

ONSET DENSITY AND INHIBITORY EFFECTS ON LEXICAL ACCESS IN SPEECH  
PRODUCTION

by

JESSICA ANANDA CASIRO

B. AppSc., University of Manitoba 2004

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Audiology and Speech Sciences)

THE UNIVERSITY OF BRITISH COLUMBIA  
(Vancouver)

June 2008

© Jessica Ananda Casiro 2008

## ABSTRACT

Lexical access in speech production involves multiple processing stages, beginning with the mental generation of a target concept and ending with a speaker's articulation of the target word. The current study aimed to explore the influence of competition and inhibition on the process of lexical access. In particular, the position of phonological overlap between a target word (e.g., lip) and its neighbors (e.g., lid vs. sip) was investigated for its influence on picture naming. It was hypothesized that greater inhibitory effects and slower response times in participants' naming would be observed for target words that have a predominance of neighbors which are onset related compared to those which are rhyme related. In addition, it was predicted that there would be a strong relationship between performance on the naming task and several inhibition tasks due to the common role of inhibition across tasks. Twenty-five native English participants completed a picture naming task, two language based inhibition tasks, and two non-language inhibition tasks. Participants' response times were recorded for incongruent/dense and congruent/sparse trials, and mean difference scores were examined to determine the inhibition effect sizes.

The results showed that response times for dense onset trials were significantly slower than sparse onset trials, thereby supporting the first hypothesis. Inter-task correlation results, however, did not provide support for the second hypothesis that inhibition capacity would be common to different tasks. Factors such as varying task characteristics, modality of stimulus presentation, length of testing session, task counterbalancing, perceived task difficulty, and allocation of cognitive effort are discussed as having contributed to the lack of significant correlations.

## TABLE OF CONTENTS

<b>ABSTRACT</b> .....	ii
<b>TABLE OF CONTENTS</b> .....	iii
<b>LIST OF TABLES</b> .....	v
<b>ACKNOWLEDGEMENTS</b> .....	vi
<b>CHAPTER 1: LITERATURE REVIEW</b> .....	1
1.1 INTRODUCTION .....	1
1.2 LITERATURE REVIEW .....	2
1.2.1 Theories of Lexical Access.....	2
1.2.1.1 Levelt’s Model.....	3
1.2.1.2 Dell et al.’s Model.....	3
1.2.1.3 The Neighborhood Activation Model: Lexical Access in Speech Perception.....	4
1.2.2 Lexical Access in Speech Production .....	6
1.2.3 The Role of Inhibition in Lexical Access .....	9
1.3 RESEARCH QUESTIONS AND HYPOTHESES.....	12
1.3.1 Research Questions.....	12
1.3.2 Hypotheses.....	13
<b>CHAPTER 2: METHODS</b> .....	15
2.1 OVERVIEW.....	15
2.2 PARTICIPANTS .....	15
2.2.1 Shipley Vocabulary Test.....	16
2.2.2 Vision Screening .....	16
2.2.3 Participant Consent Form and Demographics Form .....	16
2.3 MATERIALS AND PROCEDURES .....	17
2.3.1 Picture Naming Task .....	17
2.3.1.1 Picture Naming Task Stimuli.....	17
2.3.1.2 Picture Naming Task Procedure .....	18
2.3.1.2.1 Participant Instructions .....	18
2.3.1.2.2 Experimental Testing.....	18
2.3.2 FLAG Task .....	19
2.3.2.1 FLAG Task Stimuli.....	19
2.3.2.2 FLAG Task Procedure .....	20
2.3.2.2.1 Participant Instructions .....	20
2.3.2.2.2 Experimental Testing.....	21
2.3.3 Sommers Auditory Stroop Task.....	21
2.3.3.1 Sommers Auditory Stroop Task Stimuli.....	22
2.3.3.2 Sommers’ Auditory Stroop Task Procedure .....	22
2.3.3.2.1 Participant Instructions .....	22
2.3.3.2.2 Experimental Testing.....	23
2.3.4 Simon Task .....	23
2.3.4.1 Simon Task Stimuli.....	24
2.3.4.2 Simon Task Procedure .....	24
2.3.4.2.1 Participant Instructions .....	24
2.3.4.2.2 Experimental Testing .....	24
2.3.5 Stroop Task.....	25
2.3.5.1 Stroop Task Stimuli.....	25
2.3.5.2 Stroop Task Procedure.....	26
2.3.5.2.1 Participant Instructions .....	26
2.3.5.2.2 Experimental Testing.....	26

<b>CHAPTER 3: RESULTS</b> .....	27
3.1 OVERVIEW.....	27
3.2 PREPARATION OF THE REACTION TIME DATA FOR ANALYSIS.....	27
3.2.1 Response Errors (Accuracy) .....	27
3.2.2 Outliers (Reaction Time Data) .....	28
3.3 RESULTS .....	28
<b>CHAPTER 4: DISCUSSION</b> .....	32
4.1 INTRODUCTION .....	32
4.2 ONSET DENSITY.....	32
4.3 CORRELATIONS BETWEEN PICTURE NAMING AND INHIBITION TASKS.....	33
4.4 CORRELATIONS BETWEEN INHIBITION TASKS.....	35
4.5 LIMITATIONS AND IMPLICATIONS .....	42
4.6 CONCLUSIONS.....	44
<b>APPENDIX A: PARTICIPANT INFORMATION AND CONSENT FORM</b> .....	50
<b>APPENDIX B: DEMOGRAPHICS FORM</b> .....	53
<b>APPENDIX C: PICTURE NAMING STIMULI – IMAGES</b> .....	57
<b>APPENDIX D: STIMULUS CHARACTERISTICS - VITEVITCH, ARMBRUSTER AND CHU (2004)</b> .....	59
<b>APPENDIX E: FLAG TASK STIMULI – IMAGES</b> .....	60
<b>APPENDIX F: SIMON TASK STIMULI – IMAGES</b> .....	61
<b>APPENDIX G: DELL ET AL.'S APHASIA MODEL OF LEXICAL ACCESS (1999)</b> .....	62
<b>APPENDIX H: LEVELT ET AL.'S MODEL OF LEXICAL ACCESS (1999)</b> .....	63
<b>APPENDIX I: UBC RESEARCH ETHICS BOARD CERTIFICATES OF APPROVAL</b> .....	64

## LIST OF TABLES

Table 1: Participant Mean (SD) Reaction Times (ms) for Experimental Tasks.....	35
Table 2: Pearson correlation matrix of difference scores (incongruent – congruent) by task.....	36

## ACKNOWLEDGEMENTS

I would first like to thank Jeff Small whose unwavering support, patience and guidance has made the completion of this project possible. I would also like to extend my gratitude to my other committee members, Dr. Barbara Purves and Dr. Valter Ciocca for their thoughtful comments and suggestions. My thanks extend to Michael Vitevich and Kristina Campbell for providing me with the Picture Naming task and the Simon task stimuli, respectively. Special thanks go to my parents who have lovingly prepared me for this process since birth.

## CHAPTER 1: Literature Review

### 1.1 Introduction

Lexical access in speech production involves multiple processing stages, beginning with the mental generation of a target concept and ending with a speaker's articulation of the target word. Lexical selection, an initial stage of lexical access, focuses on activating the meanings of words (semantics) and the abstract word representation (or lemma) in the mental lexicon. The lemma constitutes the grammatical properties of the target word, including its syntactic category and features such as gender or number. Activation at the lemma level of representation cascades to activation at the next level of lexical processing—phonological representations—often described as the process of encoding or retrieving a word's phonological, morphemic and syllabic information. Processing at these three stages of lexical access (semantics, lemma, phonology) is sensitive to competition among lexical items. The source of this competition relates to the arbitrary relationship between speech sounds and word meanings which results in a one-to-many mapping between word forms and word meaning (de Saussure, 1912). Namely, a finite set of phonemes exists to represent an infinite number of words in a language, leading to individual phonemes being used in many different words (one-to-many mapping) (Dell, Burger & Svec, 1997). This creates a significant source of competition in the processing system because a speaker must inhibit the activation of non-target words whose phonemes overlap with the target word. As a result, lexical access is constrained by the number of words phonologically related to a particular target word. For example, *sip* is a word that shares much of its phonology with many words in the lexicon (e.g., *lip*, *tip*, *rip*, *hip*, *ship*, *sin*, *sit*, etc.) and is thus considered to be part of a “dense word neighborhood.” In contrast, a word like ‘*curb*’ has fewer lexical-phonological neighbors (e.g., *curd*, *curse*, *curve*) and is considered to be from a “sparse word

neighborhood.” Research has recently begun to address whether accessing words from denser neighborhoods creates greater competition and requires more processing effort than does retrieving words from sparser neighborhoods. The current study proposes to examine the relationship between neighborhood characteristics and inhibition in the course of word production. Furthermore, the nature of inhibition in lexical production will be explored to determine whether it is a capacity that is specific to language or proves to be a more general capacity that serves across cognitive domains. The following sections provide background on the theoretical basis of lexical access in speech production and describe previous research in this area.

## 1.2 Literature Review

### 1.2.1 Theories of Lexical Access

Various theoretical approaches have been proposed to account for the processes involved in lexical access during speech production. Two dominant models of lexical access are that of Dell (1992; et al., 1997) (see Appendix G) and Levelt (1989; Levelt, Roelof & Meyer, 1999) (see Appendix H). These models are similar in that both propose that lexical access can be divided into two major stages or subprocesses. The first stage of lexical access is “lemma selection” in which a concept (or its semantic features) is mapped onto a non-phonological representation of a word (a lemma). The second stage of lexical access is phonological encoding. At this stage, the lemma is mapped to a sequence of speech sounds representing the phonological form of the word. Although both Dell et al. and Levelt distinguish between lemma and phonological stages of encoding, their models differ regarding the nature of information flow between these stages (Dell, Chang, & Griffin 1999).

### 1.2.1.1 Levelt's Model

In Levelt's model, the two stages of processing are modular and non-interactive. Lemma selection is completed independently of and prior to the activation of any phonological encoding. For example, if the word *cake* were being accessed, the semantic and grammatical properties of the word would be processed completely (or above threshold) prior to the activation of the word's speech sounds. Furthermore, while the sequence of speech sounds corresponding to the target word (i.e., /k/ /ey/ /k/) are being accessed, semantic information is not consulted.

### 1.2.1.2 Dell et al.'s Model

Dell et al.'s model, on the other hand, is non-modular and involves bidirectional feedforward/back (i.e., interactive) activation between the lemma and phonological levels of representation. Dell et al. explain that lexical access involves the activation of semantic units followed by the spread of activation interactively throughout the network. Bidirectional excitatory connections result in the activation of words/lemmas that share semantics, phonemes, or both. For example, taking the word *cake*, activation of its semantic information activates all lemmas that share its semantic features (e.g., *cookie*, *icing*) through bidirectional connections between lemma and semantic levels. Overlapping in time with this activation of semantic-lemma representations is the activation of the phonological level of representation of *cake* and, through bidirectional connections, other words that share its phonology (e.g., *rake*, *cane*). Through interactive activation, Dell et al.'s model accounts for lexical selection errors such as *cookie* (semantically related), *cane* (phonologically related), or *bake* (semantic and phonologically related). According to Dell et al., a target word's competitors can be erroneously

selected when they receive greater activation than the target word due to activation noise or network “competition” across levels of processing.

Although both Dell and Levelt’s models have garnered substantial empirical support (Levelt et al. 1999; Dell et al. 1997), the principle of bidirectional connections allows Dell’s model to better account for the effects of competition during lexical access by individuals with and without language disorders. For example, competition often leads to mixed (semantically and phonologically related) errors by normal and aphasic speakers, and these errors have been simulated in Dell’s model through the network’s bidirectional processing dynamics (rather than as an ad hoc monitoring system as proposed by Levelt and colleagues, (e.g., Levelt 1999). For example, when the meaning of “cake” is activated, semantically and phonologically related words (i.e., bake) may be activated due to the bidirectional connections between these levels.

The present study will draw primarily upon Dell’s theoretical approach because it provides a more comprehensive explanation for the interaction between levels which occurs in the process of lexical access in production. In addition, since much of the research on the role of competition and inhibition during lexical access has been in the realm of comprehension, a complementary model of lexical access in this domain (comprehension) is reviewed in the next section.

