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THE EFFECTS OF AGE AND PROFICIENCY ON VERBAL MORPHOLOGICAL PROCESSING IN ENGLISH AS L1 AND L2

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“We keep moving forward, opening new doors, and doing new things because we´re curious and curiosity keeps leading us down new paths.”

Walt Disney

To my family, for the encouragement throughout these years.

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ABSTRACT

THE EFFECTS OF AGE AND PROFICIENCY ON VERBAL MORPHOLOGICAL PROCESSING IN ENGLISH AS L1 AND L2

MARIANA BEATRIZ PERRINO

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The linguistic focus of the present study is English verbal morphology. More specifically, regular and irregular verbs in English are the items under investigation. For the last 25 years, in the context of the past tense debate, dual-mechanism models and single-mechanism models of verbal morphological processing have presented evidence for the storage vs. composition theory and connectionist theory, respectively (Marslen-Wilson & Tyler, 1998). On the one hand, dual-mechanism models, such as the Declarative/Procedural Model, suggest that in English as L1, regular verbs are processed in procedural memory with the application of a rule, the addition of the –ed suffix, while irregular verbs are stored in declarative memory (Ullman, 2001, 2004, 2005). In English as L2, the D/P Model suggests that, at high proficiency levels, regular verbs are also processed in procedural memory whereas irregular verbs are stored in declarative memory (Ullman, 2001, 2004, 2005). In contrast, at beginning stages of L2 learning, regular and irregular verbs are stored in declarative memory (Ullman, 2001, 2004, 2005). Single-mechanism models, on the other hand, have presented evidence in favor of a connectionist theory of verbal morphological processing, in which regular and irregular verbs in English as L1are stored in associative memory, based on phonological and semantic connections (Joanisse & Seidenberg, 2005). In this context, the present study has 2 objectives: (1) to investigate the effects of age and proficiency on the processing of regular and irregular verbs in English as L1 and L2 in healthy adults; (2) to investigate the effect of individual differences on the processing of regular and irregular verbs in

English. Thirty one participants, 11 Brazilian advanced late bilinguals (Portuguese-English), 11 Brazilian beginner late bilinguals (Portuguese-English) and 9 native speakers of American English, were required to perform a battery of tasks. The following materials were employed in this study: (a) a background questionnaire; (b) two proficiency tests (KET / PET); (c) a frequency effects task of regular and irregular English verbal morphology (Pinker & Ullman, 2002; Prado & Ullman, 2009, VanderLely & Ullman 2001; Walenski, Mostofsky & Ullman, 2007); (d) a non-linguistic working memory task called "the letter-number ordering task" (Maurits, Bosch & Hugdahl, 2006; Tagarelli, Borges-Mota & Rebuschat, 2011; Wechsler, 1997); and (e) a non-linguistic inhibitory control task called "the Simon arrows task" (Bialystok, 2006; Bialystok, Craik & Luk, 2008). The frequency effects task was included with the objective of investigating if dissociations exist between the processing of regular and irregular English verb forms. The inhibitory control and working memory tasks were included with the objective of investigating whether individual differences, measured through these executive functions, have an effect on English verbal morphological processing. Results show that native speakers and late beginner bilinguals store regular and irregular verbs. Late advanced bilinguals store regular verbs and compute irregular verbs. These results are explained in terms of associative memory overload and the application of subregularities (Stockall & Marantz, 2006). The results obtained through the frequency effects task support single-mechanism theories of verbal morphological processing. Finally, the results of the present study show that individual differences did not influence participants´ performance on the frequency effects task of regular and irregular morphological processing.

