonological encoding does exist between the two groups, one variable which should appear if the slower group approximates the speed of the faster group is speech production errors/disfluencies. If PWS are slower than PWNS in their phonological encoding abilities, PWS should produce more errors/disfluencies at a given speech rate. The results of this study reflect no significant difference in speech onset latencies between PWS and PWNS and an identical number of errors combined with outlying latencies (5%). Therefore, the results of this study do not support the belief that PWS are slower than PWNS in their phonological encoding abilities.

A potential clinical implication of these results relates to rate control therapy for PWS. One common component of stuttering therapy involves reduction of speech rate. Based on the results of the this study, one might conclude that PWS are not significantly slower than PWNS in speech planning and, therefore, do not need to reduce their speech rate. However, even if the two groups are comparable in speech planning, it may be that a difference exists in another area, such as motor skills, that would still make it beneficial for PWS to reduce their speaking rate. Also, as the heterogeneity of stuttering becomes more evident, one should exercise caution in applying any between group (PWS vs. PWNS) difference to an individual case of stuttering, which is a potential problem with interpreting these, or any other, research findings.

Although the results of this study do not support the covert repair hypothesis of disfluencies as it is applied to the difference between PWS and PWNS, two points should be noted. First, the small sample size of PWS in this study limits the power of the results. Although the differences produced between the two groups were not significant, there does appear to be a trend because PWS exhibited slower speech onset latencies across all conditions Second, the speed of phonological encoding may be related to severity of stuttering. The PWS in this study were mild to moderate in severity, whereas the nine subjects in the Wijnen and Boers study were divided equally between mild, moderate, and severe. Future studies should incorporate larger experimental groups and inclusion of PWS demonstrating greater severity of stuttering. These additions would increase the power and applicability of the results.

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# STIMULUS SET 1

| | | | | | | |
|---|---|---|---|---|---|---|
| cheek cheese | rope cheese | robe cheese | sun cheese | gun cheese | dish cheese | fish cheese |
| rope robe | cheek robe | cheese robe | sun robe | gun robe | dish robe | fish robe |
| sun gun | cheek gun | cheese gun | rope gun | robe gun | dish gun | fish gun |
| dish fish | cheek fish | cheese fish | rope fish | robe fish | sun fish | gun fish |
| | | | | | | |
| coat comb | leash comb | leaf comb | jar comb | bar comb | pan comb | van comb |
| leash leaf | coat leaf | comb leaf | jar leaf | bar leaf | pan leaf | van leaf |
| jar bar | coat bar | comb bar | leash bar | leaf bar | pan bar | van bar |
| pan van | coat van | comb van | leash van | leaf van | jar van | bar van |
| | | | | | | |
| sail safe | can safe | cap safe | wreath safe | teeth safe | mug safe | bug safe |
| can cap | sail cap | safe cap | wreath cap | teeth cap | mug cap | bug cap |
| wreath teeth | sail teeth | safe teeth | can teeth | cap teeth | mug teeth | bug teeth |
| mug bug | sail bug | safe bug | can bug | cap bug | wreath bug | teeth bug |
| | | | | | | |
| cage cane | bed cane | bell cane | tire cane | fire cane | pig cane | wig cane |
| bed bell | cage bell | cane bell | tire bell | fire bell | pig bell | wig bell |
| tire fire | cage fire | cane fire | bed fire | bell fire | pig fire | wig fire |
| pig wig | cage wig | cane wig | bed wig | bell wig | tire wig | fire wig |
| | | | | | | |
| dog doll | root doll | roof doll | whip doll | ship doll | bee doll | knee doll |
| root roof | dog roof | doll roof | whip roof | ship roof | bee roof | knee roof |
| whip ship | dog ship | doll ship | root ship | roof ship | bee ship | knee ship |
| bee knee | dog knee | doll knee | root knee | roof knee | whip knee | ship knee |
| | | | | | | |
| cork corn | bows corn | bowl corn | face corn | vase corn | mop corn | top corn |
| bows bowl | cork bowl | corn bowl | face bowl | vase bowl | mop bowl | top bowl |
| face vase | cork vase | corn vase | bows vase | bowl vase | mop vase | top vase |
| mop top | cork top | corn top | bows top | bowl top | face top | vase top |
| | | | | | | |
| rake rain | bat rain | bag rain | girl rain | pearl rain | dice rain | mice rain |
| bat bag | rake bag | rain bag | girl bag | pearl bag | dice bag | mice bag |
| girl pearl | rake pearl | rain pearl | bat pearl | bag pearl | dice pearl | mice pearl |
| dice mice | rake mice | rain mice | bat mice | bag mice | girl mice | pearl mice |
| | | | | | | |
| cake cave | sheet cave | sheep cave | chair cave | hair cave | bone cave | phone cave |
| sheet sheep | cake sheep | cave sheep | chair sheep | hair sheep | bone sheep | phone sheep |
| chair hair | cake hair | cave hair | sheet hair | sheep hair | bone hair | phone hair |
| bone phone | cake phone | cave phone | sheet phone | sheep phone | chair phone | hair phone |
| | | | | | | |
| shell shed | cup shed | cuff shed | ring shed | wing shed | hat shed | bat shed |
| cup cuff | shell cuff | shed cuff | ring cuff | wing cuff | hat cuff | bat cuff |
| ring wing | shell wing | shed wing | cup wing | cuff wing | hat wing | bat wing |
| hat bat | shell bat | shed bat | cup bat | cuff bat | ring bat | wing bat |