#### 1.2.1.3 The Neighborhood Activation Model: Lexical Access in Speech Perception

The Neighborhood Activation Model (NAM) (Luce and Pisoni, 1998) is a theoretical account which attempts to explain the structural organization of perceptual information as it relates to auditory word recognition. This model states that words are recognized in the context of other words in long-term memory. Similar to the previous two models reviewed, the NAM states that word identification relies on discriminating among the lexical items which are

activated in response to a stimulus input. The amount of activation a word in the mental lexicon receives initially is proportional to its similarity to the stimulus input and the number and frequency of neighboring words related to it. The activation levels of words are then adjusted by taking into account higher-level information, such as the frequency or recency of each word in the listener's experience. According to the NAM, a "similarity neighborhood" is described as the words which can be created from a target item by adding, deleting, or substituting a single phoneme. For example, the similarity neighborhood of the word "sat" includes words such as "sad", "sit", "sack", and "hat".

The NAM accounts for the effect that neighborhood similarity (or density) has on the discrimination between lexical-phonological representations in lexical access. Experiments conducted by Luce and Pisoni (1998) demonstrated that neighborhood density affects the speed and accuracy of word recognition. Namely, words from high density neighborhoods were recognized by listeners more slowly than words from low density neighborhoods. These findings demonstrate that the number of words phonologically related to the target word affects how much energy is expended to suppress the competing word candidates and, consequently, how quickly the target can be selected during spoken word recognition. Replicating Luce and Pisoni's findings (1998), other studies have shown that words from dense (compared to sparse) neighborhoods have slower recognition response times, and these findings have been attributed to greater competition and need for inhibition caused by the activation of phonologically similar lexical items (Sommers, 1996; Sommers & Danielson, 1999). However, relatively few studies have investigated the effects of inhibition on lexical access in word production.

### 1.2.2 Lexical Access in Speech Production

While research on lexical comprehension has found that words with a greater number of neighbors are more difficult to access, resulting in slower recognition response times, much of the research on lexical access in speech production suggests a contrasting effect. For example, a picture naming study by Vitevitch (2002a) found that pictures of words with high neighborhood densities were named faster than words with low neighborhood densities.

This facilitatory effect was further explored by Vitevitch, Armbruster and Chu (2004), who argued that the appearance of facilitation versus inhibition effects may be related to the position of phonological overlap across words in a lexical neighborhood. Previously, onset density (the number of neighbors sharing the onset of the target word) had been examined in word recognition but not in production (other than in priming studies). The results of word recognition research showed that words with sparse onsets (words with fewer neighbors that share the same onset phonology) were recognized faster than words with dense onsets (words with a high proportion of neighbors that share the same onset phonology) (Vitevitch 2002b). Vitevitch et al. (2004) investigated whether onset density would affect naming response times in a picture naming task. In their study, a word with a dense onset shared the same onset with many ( $M = 74.4\%$ ) of its word neighbors while a word with a sparse onset shared the same onset with fewer ( $M = 43.3\%$ ) of its word neighbors. Participants were asked to name pictures in a timed response task. The stimuli consisted of line drawings of words/concepts divided into sparse onset and dense onset conditions. In manipulating onset density, the authors controlled for various lexical, phonological and visual factors including word frequency, neighborhood

frequency, familiarity, overall neighborhood density, phonotactic probability, animacy, initial phoneme, syntactic class, and picture complexity.

They found that the subjects named pictures of words with sparse onsets more quickly than those with dense onsets. Vitevitch et al. explained these results using the example words *mass* and *sad*. First consider the word *mass*, which has high onset density; according to an interactive activation model of speech production, activation from the semantic features to the lemma and to the phonemes /m/ /ae/ /s/ is followed by reciprocal activation back to words (lemma level) which connect to the same phonological segments (e.g., *miss*, *mad*, *man*, *pass*). Due to the high onset density of this word, the phoneme /m/ will obtain support from its neighbors with similar onsets and become quickly activated. However, inhibition is then required to suppress the many other dissimilar phonological segments belonging to the target word's neighbors which have become activated through feedback from the phonological level. Vitevitch et al. explain that it is this competition between the neighbors' activated segments and the target word's segments (i.e., /ae/ and /s/), which causes slower response times for words with dense onsets. In contrast, words such as *sad*, which have sparse onsets, are named faster. This is because the neighboring words which become activated such as *bad*, *fad* and *lad* will reinforce the activation of the phonological segments /ae/ /d/ rather than competing for the activation of segments which are dissimilar to that of the target. The strong activation of the onset /s/, which is the initially activated and most salient component of the word, effectively inhibits competing words which share only rhyme segments (while permitting residual feedback to reinforce the target word's rhyme). Although Vitevitch et al. do not provide evidence for the salience of the onset from a processing standpoint, one could argue that in addition to being initially activated, onsets receive continuing activation throughout the process of retrieving the target word.

One earlier study by Sullivan and Riffel (1999) reported findings consistent with Vitevitch et al. (2004). Sullivan and Riffel (1999) utilized a priming design to examine lexical access and density effects in production. Their study included the within-subject factors of location of phonological overlap between prime and target word (onset vs rhyme) and prime type (related or unrelated). Their stimuli consisted of line drawings of monosyllabic words which were divided into pairs of onset-related and rhyme-related stimuli. A set of unrelated pairs was created by mixing the existing targets and primes. In this study, the participants were asked to name one picture (the prime, e.g., *bell*) followed by another picture (the target) which was onset-related (e.g., *bed*), rhyme-related (e.g., *shell*), or unrelated (e.g., *mouse*) to the previous picture. The results of this experiment showed that a) naming times were slower for related pairs than unrelated pairs, and b) naming times for onset-related pairs were slower than for rhyme-related pairs. Thus, the density effects in this study are congruent with the findings of Vitevitch et al. (2004) and showed similar findings to those of comprehension studies; namely, phonological similarity between words can inhibit rather than facilitate lexical access in lexical production.

According to Sullivan and Riffel, the results showing a large inhibition effect for onset related targets and a smaller inhibition effect for rhyme related targets are consistent with a two-stage interactive activation model proposed by Dell (1988), which states that an initial parallel activation of phonemes is followed by sequential selection within the word shape. They explain that initial parallel activation is spread to all words which contain onset or rhyme phonemes related to the target. For onset-related targets, Sullivan and Riffel suggest that competition occurs at both the parallel activation and sequential phoneme selection stages of processing. For rhyme-related targets, on the other hand, inhibitory effects are present but weaker than onset-

related effects due to competition occurring primarily during the first stage of parallel activation followed by less competition during sequential phoneme selection. The Sullivan and Riffel (1999) and Vitevitch et al. (2004) studies therefore converge both in findings and interpretation.

### 1.2.3 The Role of Inhibition in Lexical Access

The results from studies of lexical comprehension (Vitevitch, 2002a; 2002b) and production (Sullivan & Riffel, 1999; Vitevitch et al., 2004) appear to converge with regard to the presence of competition and the accompanying inhibitory effects associated with words having dense onsets. However, given the limited research in this area, Vitevitch's findings need to be replicated. In addition, there has to date been little exploration of the nature of the inhibitory processes utilized in lexical access. Specifically, it is not clear whether inhibitory processing is specific to lexical access, or whether it is part of a more general selective attention capacity. Theories of selective attention have acknowledged the role of inhibition in the allocation of resources necessary for selective processing (Hasher & Zacks, 1988; Tipper, 1985). They suggest that inhibition is required to suppress irrelevant information in order to sustain focus during higher level cognitive tasks involving, for example, working memory or language performance. While theories of attention had previously proposed that unselected information passively decays in the process of selecting a target (Broadbent, 1970), more recently emphasis has been placed on the notion that active suppression (inhibition) of distracting information is occurring during the selection process (Tipper, 1985; Weiner, Connor & Obler, 2004). Two studies have investigated this concept of active suppression (inhibition) with regard to lexical access in word comprehension tasks (Sommers & Danielson, 1999; Weiner et al., 2004).

Sommers et al. (1999) examined the role of inhibition in the process of word recognition by younger and older adults. Sommers et al. had previously hypothesized that older adults may

have greater difficulty identifying lexically hard words (words with dense neighborhoods) due to age-related declines in inhibitory control (1996, 1998). Sommers et al. (1999) presented younger and older listeners with single words, and words in high predictability and low predictability sentences, all within a background of speech shaped noise. Participants were required to write down the word that they heard (or the last word in the case of the sentence stimuli). Their results showed that the older adults were significantly poorer than the younger subjects at identifying words with dense neighborhoods (lexically hard words). As a follow up experiment, Sommers et al. (1999) examined the relationship between individual differences in inhibitory control and word recognition ability. They hypothesized that the individuals who showed the greatest difficulty recognizing lexically hard words in experiment one would also obtain the poorest inhibition scores in experiment two. Inhibitory control was measured using a Speeded Classification task and an Auditory Stroop task. The first task involved an auditory presentation of words beginning with /p/ and /b/ in both male and female voices. In one condition, the subject was required to classify words by voice (ignoring phoneme) and in the other condition the subject responded based on the word's initial phoneme (ignoring voice). The second measure of inhibition was an auditory version of the original Stroop color naming paradigm. In this Auditory Stroop task, the participants had to decide as quickly as possible whether the words 'father', 'mother' and 'person' were spoken by a man or a woman. The three conditions included a) congruent – 'father' spoken by a man, 'mother' spoken by a woman; b) neutral – 'person' spoken by either a man or woman; and c) incongruent – 'mother' spoken by a man or 'father' spoken by a woman. The results showed slower response latencies and greater interference for older than younger adults on both inhibition tasks. The scores for both inhibition tasks were then combined and a single z score was computed to create a standard measure of

inhibition for each participant. These scores showed that the older adults exhibited a poorer ability to suppress irrelevant semantic, phonetic and voice information and, therefore, reduced inhibitory ability. Hierarchical multiple regressions were then conducted, and the results showed that independent of age and other demographic factors, inhibitory ability made a significant contribution to word identification scores, particularly for lexically hard words.

In a similar study, Weiner et al. (2004) addressed the relationship between inhibition and auditory comprehension in Wernicke's aphasia. A numerical version of the Stroop test was administered to five subjects with Wernicke's aphasia and twelve non-brain injured controls who were matched for age and education. An analysis of reaction times for the stroop task and performance on two auditory comprehension tasks (Token test and Complex Ideational Material Subtest of the Boston Diagnostic Aphasia Examination) showed that the interference effect in the Stroop task was greater for the subjects with aphasia than for the controls. Furthermore, Stroop interference was positively correlated with severity of auditory comprehension deficit measured by the token test. The authors suggested that these results reflected an inhibition impairment at a lexical-semantic level stemming from an inability to suppress distracting stimuli in the token task.

The findings from both Sommers et al. (1999) and Weiner et al. (2004) suggest that inhibition capacity plays a role in lexical access in comprehension. In these studies, however, the type of inhibition tasks employed do not allow one to delineate between inhibition processes in language vs. other cognitive domains. In addition, the relationship between inhibition capacity and lexical access was only examined in comprehension, not production.

In summary, a number of studies have explored the role of competition in both lexical production and comprehension. While initial findings varied across modalities, recent research

has indicated that inhibition may, in fact, be similarly involved in word comprehension and production. Namely, research on comprehension revealed an inhibitory effect when recognizing words with dense onsets (Vitevitch, 2002b), and recent research on production has provided analogous results, showing an inhibitory effect when naming pictures of words with dense onsets (Vitevitch et al., 2004). One goal of the present study is to replicate the findings of Vitevitch et al. (2004) in regard to onset density effects in production. The second objective is to explore the relationship between neighborhood competition in lexical production and inhibitory processing. Finally, previous research has measured inhibition using tasks that confound the domain of inhibition being assessed (language and/or non-language). This study, therefore, explores the nature of inhibition using both language-specific and non-language inhibition tasks to examine whether the inhibition in word production is a capacity that is specific to language or serves more general cognitive operations.

### 1.3 Research Questions and Hypotheses

In this section, the research questions for this study will be presented followed by the research hypotheses and the rationale and theory supporting each hypothesis.

#### 1.3.1 Research Questions

1. Does onset density influence picture-word naming performance?
2. What is the role of inhibition in lexical production?
  - a) Do individual differences in picture naming response times correlate with individual differences in inhibition task performance?
  - b) Does the predicted correlation depend on the type of inhibition task (linguistic vs. non-linguistic)?

### 1.3.2 Hypotheses

1. Using the same methods and stimuli as Vitevitch et al. (2004), I expect to replicate their findings, namely, that greater inhibitory effects and slower response times will be observed for target words with neighbors which are onset related than those which are rhyme related. During phonological encoding in lexical access, the target word's onset will receive activation along with all other neighbors which share the same onset. Subsequently, competition will occur between the phonemes of the activated onset related words. In the case of rhyme related words, the onset of the target word will receive greater activation due to fewer competitors which share the same onset as the target. Once the onset of the target word is more activated than other words in the neighborhood, words which share the same rhyme will primarily provide facilitatory support for the access of this word. Due to the processing dynamics across onset and rhyme conditions, more inhibition will be required to suppress target word neighbors which share onsets than rhymes with the target word, leading to slower picture-naming response times in the shared onset condition.