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RESUMO

EFEITOS DA IDADE E DA PROFICIÊNCIA NO PROCESSAMENTO MORFOLÓGICO VERBAL EM INGLÊS COMO L1 E L2

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2012

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O foco linguístico do presente estudo é a morfologia verbal do inglês. Mais especificamente, os verbos regulares e irregulares são os itens investigados. Nos últimos 25 anos, no contexto do debate do tempo passado, os modelos de via dual e os modelos de via simples de processamento morfológico verbal têm apresentado evidência para a teoria de armazenamento vs. composição e a teoria conexionista, respectivamente (Marslen-Wilson & Tyler, 1998). Por sua vez, os modelos de via dual, como o Modelo Declarativo/Procedural, sugerem que no inglês como L1, os verbos regulares são processados na memória procedural com a aplicação de uma regra, a adição do sufixo –ed, enquanto os verbos irregulares são armazenados na memória declarativa (Ullman, 2001, 2004, 2005). Para o inglês como L2, o Modelo D/P sugere que no caso de aprendizes com alta proficiência, os verbos regulares também são processados na memória procedural enquanto os verbos irregulares são armazenados na memória declarativa (Ullman, 2001, 2004, 2005). Porém, no caso de aprendizes com baixa proficiência os verbos regulares e irregulares são armazenados na memória declarativa (Ullman, 2001, 2004, 2005). Em oposição aos modelos de mecanismos por via dual, os modelos de via simples têm apresentado evidencia a favor de uma teoria conexionista de processamento verbal morfológico, no qual os verbos regulares e irregulares no inglês como L1 são armazenados na memória associativa, baseada em conexões fonológicas e semânticas (Joanisse & Seidenberg, 2005). Neste contexto, o presente estudo tem 2 objetivos: (1) investigar os efeitos da

idade e da proficiência no processamento dos verbos regulares e irregulares no inglês como L1 e L2 em adultos saudáveis; (2) investigar o efeito das diferenças individuais no processamento dos verbos regulares e irregulares no inglês. Trinta e um participantes, 11 brasileiros bilíngües tardios avançados (português-inglês), 11 brasileiros bilíngües tardios iniciantes (português-inglês) e 9 falantes nativos de inglês americano foram reunidos para realizar uma bateria de testes. Os seguintes materiais foram utilizados no presente estudo: (a) um questionário geral; (b) 2 testes de proficiência em inglês (KET/PET); (c) uma tarefa de efeitos de frequência baseada na morfologia verbal do inglês (Pinker & Ullman, 2002; Prado & Ullman, 2009, VanderLely & Ullman 2001; Walenski, Mostofsky & Ullman, 2007); (d) uma tarefa não linguística de memória de trabalho, a tarefa de ordenação de letras e números (Maurits, Bosch & Hugdahl, 2006; Tagarelli, Borges-Mota & Rebuschat, 2011; Wechsler, 1997); (e) uma tarefa não linguística de controle inibitório, a tarefa Simon flechas (Bialystok, 2006; Bialystok, Craik & Luk, 2008). A tarefa de efeitos de freqüência foi incluída com o objetivo de investigar se existem dissociações entre o processamento das formas verbais regulares e irregulares em inglês. As tarefas de controle inibitório e memória de trabalho foram incluídas com o objetivo de investigar se as diferenças individuais têm algum efeito no processamento morfológico verbal. Os resultados mostram que os falantes nativos de inglês e os bilíngues tardios iniciantes armazenam os verbos regulares e irregulares na memória associativa. Os bilíngues tardios avançados, por sua vez, armazenam os verbos regulares e computam os verbos irregulares. Estes resultados são explicados em termos de um sobre carregamento da memória associativa e a aplicação de subregularidades (Stockall & Marantz, 2006). Os resultados obtidos por meio da tarefa de efeitos de frequência fornecem suporte aos modelos de via simples de processamento morfológico verbal. Finalmente, os resultados do presente estudo mostram que as diferenças individuais não afetaram os resultados da tarefa de efeitos de frequência.

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CHAPTER 1
INTRODUCTION

1.1 Preliminaries

It was in 1986, with the presentation of Rumelhart and McClelland connectionist single-mechanism model of regular and irregular English verbal morphology and with Pinker and Prince opposing answer to the former model in 1988, that the debate known as the Past Tense Debate began (Pinker & Ullman, 2002). This means that for the last 25 years, empirical evidence has been presented supporting, on the one hand, dual-mechanism models and their storage vs. composition theory of regular and irregular English verbal morphological processing and, on the other hand, single-mechanism models and their connectionist theory of regular and irregular English verbal morphological processing (Pinker & Ullman, 2002; Stockall & Marantz, 2006).

Although the distinction between regular and irregular forms can be found in different morphological pairs in different languages (Marslen-Wilson & Tyler, 1998; Marslen-Wilson, 2007; Pinker & Ullman, 2002; Woollams, Joanisse & Patterson, 2009), the investigation of this distinction has been more prominent in the study of regular and irregular past tense forms in the English language (Marslen-Wilson & Tyler, 1998; Marslen-Wilson, 2007; Pinker & Ullman, 2002; Woollams et al., 2009). The reason for centering the debate between dual and single-mechanism models in the past tense distinction of regular and irregular verbs in English is that it provides a marked contrast between a rule-based process and the random process of irregular formation (Marslen-Wilson & Tyler, 1998; Marslen-Wilson, 2007; Pinker & Ullman, 2002; Woollams et al., 2009). The past forms of regular verbs in English are produced by adding the inflectional suffix –ed to the stem. As a result of this rule application, a decomposable new form is created (Marslen-Wilson, 2007). On the other hand, the past forms of irregular verbs in English change phonologically into a non-decomposable new form (Marslen-Wilson, 2007).