# STIMULUS SET 2

| | | | | | | |
|---|---|---|---|---|---|---|
| cheese cheek | robe cheek | rope cheek | gun cheek | sun cheek | fish cheek | dish cheek |
| robe rope | cheese rope | cheek rope | gun rope | sun rope | fish rope | dish rope |
| gun sun | cheese sun | cheek sun | robe sun | rope sun | fish sun | dish sun |
| fish dish | cheese dish | cheek dish | robe dish | rope dish | gun dish | sun dish |
| | | | | | | |
| comb coat | leaf coat | leash coat | bar coat | jar coat | van coat | pan coat |
| leaf leash | comb leash | coat leash | bar leash | jar leash | van leash | pan leash |
| bar jar | comb jar | coat jar | leaf jar | leash jar | van jar | pan jar |
| van pan | comb pan | coat pan | leaf pan | leash pan | bar pan | jar pan |
| | | | | | | |
| safe sail | cap sail | can sail | teeth sail | wreath sail | bug sail | mug sail |
| cap can | safe can | sail can | teeth can | wreath can | bug can | mug can |
| teeth wreath | safe wreath | sail wreath | cap wreath | can wreath | bug wreath | mug wreath |
| bug mug | safe mug | sail mug | cap mug | can mug | teeth mug | wreath mug |
| | | | | | | |
| cane cage | bell cage | bed cage | fire cage | tire cage | wig cage | pig cage |
| bell bed | cane bed | cage bed | fire bed | tire bed | wig bed | pig bed |
| fire tire | cane tire | cage tire | bell tire | bed tire | wig tire | pig tire |
| wig pig | cane pig | cage pig | bell pig | bed pig | fire pig | tire pig |
| | | | | | | |
| doll dog | roof dog | root dog | ship dog | whip dog | knee dog | bee dog |
| roof root | doll root | dog root | ship root | whip root | knee root | bee root |
| ship whip | doll whip | dog whip | roof whip | root whip | knee whip | bee whip |
| knee bee | doll bee | dog bee | roof bee | root bee | ship bee | whip bee |
| | | | | | | |
| corn cork | bowl cork | bows cork | vase cork | face cork | top cork | mop cork |
| bowl bows | corn bows | cork bows | vase bows | face bows | top bows | mop bows |
| vase face | corn face | cork face | bowl face | bows face | top face | mop face |
| top mop | corn mop | cork mop | bowl mop | bows mop | vase mop | face mop |
| | | | | | | |
| rain rake | bag rake | bat rake | pearl rake | girl rake | mice rake | dice rake |
| bag bat | rain bat | rake bat | pearl bat | girl bat | mice bat | dice bat |
| pearl girl | rain girl | rake girl | bag girl | bat girl | mice girl | dice girl |
| mice dice | rain dice | rake dice | bag dice | bat dice | pearl dice | girl dice |
| | | | | | | |
| cave cake | sheep cake | sheet cake | hair cake | chair cake | phone cake | bone cake |
| sheep sheet | cave sheet | cake sheet | hair sheet | chair sheet | phone sheet | bone sheet |
| hair chair | cave chair | cake chair | sheep chair | sheet chair | phone chair | bone chair |
| phone bone | cave bone | cake bone | sheep bone | sheet bone | hair bone | chair bone |
| | | | | | | |
| shed shell | cuff shell | cup shell | wing shell | ring shell | bat shell | hat shell |
| cuff cup | shed cup | shell cup | wing cup | ring cup | bat cup | hat cup |
| wing ring | shed ring | shell ring | cuff ring | cup ring | bat ring | hat ring |
| bat hat | shed hat | shell hat | cuff hat | cup hat | wing hat | ring hat |