2a. I predict that there will be a significant positive correlation between participants' picture naming response times and their performance on inhibition tasks. This hypothesis is based on findings from previous studies of lexical comprehension which have reported similar correlations (Sommers et al., 1999; Weiner et al., 2004). Given the similarities in findings of inhibition in both lexical comprehension and production, I expect to see a strong relationship between inhibition task scores and performance on a lexical production task. If the results support this hypothesis, it will provide new evidence for the role of inhibition in lexical access in production.

2b. I hypothesize that participants' performance on both language and non-language inhibition tasks will be significantly correlated. Therefore, the correlation between inhibition tasks and picture naming is not expected to differ by type of inhibition task. Previous research by Weiner et al. (2004) and Sommers et al. (1999) utilized inhibition tasks that relied on the use of language (numbers in Weiner et al., and more semantically dense in Sommers et al.). It is not clear whether a non-language inhibition task would tap into or support the same processes involved in lexical access. Evidence from other literature (e.g., Ullman, 2004) suggests that general processing dimensions (e.g., declarative vs. procedural) are relevant across cognitive domains (i.e., memory, language). Thus, in the present study, it is also hypothesized that the inhibition capacity that is utilized in both language and non-language inhibition tasks is common to that which is necessary for retrieving words in picture naming.

## CHAPTER 2: Methods

### 2.1 Overview

This chapter describes the experimental tasks, participants, materials and procedures used in this study. Following a description of the participants and screening tests (Shipley Vocabulary Test, Vision Test), the experimental tasks (Picture Naming, FLAG, Sommers Auditory Stroop, Simon, and Stroop) will be described in detail.

### 2.2 Participants

Twenty-five participants consisting of 2 men and 23 women between the ages of 20 and 45 were recruited for this study ( $M = 25$  years,  $SD = 2.3$ ). The majority of the participants ( $n = 19$ ) were Masters students in either speech-language pathology or audiology at the University of British Columbia. None were paid for their participation in the study. All were recruited by postings around the university, a recruitment flyer sent via e-mail, or personal contacts.

Participants who were native speakers of English with minimal exposure to other languages were sought for this experiment. Participants who were exposed to other languages but were not considered to be fluent bilinguals were eligible. In this study, the term bilingual refers to a participant who speaks English and a second language equally in terms of fluency and the amount of time spoken on a daily basis. After reviewing the information in the demographics form (as described in section 2.2.3), it was not necessary to exclude any participants from the study because none were considered to be fluent bilinguals. All participants reported to have normal hearing, and they were allowed to adjust the volume of the sound output in the experiments to a comfortable listening level.

### 2.2.1 Shipley Vocabulary Test

One of the five experimental tasks described below involved picture naming; therefore, a test was administered to measure of each participant's general vocabulary level. The Shipley Vocabulary Test (1940) includes 40 target words and involves participants choosing the synonym of a target word out of four possible options. This test was administered between tasks 2 and 3 during the experimental session.

### 2.2.2 Vision Screening

To ensure that participants had normal or corrected to normal vision in order to see the stimuli on the computer screen during visual experimental tasks, a vision screening was conducted using a standard eye chart. A piece of tape was placed on the floor 10 feet away from the wall on which the chart was located. The participants were asked to read the smallest row of letters they could see. If errors were made, participants were asked to read the row of letters which was one level easier than the row they had attempted until all letters were read correctly. This screening was done between tasks 4 and 5 during the experimental session. Since all vision scores were within normal limits (at least 20/20), no participants were excluded from the study based upon inadequate vision.

### 2.2.3 Participant Consent Form and Demographics Form

Ethics approval for conducting this study was received from the Behavioral Research Ethics Board at UBC (See Appendix I). At the beginning of the experimental session the participant was given a consent form (see Appendix A) to read and sign as well as a demographics form (see Appendix B) to fill out. The demographic information included the participants' age, gender and education as well as specific language-based information such as

their native language and fluency in additional languages. Answers to the questions on the demographics form were used to determine inclusion/exclusion based on participants' language background (as described above). Data from the form were also used in analyses to examine possible relationships between these participant characteristics and experimental results.

### 2.3 Materials and Procedures

This section outlines the stimuli, procedures and experimental conditions for each of the five tasks in the following order: 1) Picture Naming, 2) FLAG, 3) Sommers Auditory Stroop, 4) Simon, and 5) Stroop. Task presentation was counterbalanced in order to avoid an experiment order bias. All tasks were developed using E-Prime Version 1.0 software (Psychology Software Tools, 2002) and were administered in a quiet room in the Adult Language Processing Lab in the School of Audiology and Speech Sciences. The participants' response times were recorded by the computer and corresponded to the onset of their response.

#### 2.3.1 Picture Naming Task

This task is a replication of Vitevitch et al.'s (2004) picture naming experiment, which examines the effect of onset density (i.e., sparse vs. dense onsets) on picture naming response times. Participants are required to name twenty-six pictures, half of which have sparse onsets and half dense onsets.

##### 2.3.1.1 Picture Naming Task Stimuli

The twenty-six images used in this task were received unedited from Michael Vitevitch (See Appendix C) These drawings consisted of both Snodgrass and Vanderwart's (1980) pictures as well as some which were similar to these artistically. Each of the images included one picture depicting a monosyllable word. The 26 stimuli were divided into two conditions

each containing 13 pictures. One condition contained words with high onset densities (dense), and the other had words with low onset densities (sparse). While onset density was manipulated, the stimuli were controlled for familiarity, word frequency, neighborhood frequency, neighborhood density, phonotactic probability, perceptual, syntactic and conceptual characteristics, animacy (natural or artifact) and initial phoneme. The images were changed into bitmap files to be compatible with the E-Prime program and were adapted to fit the computer screen.

### 2.3.1.2 Picture Naming Task Procedure

#### 2.3.1.2.1 Participant Instructions

Before beginning the task, participants were given a binder with each of the 26 images printed out on a separate sheet of paper. Below each image was the written form of the target word. Participants were asked to read each of the pictures aloud once and then go through the pictures at their own pace as many times as necessary in order to associate the target word with the target picture. Participants were told that they would be naming the pictures without the written form below and must be confident that they would be able to use the target name before beginning the experiment. Participants were informed that the microphone they would be speaking into was sensitive to noise and were encouraged to speak loudly but avoid making any sounds other than their word response. Written instructions on the computer screen directed the participants to name the images as quickly and accurately as possible.

#### 2.3.1.2.2 Experimental Testing

Participants were seated facing a 17" monitor and wore an Optimus headset microphone connected to an E-Prime Serial Response Box (SRBox) that was interfaced with the computer.

As in all experimental tasks in this study, instructions appeared on the computer screen and the participant was asked to read them. When participants indicated that they were ready to continue, the experimenter pressed a button which triggered the presentation of the first stimulus. The onset of the participant's verbal response triggered the appearance of a fixation point (“+” sign) with an inter-stimulus duration of 2000 ms, followed by the next target image. The experimenter recorded the subject's accuracy by pressing 1, 2, or 3 on the keyboard: 1 for correct response, 2 for incorrect response, and 3 for machine errors. All 26 stimuli were presented to each participant and appeared in random order.

### 2.3.2 FLAG Task

This task, designed by the experimenter, used visual and auditory stimuli to measure the inhibition of non-language visual information. The participant is presented with a visual picture (male or female sign) on the computer monitor while being simultaneously presented with an auditory stimulus (male or female opera voice). Participants must then indicate whether they heard a male or female voice while inhibiting the gender related information presented on the monitor.

#### 2.3.2.1 FLAG Task Stimuli

Audio as well as visual stimuli were used in this task. The audio files were comprised of the voices of four opera singers downloaded from the Limewire (2008) and edited by means of Cool Edit 2000 (Syntrillium Software Corporation 2000) and saved in a WAV-file format. Two male and two female voices were used to emulate the number of voices used in Sommers Auditory Stroop Task (Sommers et al.,1999). Each of the 4 sound files consisted of one voice singing a single vowel sound for approximately 1000 milliseconds. The 4 recordings did not

include any words or consonant sounds, and each of the notes was sung at a different frequency across singers. Cool Edit 2000 was used to fade the onset and offset of the sound files in order to ease the transition from silence to singing for the listener. The amplification function in Cool Edit 2000 was used to attain a perceptibly comparable amplitude for the sound files. The visual images used in this task included one female stick figure and one male stick figure image (see Appendix E). Both visual stimuli were found in a Google internet search for male and female images. The files were then changed into a bitmap-file format in order to be compatible with E-prime. A total of 10 practice trials and 48 experimental trials were created for this task. Two congruency conditions occurred: 1) Congruent – female image and female voice, male image and male voice, and 2) Incongruent – male image and female voice, female image and male voice. There were six trials of each condition (male1-congruent, male2-congruent, female1-congruent, female2-congruent, male1-incongruent, male2-incongruent, female1-incongruent, female2- incongruent).

### 2.3.2.2 FLAG Task Procedure

#### 2.3.2.2.1 Participant Instructions

Participants were asked to focus on both the auditory signal (opera voice) which would be presented through the headphones and the visual stimulus (male/female sign) which would be presented on the computer screen. This was done to avoid having the participant ignore the visual stimuli and focus only on the auditory stimuli. The instructions on the computer directed the subjects to press the SRBox's (as quickly and accurately as possible) number "1" when they heard a male voice, and number "5" when they heard a female voice.

#### 2.3.2.2.2 Experimental Testing

In this task, participants were seated in front of the computer, and both the participant as well as the experimenter wore a pair of JVC HA-G33 headphones, which were plugged into the audio output of the computer. This allowed the experimenter to track the course of the experiment. An SRBox was placed in a comfortable position in front of the participant. A white circle with the number “1” written on it in black ink was attached directly under the leftmost button on the SRBox and a similar circle with the number “5” on it was attached under the rightmost button on the SRBox. After the instructions, a fixation point (“+” sign) appeared for 2000 ms on the centre of the screen followed by the practice trials in a fixed order. Further instructions then appeared on the screen instructing participants to indicate whether they were ready to continue. When ready, the experimental trials were presented in random order. Each of the practice trials and experimental trials consisted of a simultaneous presentation of a visual image and an auditory sound file and were always separated from the adjacent stimuli by an interstimulus duration of 2000 ms.

#### 2.3.3 Sommers Auditory Stroop Task

This task, replicating that of Sommers et al. (1999), was used to measure the inhibition of language based auditory information. In this task, participants are presented with auditory stimuli consisting of a male or female voice saying a male-related (*father*), female-related (*mother*) or neutral (*person*) word. Participants must indicate whether they hear the voice of a male or female while inhibiting the gender related information contained in the actual word which is spoken.

### 2.3.3.1 Sommers Auditory Stroop Task Stimuli

There were 12 sound files used in this task, consisting of 3 single words (mother, father, person) each recorded by 4 different speakers (2 male voices, 2 female voices). The stimuli were recorded using the voices of the experimenter (female), a speech-language pathology student (female), a speech-language pathology professor (male), and a master of business graduate (male). All were native speakers of North American English. The words were recorded directly onto the hard drive using an external microphone and Cool Edit 2000. The amplitude was calibrated to be similar across stimuli. A total of 10 practice trials and 72 experimental trials were presented. Three different congruency conditions were constructed: 1) Congruent – female voice saying “mother”, male voice saying “father”, 2) Incongruent – female voice saying “father”, male voice saying “mother”, and 3) Neutral – female voice saying “person”, male voice saying “person”. Six trials of each congruent combination (male1 voice/father, male2 voice/father, female1 voice/mother, female2 voice/mother), 6 trials of each neutral combination (male1 voice/person, male2 voice/person, female1 voice/person, female2 voice/person) and 6 trials of each incongruent combination (male1 voice/mother, male2 voice/mother, female1 voice/father, female2 voice/father) were presented.

### 2.3.3.1 Sommers' Auditory Stroop Task Procedure

#### 2.3.3.1.1 Participant Instructions

Participants were instructed to press as quickly and accurately as possible number “1” when they heard a male voice, and number “5” when they heard a female voice.