As regards the learning and processing of regular and irregular forms, both single and dual-mechanism models agree in that irregular past forms are acquired, stored and processed as non-decomposable forms by means of a network of connections, in declarative memory according to dual-mechanism models and in associative memory

according to single-mechanism models (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; Pinker & Ullman, 2002; Ullman, 2001; Ullman, 2004; Woolams et al., 2009). However, for the learning and processing of regular verbs, single-mechanism models stick to the connectionist view and claim that regular verbs, like irregular verbs, are learned, stored and processed by means of connections based on phonological and semantic proximity (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al., 2009). On the other hand, dual-mechanism models suggest that regular verbs, unlike irregular verbs, are learned and processed as decomposable forms by a concatenation rule (Alegre & Gordon, 1999; Newman, Ullman, Pancheva, Waligura & Neville, 2007; Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz & Pinker, 1997, Van der Lely & Ullman, 2001; Ullman, 2004; Ullman, 2005).

In 2009, when I decided to pursue my Masters at PPGI (Programa de Pós Graduação em Inglês) at UFSC, in the first discipline I took as an auditing student called "The Bilingual Brain", I came across with Newman et al. (2007), who presented electrophysiological evidence in favor of the Declarative and Procedural Model in the context of dual-mechanism theories of storage vs. composition. I kept on reading more articles on the topic, including articles presenting opposing views in the context of single-mechanism models like Woollams et al. (2009).

What called my attention in the literature investigating verbal morphological processing was the fact that, although both single and dual-mechanism theories mentioned the influence of age on language processing, I could not find any study investigating the effects of this factor on verbal morphological processing in English as a first or second language in older speakers in particular, taking into consideration the influence of individual differences. With the purpose of addressing this gap in the literature, the present study investigates the effects of age and proficiency and the influence of individual differences on verbal morphological processing in English as L1 and L2 by adult speakers.

1.2 The present study

The main objective of the present study was to investigate the morphological processing of regular and irregular verbs in English as a first and second language in adult speakers. More specifically, the study aimed at investigating (1) the influence of 2 variables, age and

proficiency, on verbal morphological processing, and (2) the relationship between this processing and individual differences.

To accomplish the first objective of the present study, a frequency effects task of regular and irregular verb production was designed, programmed and applied to the participants of the study. To control for age, participants needed to be above 50 years old, and to control for proficiency, two proficiency tests were applied.

To accomplish the second objective of the present study, two measures of individual differences were designed, programmed and applied. One of them, the Simon arrows task, assessed inhibitory control (Bialystok, 2006; Bialystok et al., 2008), and the other one, the letter-number ordering task, assessed working memory capacity (Maurits et al., 2006; Tagarelli et al., 2011; Wechsler, 1997).

The three groups of participants that were required to perform a battery of tasks were: (1) 11 native speakers of Brazilian Portuguese, late bilinguals, beginner speakers of English as a second language, (2) 11 native speakers of Brazilian Portuguese, late bilinguals, advanced speakers of English as a second language and (3) 9 native speakers of American English.

At this point, it is important to mention that for practical reasons no distinction will be made between second and foreign language in this study. Although I agree with Ellis (1998) in that there are differences between second and foreign language learning, both as regards what is learnt and how it is learnt, I believe that the complexity of the various linguistic situations of the contemporary world and the many different language use and learning conditions related to these situations cannot be accounted for by the second / foreign language distinction anymore, as Cook (1999) has wisely pointed out. Thus, considering that the distinction between these two terms is "far from transparent" (Cook, 1999), I will adopt the term "second language" to refer to a language that was acquired after the acquisition of a first language.

1.3 Significance of the research

The present study is significant in that it brings new data from a sample that has been excluded from the discussion and research going on for 25 years concerning the distinction between the claims of single and dual-mechanism models of language processing. Moreover, most of the studies that take into account the connections between the cognitive aspects of bilingualism and aging have focused on native English-speaking participants (Bialystok, Craik, Klein & Viswanathan, 2004).

The present study contributes with data from native speakers of Portuguese who have English as a second language.