#### 2.3.3.1.2 Experimental Testing

Just as in the FLAG task, participants were seated in front of the computer and both the participant and the experimenter wore a pair of headphones, which were plugged into the audio output of the computer. An SRBox was placed in a comfortable position in front of the subject. A white circle with the number “1” written on it in black ink was attached directly under the leftmost button on the SRBox and a similar circle with the number “5” on it was attached under the rightmost button on the SRBox. After the instructions, a fixation point (“+” sign) appeared for 2000 ms on the centre of the screen followed by the practice trials. Further instructions then appeared on the screen instructing participants to indicate whether they were ready to continue. When the participants were ready, the experimental trials were presented in random order. Each of the practice trials and experimental trials consisted of the presentation of an auditory sound file, and each was always separated from the adjacent stimuli by an interstimulus duration of 2000 ms.

#### 2.3.4 Simon Task

The Simon task is used to measure inhibition of non-language visual-perceptual information. The task used in the current study was the same as the one used by Bialystok, Martin, and Viswanathan (2005) and Marcoux (2004). In this task, participants are presented with red and blue squares, which appear one at a time on either the right or left side of the computer screen.

#### 2.3.4.1 Simon Task Stimuli

The images of a red and a blue square were used for this task and were both of equal size (see Appendix F). In order to emphasize the color of the squares, the background of the computer screen was black. A total of 4 practice trials and 36 experimental trials were presented. Two congruency conditions were constructed: 1) Congruent - blue square on right –blue key on right, or red square on left – red key on left, and 2) Incongruent – blue square on left – blue key on right, or red square on right – red key on left. Nine trials of each congruency condition were presented (blue-congruent, red-congruent, blue-incongruent, red- incongruent).

#### 2.3.4.2 Simon Task Procedure

##### 2.3.4.2.1 Participant Instructions

Participants are instructed to press as quickly and accurately as possible a designated key on the left side of the keyboard when a red square appears on the screen, and a designated key on the right side of the keyboard when a blue square appears.

##### 2.3.4.2.2 Experimental Testing

Participants were seated in front of the computer with the SRBox placed in a comfortable position in front of them. One blue circle was attached below the rightmost button on the SRBox and one red circle was placed below the leftmost button. After the computerized instructions, a fixation point (“+” sign) appeared for 500 ms on the centre of the screen followed by the practice trials in a fixed order. Further instructions then appeared on the screen instructing participants to indicate whether they were ready to continue. When ready, the experimental trials were presented in random order. Each of the practice and experimental trials

consisted of a presentation of either a red or blue square on a black background. The single square appeared on one side of the screen leaving the other side of the screen empty (black). The images were separated from the adjacent stimuli by a 500 ms interstimulus interval, filled with a white-colored fixation point which appeared on a black background.

### 2.3.5 Stroop Task

This task was adapted from Stroop (1935) and was used in this study to measure the inhibition of language based visual information. In this task, participants are presented with the color words “green”, “blue” and “red.” These words appear one at a time on the computer screen written in either green, blue or red ink. Participants must indicate what color ink the word is written in while ignoring the meaning of the word itself.

#### 2.3.5.1 Stroop Task Stimuli

The stimuli used for this task consisted of three visually presented words; 1) *green*, 2) *blue*, and 3) *red*. The 3 words appeared written in either green, blue or red ink and appeared in the center of the screen on a white background. Each word was written in E-prime in size 32 Courier New font. A total of 10 practice trials and 72 experimental trials were presented in this task. Two congruency conditions were constructed; 1) Congruent – in which the meaning of the word and ink color matched (i.e., the word *green* written in green ink), and 2) Incongruent – in which the meaning of the word and ink color did not match (i.e., the word *green* written in blue ink). Twelve trials of each congruent condition (green word-green ink, blue word-blue ink, red word-red ink) and 6 trials of each incongruent condition (green word-blue ink, green word-red ink, blue word-green ink, blue word- red ink, red word-green ink, red word-blue ink) were presented.

### 2.3.5.2 Stroop Task Procedure

#### 2.3.5.2.1 Participant Instructions

Participants were instructed to press as quickly and accurately as possible number “1” when they saw a word written in green ink, number “2” when they saw a word written in blue ink, and number “3” when they saw a word written in red ink. They were also informed by the experimenter that the numbers and the colors they corresponded to would always appear at the bottom of the screen in black ink in case they had difficulty remembering.

#### 2.3.5.2.2 Experimental Testing

Participants were seated in front of the computer monitor with the SRBox placed in a comfortable position in front of them. Three white circles were attached below the 3 leftmost buttons on the SRBox to represent the buttons for 1, 2 and 3 respectively. After the computerized instructions, a fixation point (“+” sign) appeared for 1000 ms in the centre of the screen followed by the practice trials. Further instructions then appeared on the screen instructing the participants to indicate whether they were ready to continue. When ready, the experimental trials were presented in random order. Each trial was separated from the next by an interstimulus interval of 1000 ms.

## CHAPTER 3: Results

### 3.1 Overview

This chapter begins by outlining how the data were prepared for analysis, including the exclusion of errors and outliers. The remainder of the chapter describes the findings from the experimental tasks as they relate to each of the study hypotheses.

### 3.2 Preparation of the Reaction Time Data for Analysis

Reaction time trials containing outliers or errors were eliminated to prevent the final results from becoming distorted by extreme values or incorrect responses. A breakdown of the procedure used to exclude trials is outlined below.

#### 3.2.1 Response Errors (Accuracy)

Each of the 5 experimental tasks involved the recording of participants' response accuracy. For the FLAG, Sommers Auditory Stroop, Simon, and Stroop tasks, participants were required to press specific buttons to indicate their responses. For the Picture Naming Task, the experimenter recorded the participant's responses as either correct or incorrect. Response errors were logged by the experimenter and/or E-Prime, and were excluded from the final data set. This resulted in the exclusion of 35 out of 650 (5%) Picture Naming task trials, 24 out of 1200 (2%) FLAG task trials, 42 out of 1800 (2%) Sommers Auditory Stroop task trials, 47 out of 1800 (3%) Stroop task trials, and 24 out of 900 (3%) Simon task trials. These percentages of errors across tasks are commensurate with those reported in a previous similar study (Sommers, 1999).

### 3.2.2 Outliers (Reaction Time Data)

The procedure used to identify outliers in each task involved the following steps. Descriptive statistics were generated for each congruency (i.e., congruent, incongruent) or onset density (i.e., dense, sparse) condition. The minimum and maximum reaction times for each condition were then examined and all values in the data which exceeded 3000 ms, or were less than 100 ms, were excluded because these were likely due to lapses of attention. This resulted in the exclusion of 3 (0.4%) Picture Naming task trials, 0 FLAG task trials, 1 (0.05%) Sommers Auditory Stroop task trial, 1 (0.05%) Stroop task trial, and 0 Simon task trials. The value representing 2 standard deviations +/- from the mean was then calculated for each congruency/onset density condition. Reaction time values which were greater or less than 2 standard deviations from the mean were considered outliers and were excluded from the data. This resulted in the exclusion of 26 (4%) Picture Naming task trials, 63 (5%) FLAG task trials, 74 (4%) Sommers Auditory Stroop task trials, 81 (5%) Stroop task trials, and 32 (4%) Simon task trials. These percentages of errors across tasks are commensurate with those reported in a previous similar study (Sommers et al., 1999).

### 3.3 Results

Hypothesis 1 was that results would show an onset density effect in the picture-word naming task. To examine this hypothesis, a paired samples t-test was conducted on dense vs. sparse onset stimuli in the picture naming data. The results supported this hypothesis in that the effect of onset density was significant,  $t = 2.67$ ,  $df = 24$ ,  $p = .014$ . Participant reaction times were significantly faster for words with sparse onsets ( $M = 757$ ms,  $SD = 75$ ) than words with dense onsets ( $M = 781$ ms,  $SD = 83$ ), thus replicating Vitevitch et al.'s (2004) onset density findings.

Before reporting the correlation findings, it is important to note the validity of each task as a measure of inhibition within a particular domain. Paired samples t-test results showed significant differences between the incongruent and congruent response time means for 3 out of the 4 inhibition tasks (FLAG:  $t = 4.59$ ,  $df = 24$ ,  $p = .000$ ; Stroop:  $t = 8.92$ ,  $df = 24$ ,  $p = .000$ ; Simon:  $t = 2.66$ ,  $df = 24$ ,  $p = .014$ ) (see Table 2 for subject response time means by task congruency). Although the Sommers Auditory Stroop task did not show a significant difference between incongruent and congruent conditions ( $t = 1.13$ ,  $df = 24$ ,  $p = .268$ ), a significant difference was found between this task's incongruent and neutral conditions ( $t = 2.33$ ,  $df = 24$ ,  $p = 0.029$ ), thus replicating Sommers et al.'s (1999) results.

Table 1: Participant Mean (SD) Reaction Times (ms) for Experimental Tasks

Experimental Task	Congruent/Sparse		Incongruent/Dense		Neutral	
	M	SD	M	SD	M	SD
Picture Naming	757	75	781	83	-	-
FLAG	607	139	670	167	-	-
Sommers	781	156	769	136	744	142
Stroop	624	136	742	154	-	-
Simon	438	72	452	66	-	-

Given that the validity of each task seemed to be supported by the congruency difference score means, the robustness of this inhibition effect across tasks was of interest. A repeated measures one-way ANOVA was conducted to determine whether the effects of congruency differed across tasks. The results showed significant differences across tasks:  $F(4, 24) = 16.56$ ,  $p = .000$ . To further explore the relative magnitude of each task's mean difference score, effect

sizes were calculated. The Stroop task's effect size was large (Cohen's  $d = .81$ ), the FLAG (Cohen's  $d = .41$ ) and Picture Naming (Cohen's  $d = .30$ ) tasks' effect sizes were medium, and the Simon (Cohen's  $d = .20$ ) and Sommers Auditory Stroop (Cohen's  $d = .18$ ) tasks' effect sizes were small.

Hypothesis 2a predicted that a significant positive correlation would be found between participants' picture naming response time difference scores (dense – sparse) and inhibition task response time difference scores (incongruent – congruent). This hypothesis was not supported insofar as the results from correlation analyses revealed no significant correlations between the picture naming task and any of the inhibition tasks (see Table 1).

Table 2: Pearson Correlation matrix of difference scores (incongruent – congruent) by task

	FLAG	Pic Naming	Stroop	Simon	Sommers	Sommers (I-N)*
FLAG	1.000	-.137	.215	.050	-.076	.112
Pic Naming	-.137	1.000	-.123	.007	.087	.098
Stroop	.215	-.123	1.000	.170	.092	.087
Simon	.050	.007	.170	1.000	-.314	-.155
Sommers	-.076	.087	.092	-.314	1.000	.548
Sommers (I-N)*	.112	.098	.087	-.155	.548	1.000

\* I-N = Incongruent - Neutral

Hypothesis 2b was that participants' individual scores on both language and non-language inhibition tasks would be consistent, and therefore, any correlations between inhibition tasks and picture naming would not differ across inhibition tasks. As noted above, however, there were no significant correlations between any of the inhibition tasks and the Picture

Naming task. Thus, this hypothesis also did not receive support. Furthermore, the correlation analysis showed that there were no significant correlations between different inhibition tasks (see Table 1). In other words, individuals' scores were not found to be consistent across the different inhibition tasks.

Finally, no significant correlations were found between participant characteristics age (range = 21 – 31,  $\underline{M}$  = 25,  $SD$  = 2.3) (one participant did not disclose their age) and education (range = 15 years – 17 years;  $\underline{M}$  = 17,  $SD$  = 0.4), scores on the Shipley Vocabulary Test (range = 26 – 39;  $\underline{M}$  = 33,  $SD$  = 3.1), and difference scores on each of the experimental tasks.

## CHAPTER 4: Discussion

### 4.1 Introduction

As stated in the first chapter, the current study intended to examine the effect of competition in lexical access during speech production. This exploration sought to better understand the lexical processing conditions in which competition and inhibition are present and how the effects of inhibition emerge in language and non-language tasks. In this chapter, the findings for the effects of onset density on picture naming will be discussed, as well as how these effects relate to performance on language and non-language inhibition tasks. This chapter is organized by the order of hypotheses presented in Chapter 1. The concluding section addresses the study's limitations and implications for future research.

### 4.2 Onset Density

The current study attempted to replicate Vitevitch et al.'s (2004) onset density study to test whether words with sparse onsets would be named faster than words with dense onsets. It was predicted in hypothesis 1 that the replication results would match those of Vitevitch et al. (2004). The present study findings support hypothesis 1. These findings can be explained using an interactive activation model of speech production (Dell 1992; Dell et al. 1997). According to this model, cascading activation at the semantic, lemma and phonological levels triggers reciprocal activation from the phonological to the lemma and semantic levels. For words with dense onsets, the word initial phoneme obtains support from its neighbors with the same onset and becomes quickly activated. However, competition becomes an issue during the retrieval of the remaining phonemes, and inhibition is required to suppress the activated dissimilar phonological segments (rhymes) belonging to the target word's neighbors. Vitevitch et al.

explain that it is this competition between the neighbors' activated segments and the target word's segments which causes slower response times for words with dense onsets. In contrast, words which have sparse onsets are named faster. This is attributed to the target word having mostly rhyme-related competitors with different onsets. As a result, the initial phoneme of words with sparse onsets experience minimal competition, which when combined with the more highly activated rhyme (due to similarity between target rhyme and competitor rhymes) results in reinforcement of the target word's activation level. Dell's model differs from Levelt's model in that the former involves bidirectional excitatory connections between semantic, lemma and phonological levels. The inhibition effect required to suppress the target words neighbors is, therefore, better explained by Dell's model in that Levelt's one-way model does not sufficiently account for competition effects due to the interaction between lemma and phonological levels.

#### 4.3 Correlations between Picture Naming and Inhibition Tasks

A second goal of the current inquiry was to investigate the strength or nature of the relationship between the competition effect expected in the naming task and the competition effects expected in the four inhibition tasks. Sommers et al. (1999) found that individuals who showed greater difficulty recognizing lexically hard words (words with dense neighborhoods) in a word recognition task obtained the poorest scores on inhibition tasks. Similarly, Wiener (2004) found that the level of interference (competition) participants experienced on a numerical Stroop inhibition task was positively correlated with severity of auditory comprehension deficit for participants with Wernicke's aphasia (measured by the token test). Therefore, it was predicted in the present study that the level of interference participants experienced due to onset density competition effects would correlate with their scores on the inhibition tasks.

The findings, however, yielded no significant correlations between the picture naming task and each of the inhibition tasks. Thus, hypothesis 2a was not confirmed. Because Sommers et al.'s neighborhood density findings were similar to the present study's onset density results (i.e., words with dense onsets were named more slowly than words with sparse onsets.) it was expected that the correlation reported in Sommers et al.'s study between language and inhibition tasks would be replicated in the current study, especially for Sommers' Auditory Stroop task. The absence of such a significant correlation between the picture naming task and Sommers' Auditory Stroop task may be related to participant and/or task characteristics. In Sommers et al.'s study, the participants included 22 young individuals with a mean age of 20, and 22 older individuals with a mean age of 75.5. The older group's performance was poorer on both the word recognition task and inhibition tasks than the younger group. The older group also showed greater variability in their scores than the younger group. Therefore, it is plausible that the performance variability across older and younger participants contributed to the significant correlations between word recognition task and inhibition task performance. In contrast, in the present study, there were relatively small standard deviations across tasks. Thus, the more limited inter-individual variability in performance may have resulted in insufficient power to detect a significant relationship in performance between tasks. In addition the Weiner et al. study, participants included individuals with Wernicke's aphasia. Because participants varied in severity of language disorder there was a wide range of auditory comprehension and inhibition task scores across participants. Thus, Weiner et al.'s participant pool also contrasted with the current study's relatively homogenous sample.

Task characteristics may also have affected inter-task correlations. The language tasks in Sommers et al. and Weiner et al. were auditory tasks while the picture naming task in the

current study was only visual. The difference between tasks in these two modalities and how this may affect task performance is discussed below.

Although the correlation analysis yielded unexpected results, response time data for congruent and incongruent trials were consistent with findings from previous research (Stroop, 1935; Bialystok et al., 1995, Wiener, 2004). The novel FLAG task created for this study was among the inhibition tasks which proved to be sensitive as a measure of inhibition by showing expected directions for congruency response times. Namely, response times for congruent trials were faster than incongruent trials across tasks (except for the Sommers Auditory Stroop task) indicating greater inhibition is required for incongruent trials. In the present study, Sommers' Auditory Stroop task showed that incongruent trial responses were not slower than congruent conditions (contrary to Sommers et al.'s findings). However, trial response times were significantly slower for incongruent than neutral trials, which Sommers et al. also reported.

#### 4.4 Correlations between Inhibition Tasks

Evidence from previous research suggests that certain capacities or processes such as working memory or inhibition are not specific to a particular cognitive domain but rather support multiple domains. (e.g., Ullman, 2004; Bialystok, Craik, Klein and Viswanathan, 2004). For example, Ullman (2004) argues that processing capacities for declarative and procedural knowledge are applicable across cognitive domains (e.g, memory, language).

Bialystok, Craik, Klein and Viswanathan (2004) found that bilinguals performed better on an inhibition task (Simon task) than monolinguals. Namely, bilinguals showed a smaller Simon effect, meaning they were able to respond faster to incongruent task items. This was attributed to their greater inhibition ability presumably developed by their frequent inhibition of one language while speaking another. A model proposed by Green (1998) is able to explain

Bialystok's findings by stating that bilinguals' nonrelevant language is suppressed by the same general executive functions used for attention and inhibitory control. This suggests that the inhibition used by bilinguals to inhibit the language that is not being used is coming from the same source as the inhibition used for a non-language task (i.e., the Simon task). The current study attempted to provide further evidence for this general inhibition capacity by exploring whether performance on language and non-language inhibition tasks revealed consistent or inconsistent competition effects. The scores from the language inhibition tasks were expected to correlate with the scores from the non-language inhibition tasks, suggesting that the inhibition capacity utilized in both language and non-language inhibition tasks emanates from a common source.

The results, however, showed no significant correlations between any of the four inhibition tasks. Thus, hypothesis 2b was not supported. Although null results could be due to many factors, these findings may provide support for the existence of different inhibition capacities. Evidence against this interpretation comes from Wager, Sylvester, Lacey, Nee, Franklin and Jonides (2005) who utilizing brain imaging found that lack of behavioral correlations between inhibition tasks occurred despite the activation of common brain regions during these tasks. They utilized three response inhibition tasks (Stimulus response compatibility (SRC), Go/no-go (GNG), and Flanker tasks) and fMRI to measure brain and behavior relationships. For the SRC task, participants were presented with either a left or right pointing arrow in the center of the screen. Preceding each block of trials instructions were given indicating whether the participant was to press the button (right or left side) corresponding to the same direction the arrow was facing (congruent) or the opposite direction (incongruent). In the GNG task a sequence of letters was presented one at a time on the screen. Participants were

required to press a button when they saw any letter other than X and refrain from pressing a button when an X appeared. The Flanker task involved the presentation of 3 colored circles in the middle of the screen. The middle circle was the target and was always a different color from the 2 distracting circles. Participants were asked to press a button with their right index finger when the target circle was either yellow or blue, and respond with their left index finger when the target circle was red or green. Although every participant showed interference effects in the expected direction on each task, correlation analyses for the 3 inhibition tasks revealed negligible intertask results. fMRI results showed activation across tasks in the: (1) superior and inferior parietal cortex, (2) anterior prefrontal, (3) premotor, (4) insula, (5) caudate/putamen, (6) anterior cingulate, (7) posterior cingulate, and (8) premotor cortex bilaterally, as well as (9) right dorsolateral prefrontal and (10) thalamus. Among all of these regions, Wager et al. found that significant correlations between brain activation and behavioral performance occurred for only 3 regions. A positive correlation was found between activation of the bilateral anterior prefrontal cortex, anterior cingulate and bilateral anterior insula and interference on all three inhibition tasks. They explain these findings by suggesting that when task difficulty increases (i.e., requiring more inhibition ability) activation of relevant brain regions increases. The question pertinent to Wager et al. and the present study's findings remains, if common brain mechanisms are involved in resolving interference effects, why is there a lack of correlations between the tasks that measure this interference effect? Wager et al. suggest that although activation of a common mechanism may occur across participants to resolve interference, each participant may engage this mechanism to varying degrees across tasks. This suggests that individual participants may experience different amounts of conflict across tasks in spite of a general

inhibition ability. Explanations as to why participants may differ in their activation level of a common mechanism are described below (i.e., cognitive effort and length of testing session).

Another approach to explaining these findings may be, as mentioned earlier, by examining differences in task characteristics. For example, although Sommers' Auditory Stroop task and the traditional Stroop task were both language tasks, the former required that the participant focus on auditory stimuli while the latter involved only visual stimuli. Similarly, the FLAG task and the Simon task were both non-language based tasks; however, the former required that the participant focus on both visual and auditory stimuli while the latter involved only visual stimuli. The absence of correlations, especially between the tasks with the same language or non-language base suggests that task characteristics such as the sensory modalities involved may have a greater impact on reaction time than whether or not a task involves language.

Baker, Taylor and Leyva (1995) explored the effect of modality on task performance using a continuous performance test, which has been popular in the assessment of attentional processes (GDS; Gordon 1983). The specific test they used, entitled the Gordon Diagnostic System (GDS), assessed sustained attention with two different tasks. The *vigilance* task required participants to press a button when they saw the number "1" followed by a "9". The *distractibility* task required the participants to respond to the same "1/9" sequence while additional numbers were flashed on both sides of the target stimuli. Errors of omission (failing to respond to the correct target) were considered to be a measure of sustained attention while errors of commission (response to an incorrect target) were regarded as an indicator of impulsivity. Baker et al. were interested in comparing performance on visual and auditory tasks; therefore, 100 participants ranging in age from 17-45 were administered the vigilance and

distractibility tasks of the GDS in both visual and auditory modalities. A cassette tape of background noise acted as the distractor for the auditory distractibility task. Baker et al. found that auditory tasks were more difficult than visual tasks, resulting in a greater number of both errors of omission and errors of commission. With regard to the present study, Baker et al.'s finding would suggest that the Stroop task and the Simon task which both involve only visual stimuli would produce similar results. However, these two tasks did not significantly correlate, and they were on opposite poles in terms of task effect size (Stroop: Cohen's  $d = .81$ , Simon: Cohen's  $d = .2$ ). If visual tasks are in fact easier than auditory tasks, then a smaller interference effect characterized by similar response times on both congruent and incongruent trials would have been expected. The fact that the Stroop task (visual) showed the largest effect size of all the inhibition tasks suggests that modality was not playing a significant role by itself. The modality in which the stimuli were presented may not have had the same effect in the current study as in Baker et al.'s study due to differences in each study's methodology. While Baker et al.'s tasks were relatively equal in terms of number of trials, inter-stimulus interval, number of modalities used (auditory, visual or both), and number of response buttons, these characteristics varied across tasks in the present study. This suggests that modality of stimulus presentation effects (auditory vs. visual) may only be present when there are no methodological task differences, other than modality. As a result, modality of stimulus presentation does not appear to sufficiently explain the lack of correlations found between inhibition tasks in this study.

Another possible explanation for the absence of inhibition task correlations may be a lack of performance consistency due to fluctuations in each participant's cognitive effort. Theories of motivation consider *effort* to be a dynamic concept which can change in an individual depending on varying individual and environmental factors (Ackerman and

Heggestad, 1996). Yeo and Neal (2008) examined the factors that may produce intra-individual changes in cognitive effort over time. They state that cognitive effort is conceptualized as a resource with a limited capacity that affects the speed of information processing, and that allocating more cognitive effort to a task will improve task performance. Contrastingly, if the amount of effort required to complete a task decreases, self regulation theories suggest that individuals will allocate less cognitive effort towards task performance. Yeo and Neal examined these theories using a cognitively complex air traffic control task. A radar screen was frozen five times during each of the five trials and participants were required to rate how difficult they found the task and how hard they were trying just before the screen froze (responses were based on an 11-point scale from *not at all* to *extremely difficult*). They found that higher levels of subjective cognitive effort were related to higher task performance. Furthermore, individual differences in perceived difficulty showed that some participants appeared to maintain a consistently high level of effort while others reserved high levels of effort for instances of increased task difficulty. These results suggest that the level of cognitive effort a participant allocates to a task will affect their performance and that the level of effort varies across individuals. While participants' subjective cognitive effort or perceived difficulty was not measured in the current study, it is plausible based on Yeo and Neal's findings that these factors may have contributed to the intra and inter-individual differences shown across tasks.

Participants may differ both in their allocation of cognitive effort relative to task difficulty and at what level they perceive a specific task to be difficult resulting in varying response speed. If an individual participant tends to maintain a high level of cognitive effort, their attention to the stimuli across tasks, regardless of task difficulty, may be high, resulting in consistently fast response times. Contrastingly, individuals who reserve high levels of cognitive effort for tasks

which are perceived to be more difficult may perform differently on different tasks as compared to other participants. For example, to one individual the Stroop task may be perceived as more difficult than the Simon task resulting in higher levels of cognitive effort being allocated to completing the Stroop task. This increased effort and attention to the task may result in faster response times for the Stroop task than for the Simon task which was not allocated an equal amount effort. Furthermore, perception of task difficulty may have varied for each participant (e.g., Stroop > Simon) resulting in higher levels of cognitive effort being allocated to different tasks for different people, and consequently, producing a lack of correlation between these tasks.

Another factor affecting cognitive effort differently across participants may have been the length of the testing session. All five inhibition tasks were administered in one testing session for each participant. Although an eye exam and the Shipley Vocabulary test were strategically placed to divert attention away from the inhibition tasks and avoid task monotony, participants were required to expend cognitive effort for a considerable stretch of time. The mental exertion required to respond rapidly over an extended period of time may have affected each participant's response ability differently. Counterbalancing was done to control for task order biases such as initial nervousness and decreasing attention and effort on later tasks; nevertheless, these factors may have affected consistency of performance across participants. For example, because participants performed tasks in different orders, the aforementioned factors may not have affected each task equally, possibly attenuating the strength of correlations between tasks.

In summary, the lack of correlations found between inhibition tasks initially appear to suggest that different inhibition capacities are accessed during different tasks. However, another possibility is that other factors contributed to these findings. Previous research showed that

while common brain regions were activated for similar response inhibition tasks, no correlations were found between behavioral task scores (Wager et al., 2005). With regard to the present study, Wager et al's findings suggest that a lack of correlations between inhibition tasks may not necessarily have been due to the activation of different inhibition domains. Therefore, if a common inhibition mechanism may be accessed during these inhibition tasks, other factors must have contributed to the lack of inter-task correlations. As mentioned above, these factors may have included: 1) variation in task characteristics, 2) variation in modality of stimulus presentation, 3) perceived task difficulty and/or level of cognitive effort, 4) counterbalancing, and/or 5) length of the testing session.

#### 4.5 Limitations and Implications

This study points to a number of directions for future research. As mentioned above, a limitation of this study was the occurrence of complicating factors such as varying task methodology and modality, which may have contributed to non-significant inter-task correlations. Future research could continue to examine the nature of inhibition while attempting to control for these factors. This could be done by changing only one aspect of a task's methodology or modality. For example, the FLAG task could be adapted to create a language task while maintaining the tasks modality and other task characteristics. In the present study the FLAG task used male and female images as visual stimuli and male and female voices singing as auditory stimuli. This non-language task could be altered by using the same male and female images as visual stimuli but changing the auditory stimuli to a child's voice (non-gender specific) saying the words *male* or *female*. Comparing the non-language FLAG task results with the adapted language FLAG task results may provide information regarding the nature of inhibition while controlling for the task demands/characteristics and task modality. Future

neuro-imaging studies may provide additional information regarding the source of participants' inhibition ability. Wager et al. found that common brain mechanisms were active during inhibition tasks despite the lack of correlations between participants' performance across tasks. However, as in the present study, their task demands/characteristics varied across tasks. Conducting a neuro-imaging study while controlling for task variation by altering only one aspect of each inhibition task, may provide further insight regarding the sources of participants' inhibition abilities.

Information from these suggested future studies would be beneficial in that providing support for or against the existence of different inhibition domains could influence one's approach to clinically addressing a client's inhibition ability. Previous research has suggested that inhibition is a core deficit in conditions such as Wernicke's aphasia (Weiner, 2004) and Attention Deficit Hyperactivity Disorder (Suskauer, Simmonds, Fotedar, Blankner, Pekar, Denckla, Mostofsky, 2008). If inhibition is found to be divided into language and non-language capacities, this may affect intervention strategies for these inhibition related disorders.

Other limitations of this study which could be improved in future lexical access and inhibition research relate to sample variability and length of testing sessions. Including a sample of participants who are likely to perform more heterogeneously (e.g., due to differences in age, attention and/or language ability) may create more opportunity in the data to identify correlations between tasks. Lengthy testing sessions may have affected the participant's level of cognitive effort or ability to attend to the stimuli equally across tasks. Thus, conducting testing over multiple sessions may alleviate the effects of time on a participant's ability to attend fully to stimuli and exert a high level of cognitive effort.

## 4.6 Conclusions

This study has shown that a neighborhood density effect is present in lexical access in speech production and is dependent on the position of phonological overlap. While some previous speech production studies reported that dense neighborhoods facilitate naming, speech comprehension findings revealed contrasting results, namely, that dense neighborhoods inhibited lexical access. The present study's findings, therefore, along with Vitevitch et al. (2004), appear to contribute to the resolution of these conflicting results by providing evidence that high onset density results in slower picture naming response times in lexical production, just as in lexical comprehension. The increase in response times for words with dense onsets suggests increased inhibition is required to suppress the target word's competitors. It was expected that this naming inhibition effect would correlate with participants' performance on four tasks in which inhibition is a critical component; however, this did not occur. Despite this unexpected result, each task (with the exception of Sommers' Auditory Stroop task) was validated as a task requiring inhibition in that mean response times for congruent/sparse trials were significantly faster than incongruent /dense trials. Possibly the most unexpected result was the lack of significant correlations between the four inhibition tasks. While this may suggest that different inhibition capacities were tapped into for each task, other factors may have contributed to these findings. Wager et al.'s (2005) study showed that while common brain regions were activated for three response inhibition tasks, no correlations were found between behavioral task scores. This implies that lack of correlations between tasks may not necessarily indicate that different inhibition domains exist. If common processing mechanisms were activated during these tasks, other factors must have been present which contributed to the lack of inter-task correlations. It is possible that variation in the present study's task characteristics such as

number of trials, number of response buttons, and stimulus modality may have affected participant performance. Furthermore, as shown in Yeo and Neal (2008), perceived task difficulty and level of cognitive effort can affect participant performance across tasks. Amount of cognitive effort allocated to each task may have been related to task counterbalancing and the length of the testing session in which all five tasks were administered.

## REFERENCES

- Baker, D. B., Taylor, C. J., & Leyva, C. (1995). Continuous performance tests: a comparison of modalities. *Journal of Clinical Psychology, 51*(4), 548-551.
- Bialystok, E., Craik, F., Klein, R., & Viswanathan, M. (2004) Bilingualism, Aging, and Cognitive Control: Evidence From the Simon Task. *Psychology and Aging, 19*(2), 290–303.
- Bialystok, E., Martin, M. M., & Viswanathan, M. (2005). Bilingualism across the lifespan: The rise and fall of inhibitory control. *International Journal of Bilingualism, 9*(1), 103-119.
- Broadbent, D. E. (1970). Stimulus set and response set. In D. I. Mortofsky (Ed.), *Attention: Contemporary theories and analysis*. New York: Appleton-Century-Crofts.
- Dell, G.S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language, 27*, 124–142.
- Dell, G. S., & O’Seaghdha, P. (1992). Stages of lexical access in language production. *Psychological Review, 98*, 604–614.
- Dell, G. S., Burger, L. K., & Svec, W. R. (1997). Language production and serial order: A functional analysis and a model. *Psychological Review, 104*, 123-147.
- Dell, G. S., Chang, F., & Griffin, Z. M. (1999). Connectionist models of language production: Lexical access and grammatical encoding. *Cognitive Science: A Multidisciplinary Journal, 23*(4), 517-542.
- de Saussure, F. (1912a). Nature of the linguistic sign. Originally published in *Cours de*

- linguistique generale (pp.65-70). New York: The Philosophical Library, Inc. (1959).  
 Reprinted in J. Oller (ed.), *Language and experience: Classic pragmatism* (ch 8, pp. 67-75). Lanham, MD: University Press of America. 1989.
- Gordon, M. (1983). *The Gordon Diagnostic System*. Dewitt, NY: Gordon Systems.
- Hasher, L. & Zacks, R. T. (1998). Working memory, comprehension and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation, Vol. 22*. San Diego, CA: Academic Press.
- Kanfer, R., Ackerman, P. L., & Heggestad, E. D. (1996). Motivational skills and self-regulation for learning: A trait perspective. *Learning and Individual Differences, 8*(3), 185-209.
- Levelt, W.J.M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, 1-38.
- Limewire. (2008). Retrieved January 3, 2008 from <http://www.limewire.com>.
- Lu, C., & Proctor, R. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review, 2*(2), 174-207.
- Luce, P.A., & Pisoni, D.B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing, 19*, 1-36.
- Marcoux, C. (2004). The cognitive advantage in bilingualism: Attention and working memory. Unpublished master's thesis, University of British Columbia, Vancouver, British Columbia, Canada.
- Schneider, W., Eschman, A., & Zuccolotto, A. [Software manual]. (2002a). *E-Prime User's Guide*. Pittsburgh, PA: Psychology Software Tools, Inc.

- Schneider, W., Eschman, A., & Zuccolotto, A. [Software manual]. (2002b). *E-Prime Reference Guide*. Pittsburgh, PA: Psychology Software Tools, Inc.
- Shipley, W. C. (1940). A self-administering scale for measuring intellectual impairment and deterioration. *The Journal of Psychology*, 9, 371-377.
- Snodgrass, J.G., & Vanderwart, M. (1980). A standardized set of 260 pictures. *Journal of Experimental psychology: Learning, Memory and Cognition*, 6, 174–215.
- Sommers, M. S. (1996). The structural organization of the mental lexicon and its contribution to age-related changes in spoken word recognition. *Psychology and Aging*, 11, 333-341.
- Sommers, M. S. (1998). Spoken word recognition in individuals with dementia of the Alzheimer's type: Changes in talker normalization and lexical discrimination. *Psychology and Aging*, 13, 631-646.
- Sommers M. S., & Danielson, S. M. (1999). Inhibitory processes and spoken word recognition in young and older adults: The Interaction of Lexical Competition and Semantic Context. *Psychology and Aging*, 14(3), 458-472
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662.
- Sullivan, M., & Riffel, B. (1999). The nature of phonological encoding during spoken word retrieval. *Language and Cognitive Processes* 14 (1), 15–45.
- Suskauer, S., Simmonds, D., Fotedar, S., Blankner, J., Pekar, J., Denckla, M., & Mostofsky, S. (2008). Functional magnetic resonance imaging evidence for abnormalities in response selection in attention deficit hyperactivity disorder: Differences in activation associated

- with response inhibition but not habitual motor response. *Journal of Cognitive Neuroscience*, 20(3), 478-493.
- Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, 37A, 571-590.
- Ullman M. T. (2004). Contributions of memory circuits to language: the declarative/procedural model. *Cognition* 92, 231–270.
- Vitevitch, M. S. (2002a). The influence of phonological similarity neighborhoods on speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28(4), 735-747.
- Vitevitch, M. S. (2002b). The influence of onset density on spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 270–278.
- Vitevitch, M. S., Armbruster, J. & Chu, S. (2004). Sublexical and Lexical Representations in Speech Production: Effects of Phonotactic Probability and Onset Density. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 30( 2) 514–529.
- Wager, T., Sylvester, C., Lacey, S., Nee., D., Franklin, M., & Jonides., J. (2005). Common and unique components of response inhibition revealed by fMRI. *NeuroImage*, 27, 323– 340.
- Weiner, D. A., Connor, L. T., & Obler, L. K. (2004). Inhibition and auditory comprehension in Wernicke’s aphasia. *Aphasiology*, 18 (5/6/7), 599-609.
- Yeo, G., & Neal, A. (2008). Subjective cognitive effort: A model of states, traits, and time. *Journal of Applied Psychology*, 93 (3), 617–631.

## APPENDICES

### APPENDIX A: Participant Information and Consent Form



The University of British Columbia  
Faculty of Medicine  
School of Audiology & Speech Sciences

#### PARTICIPANT INFORMATION AND CONSENT FORM

##### Lexical Access and Inhibition

**Principal Investigator:** Dr. Jeff Small, PhD, Associate Professor  
School of Audiology and Speech Sciences  
UBC Faculty of Medicine  
( )

**Co-Investigator:** Jessica Casiro, M.Sc. Candidate  
School of Audiology and Speech Sciences  
UBC Faculty of Medicine  
-

**Sponsor:** UBC University Graduate Fellowship

We are inviting you to consider participating in this study. This research is being carried out as part of Jessica Casiro's Master's degree.

#### **Background:**

Lexical access is a process which involves finding words that are stored in your memory in order to understand and produce language. Previous research has shown that the words we know compete to be chosen during both language comprehension and production, and that this competition is driven by the similarities and differences between the sounds in words. This study explores the process of finding words for speech production and how this process might be common in other language and non-language tasks that involve competition between items in order for one to be chosen over another.

#### **Study Description:**

Your participation in this study will involve: a) completing a short vocabulary test; b) naming pictures of objects on a computer screen; c) completing four auditory and/or visual "stroop-like"

tasks which involve paying attention to target information while ignoring distracting information. The researcher, Jessica Casiro, would meet with you at the Adult Language Processing Lab located in the School of Audiology and Speech Sciences at the University of British Columbia, for a one-time session of approximately one hour.

**Possible benefits and risks of participation:**

There are no known risks as a result of participating in this project. If you become fatigued during the tasks in this study you will be allowed to take a break or discontinue the testing session. No participant will be compelled to complete the activities against his/her will. If you consent to participating in this study you may benefit by learning about the research process (e.g., what it is like to be a study participant) and, upon study completion, finding out more about the topic of lexical access in word production; upon request we will send you a summary of the study's overall findings. Please note that your individual scores or data will not be disclosed.

**Confidentiality:**

All information pertaining to your participation will be kept strictly confidential. The data and records will be stored in a locked cabinet or password-secured computer in the Principal Investigator's research lab. The data we gather will be used only for the purposes of this study.

**Participation:**

Participation in this study is entirely voluntary. If you choose to participate in this study, you will be asked to sign this consent form. Keep in mind that if you do consent to your participation, you may withdraw from the study at any time.

If you have any questions or would like further information about this project, please feel free to contact the Co-investigator Jessica Casiro at (████) ██████████ or the Principal Investigator Dr. Jeff Small at (████) ██████████

*If you have any concerns about your rights as a research subject and/or your experiences while participating in this study, you may contact the 'Research Subject Information Line in the University of British Columbia Office of Research Services' at (604) 822-8598.*

*Please keep this copy for your own*

*records*



**The University of British Columbia**  
Faculty of Medicine  
School of Audiology & Speech Sciences

### **Consent to Participate**

**Please check one:**

*Your signature below indicates that you have received a copy of this consent form for your own records.*

*Your signature indicates that you consent to your participation in this study.*

I have read and understood the subject information and consent form of this research study. I, \_\_\_\_\_ agree to participate in this study.

Your name: \_\_\_\_\_

Your signature: \_\_\_\_\_

Date: \_\_\_\_\_

---

Thank you very much!

APPENDIX B: Demographics Form

BACKGROUND

The information you provide on this form will be looked at by researchers only. Please do NOT write your name on it. Please try to give an answer for every question. If you are not sure, give the answer you think is the closest.

1. What is your sex? \_\_\_\_\_ Female \_\_\_\_\_ Male
2. What is your age? \_\_\_\_\_ Years
3. Where were you born? (City, State or Province, and Country): \_\_\_\_\_
4. How long have you been living in Canada? \_\_\_\_\_ years \_\_\_\_\_ months
5. How would you describe your cultural identity?  
\_\_\_\_\_
6. What is the highest level of education and/or training you have completed?  
\_\_\_\_\_ 8th grade or less  
\_\_\_\_\_ Attended high school  
\_\_\_\_\_ Completed high school  
\_\_\_\_\_ Vocational training (after high school)  
\_\_\_\_\_ Attended college (did not graduate)  
\_\_\_\_\_ College graduate (e.g., BA, BSc)  
\_\_\_\_\_ Post-graduate (e.g., MA, PhD)  
\_\_\_\_\_ Other, please specify: \_\_\_\_\_
7. People in Canada come from different racial or cultural groups. Are you.....?  
(Note: If you belong to more than one group on the list, check all that apply).  
\_\_\_\_\_ Arab  
\_\_\_\_\_ Black  
\_\_\_\_\_ Chinese  
\_\_\_\_\_ Filipino  
\_\_\_\_\_ Japanese  
\_\_\_\_\_ Korean  
specify: \_\_\_\_\_  
\_\_\_\_\_ Latin American  
\_\_\_\_\_ South Asian (e.g. East Indian, Pakistani, etc.)  
\_\_\_\_\_ Southeast Asian (e.g. Vietnamese, Cambodia, etc.)  
\_\_\_\_\_ West Asian (e.g. Iranian, Afghan, etc.)  
\_\_\_\_\_ White  
\_\_\_\_\_ Other, please

*These questions are about the languages you use throughout your life. Feel free to add comments on items where you think it would be helpful for us to know something additional. The information you provide will be looked at by researchers only.*

1. What is your native language/mother tongue? i.e., language first spoken (if more than one, please indicate which one you consider to be the dominant one): \_\_\_\_\_

2. In what language(s) are/were your parents fluent?

Mother: \_\_\_\_\_

Father: \_\_\_\_\_

3. If you have children, what language(s) do they speak fluently?

\_\_\_\_\_

4. Do you speak more than one language (please tick box)?  Yes  No. If yes, please continue by completing questions 5, 6, 7 and 8 and then proceed to page 4. If no, please go directly to page 4.

5. At what age did you start learning each of these languages?

Language Spoken	Started Learning at What Age?

6. How well do you speak each of the above languages including your mother tongue (please tick box)?

a) Today/currently, I speak it.....

Mother tongue:	<input type="checkbox"/> not very well	<input type="checkbox"/> well enough to get by	<input type="checkbox"/> really well
Language 1:	<input type="checkbox"/> not very well	<input type="checkbox"/> well enough to get by	<input type="checkbox"/> really well
Language 2:	<input type="checkbox"/> not very well	<input type="checkbox"/> well enough to get by	<input type="checkbox"/> really well



SAS

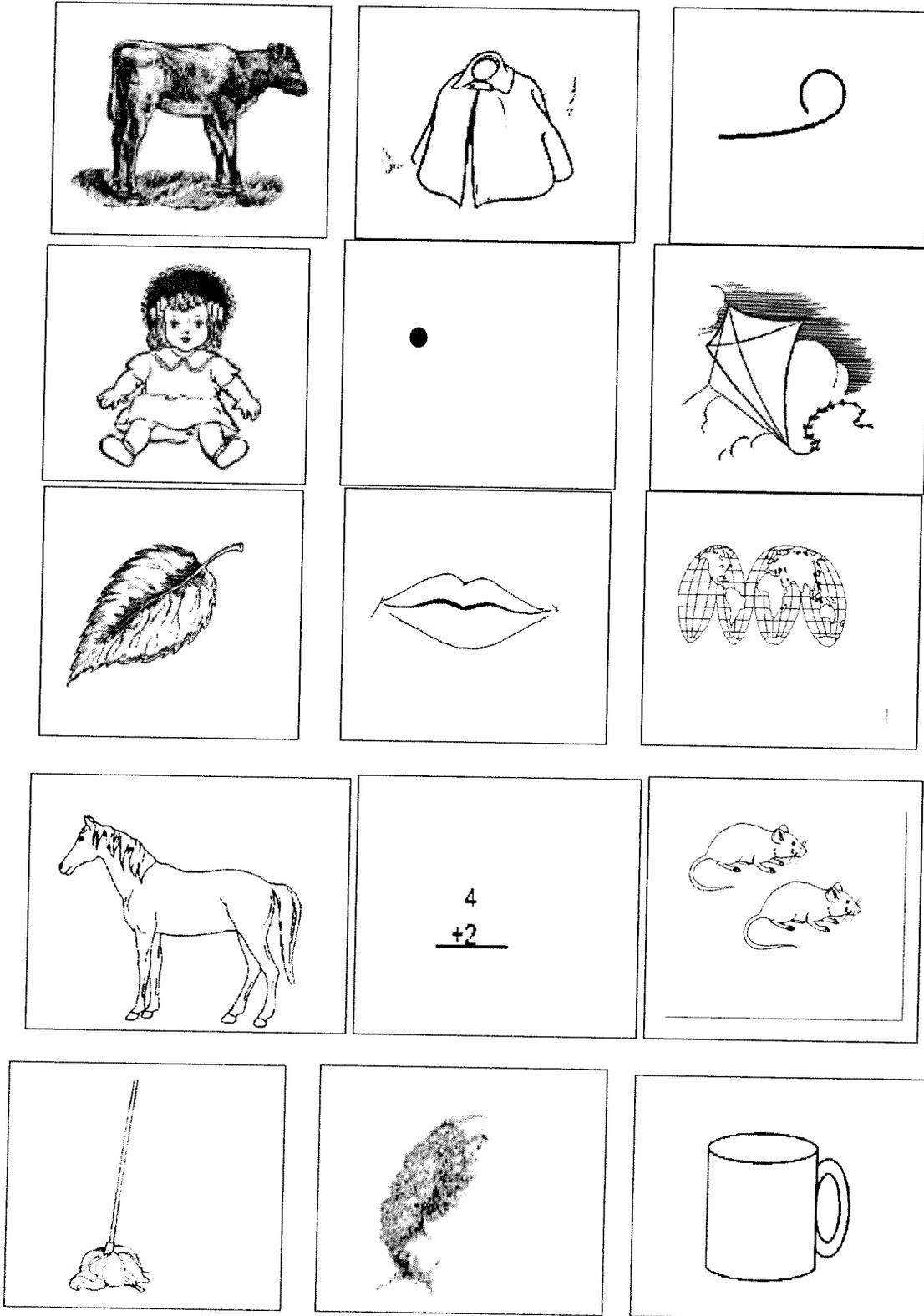
INSTRUCTIONS: The following questions look at whether and how much you use another language besides English in your daily life. In case you speak two or more languages besides English, please indicate in the space provided the language that you speak the most besides English (e.g. German, Italian, Chinese, Polish, etc.) Please then substitute this language as “X” in the scale below. For each item, circle the number that corresponds to your best answer according to the scale below.

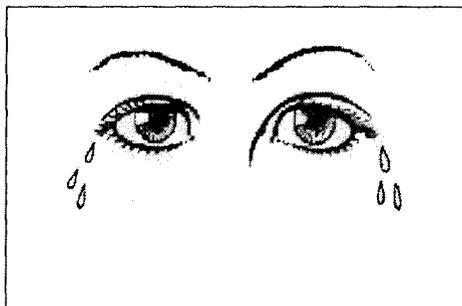
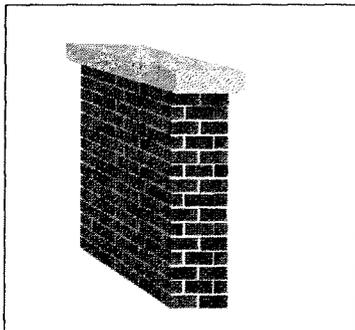
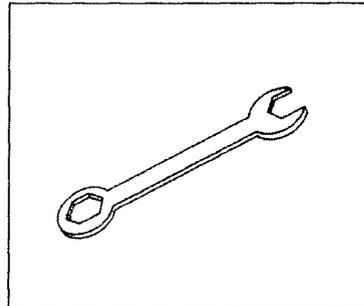
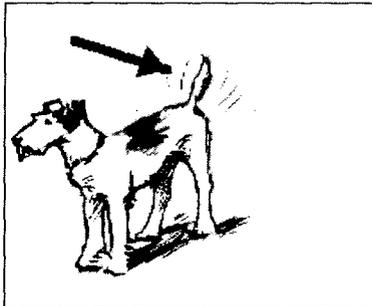
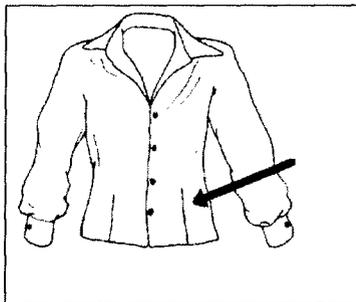
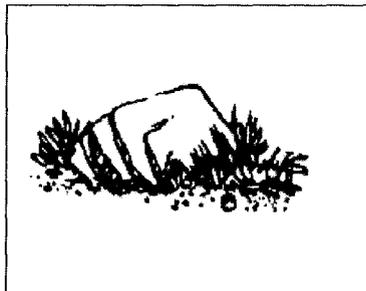
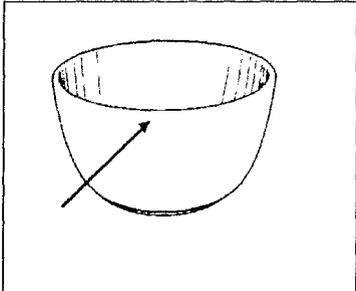
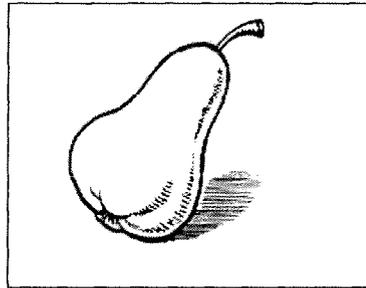
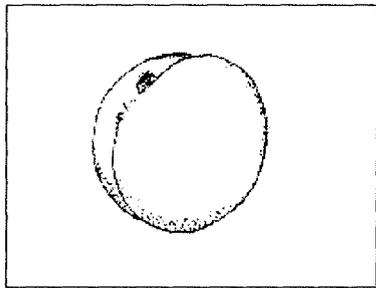
The language I use the most besides English is \_\_\_\_\_ = X [i.e., other language most used]

1	2	3	4	5
Only X	More X than English	English and X equally	More English than X	Only English

- 1. In general, what language(s) do you read and speak? ..... 1 2 3 4 5
- 2. What language(s) did you use as a child?..... 1 2 3 4 5
- 3. What language(s) do you speak at home?..... 1 2 3 4 5
- 4. In which language(s) do you usually think?..... 1 2 3 4 5
- 5. What language(s) do you usually speak with your friends? ..... 1 2 3 4 5
- 6. In what language(s) are the TV programs you usually watch?..... 1 2 3 4 5
- 7. In what language(s) are the radio programs you usually listen to? ..... 1 2 3 4 5
- 8. If you had the choice, in what languages(s) would you prefer to watch/listen to movies, TV, and radio programs? ..... 1 2 3 4 5
- 9. Your close friends speak:..... 1 2 3 4 5
- 10. You prefer going to social gatherings/parties at which the people speak: ..... 1 2 3 4 5
- 11. The persons you visit or who visit you speak: ..... 1 2 3 4 5
- 12. If you could choose your children’s friends, you would want them to speak: 1 2 3 4 5

APPENDIX C: Picture Naming Stimuli – Images

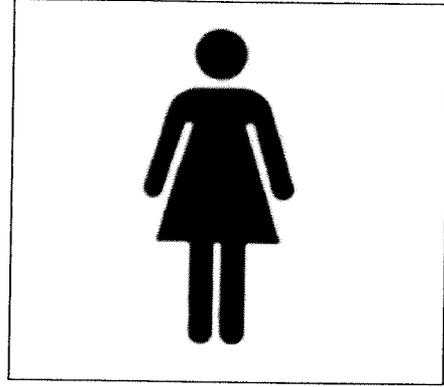
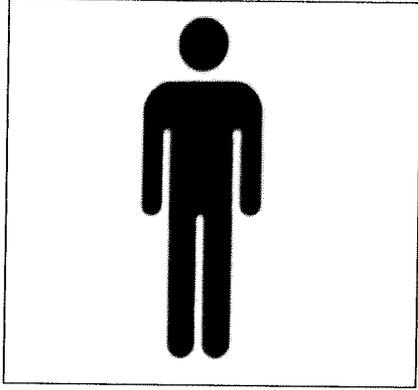




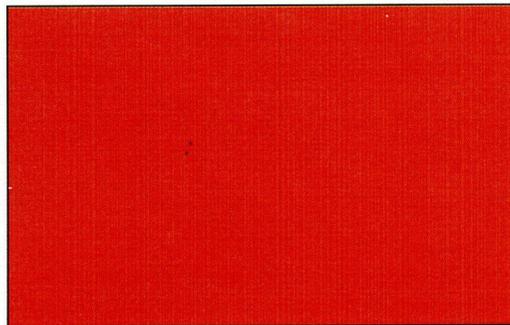
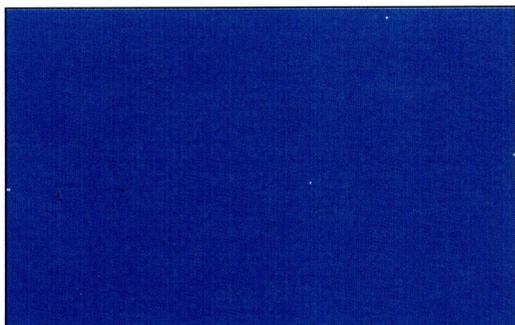
APPENDIX D: Stimulus Characteristics - Vitevitch, Armbruster and Chu (2004)

Stimuli	Onset Density
Doll	Dense
Cape	Dense
Calf	Dense
Curl	Dense
Leaf	Dense
Math	Dense
Moss	Dense
Mice	Dense
Peach	Dense
Rim	Dense
Seam	Dense
Tool	Dense
Wife	Dense
Dot	Sparse
Kite	Sparse
Lip	Sparse
Map	Sparse
Mop	Sparse
Mare	Sparse
Mug	Sparse
Pear	Sparse
Rock	Sparse
Sash	Sparse
Tail	Sparse
Wall	Sparse
Weep	Sparse

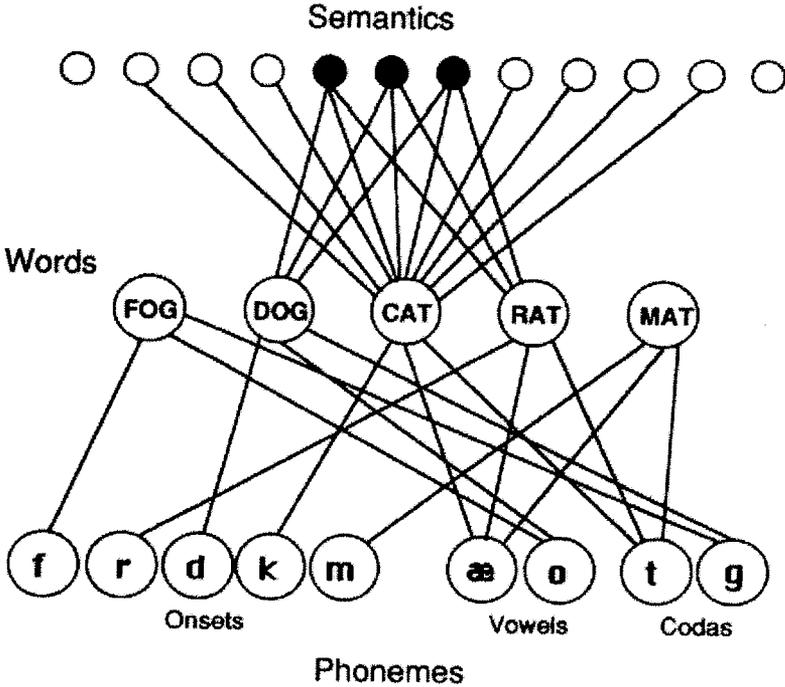
APPENDIX E: FLAG Task Stimuli – Images



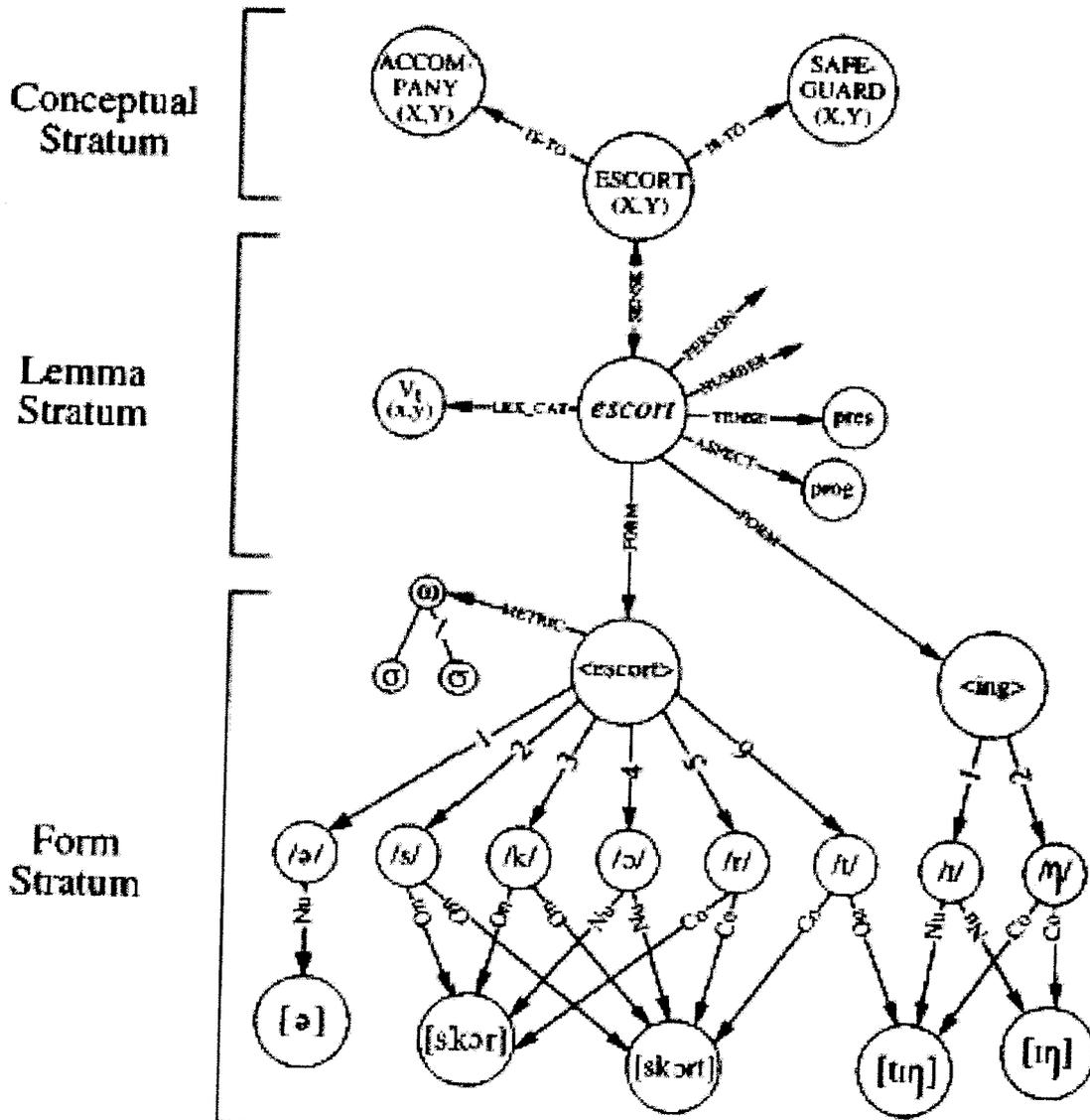
APPENDIX F: Simon Task Stimuli – Images



APPENDIX G: Dell, Chang, and Griffin's Aphasia Model of Lexical Access (1999)



APPENDIX H: Levelt, Roelofs, and Meyer's Model of Lexical Access (1999)



APPENDIX I: UBC Research Ethics Board Certificates of Approval



The University of British Columbia  
 Office of Research Services  
**Behavioural Research Ethics Board**  
 Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

## CERTIFICATE OF APPROVAL - FULL BOARD

<b>PRINCIPAL INVESTIGATOR:</b> Jeffrey A. Small	<b>INSTITUTION / DEPARTMENT:</b> UBC/Medicine, Faculty of/Audiology & Speech Sciences	<b>UBC BREB NUMBER:</b> H07-02085
<b>INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:</b>		
<b>Institution</b>	<b>Site</b>	
UBC	Vancouver (excludes UBC Hospital)	
<b>Other locations where the research will be conducted:</b> N/A		
<b>CO-INVESTIGATOR(S):</b> Jessica Ananda Casiro		
<b>SPONSORING AGENCIES:</b> University of British Columbia		
<b>PROJECT TITLE:</b> Lexical Access in Speech Production		
<b>REB MEETING DATE:</b> October 11, 2007	<b>CERTIFICATE EXPIRY DATE:</b> October 11, 2008	
<b>DOCUMENTS INCLUDED IN THIS APPROVAL:</b>		<b>DATE APPROVED:</b> November 6, 2007
<b>Document Name</b>	<b>Version</b>	<b>Date</b>
<b>Consent Forms:</b>		
Participant Information and Consent Form	2	October 23, 2007
<b>Advertisements:</b>		
Recruitment Flyer	2	October 23, 2007
<b>Questionnaire, Questionnaire Cover Letter, Tests:</b>		
Demographics form	2	October 23, 2007
<p>The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.</p>		
<p>Approval is issued on behalf of the Behavioural Research Ethics Board                  and signed electronically by one of the following:</p>		
<p>Dr. Jim Rupert, Associate Chair                  Dr. M. Judith Lynam, Chair                  Dr. Laurie Ford, Associate Chair</p>		