In addition, in the present study we gathered data and arrived to conclusions as regards regular and irregular verbal morphological processing in English as L1 and L2. This is important in that it is difficult to get to conclusions as regards the differences or similarities between L1 and L2 processing with results from different studies, carried out in different contexts, focusing on different variables. In the present study, comparisons between L1 and L2 processing are possible and reliable because the same variables have been taken into consideration and the same methodological conditions have been followed.

Furthermore, the line of research investigating verbal morphological processing as L1 or L2 has not taken into consideration the possible interaction between morphological processing and the individual differences in inhibitory control and working memory. This study considers the possible influence of these two cognitive individual difference variables in the processing of inflectional verbal morphology.

1.4 Organization of the thesis

The present thesis consists of 5 Chapters. Chapter 1 is the Introduction of the thesis and presents the preliminaries, the objectives, the significance of the study and the organization of the thesis.

Chapter 2, the Review of the Literature, presents the previous theoretical and experimental research that was found to be most relevant for the present study. In this Chapter the theories of verbal morphological processing, as well as empirical studies in L1 and L2 in favor of each theory are introduced. Previous literature concerning the method of frequency effects in L1 and L2 research are also included in Chapter 2. Finally, a discussion on the measures of individual differences, inhibitory control and working memory capacity, is presented.

Chapter 3 details the method followed to carry out this study. In this Chapter, the research questions are presented and the participants are described. The materials used, including the frequency effects task, the Simon arrows task and the letter-number ordering task are also detailed, as well as the procedures, the data analysis and the pilot study.

Chapter 4 presents the results obtained from data collection. Descriptive and inferential statistics were run and the results of these

statistical tests are discussed. Also, the answers to the research questions are provided.

Finally, Chapter 5 reports the conclusions drawn from the results obtained in the present study. Furthermore, the limitations of the study and some future directions are presented. Methodological and pedagogical implications are also pointed out.

CHAPTER 2
REVIEW OF THE LITERATURE

The objective of this Chapter is to provide the theoretical and empirical context of investigation of the present study. The relevant previous studies addressing English verbal morphological processing as L1 and/or L2 will be described here. This Chapter is divided into 4 main sections. Section 2.1 will present two theories of English verbal morphological processing. Section 2.2 will report on the previous frequency effects studies relevant to the present study. Section 2.3 will review previous studies on cognitive aging. Section 2.4 will introduce the concept and related studies on inhibitory control and finally, section 2.5 will present the concept of and related studies on working memory.

2.1 Theories of verbal morphological processing

2.1.1 Dual-mechanism models: The Declarative and Procedural Model from a first language perspective

As the name suggests, dual-mechanism models propose that morphological learning and processing depend on two distinct systems: a rule computation system to learn and process regular forms and an associative memory system to learn and process irregular forms (Marslen-Wilson, 2007; Pinker & Ullman, 2002). These models focus on the distinction between the storage of irregular morphological forms vs. the computation of regular morphological forms and on the non-decomposition nature of irregular items and the decomposition nature of regular items (Marslen-Wilson, 2007; Pinker & Ullman, 2002).

In this study, I will focus on one dual-mechanism model in particular, the Declarative and Procedural Model proposed by Ullman et al. in 1997 to account for L1 acquisition and processing. According to this dual-mechanism model, language relies on two mental abilities, the mental lexicon and the mental grammar (Pinker, 1994). On the one hand, the mental lexicon is made up of all words, arbitrary sound-meaning pairings, as well as smaller or larger structures, such as bound morphemes and idiomatic phrases (Ullman et al., 1997; Ullman, 2001, 2004, 2005). On the other hand, the mental grammar includes the rules necessary to make well formed combinations of lexical forms and allow

us to interpret those complex combinations (Ullman et al., 1997; Ullman, 2001, 2004, 2005).

The Declarative / Procedural Model binds lexicon and grammar to two brain memory systems, the declarative and procedural memory systems, respectively (Ullman et al., 1997; Ullman, 2001b, 2004, 2005). Declarative memory is claimed to be partially explicit, i.e., it is partially "available to conscious awareness" (Ullman, 2005, p. 143), and is subserved by medial temporal lobe regions, such as the hippocampus, which are closely connected to temporal and parietal neocortical regions (Suzuki & Amaral, 1994 as cited in Ullman, 2005). Procedural memory, on the other hand, is termed implicit because neither the learning nor the remembering processes are available to conscious awareness (Ullman, 2005). In other words, procedural memory "is associated with unconscious, automatic, or indirect processes" (Dörnyei, 2009, p. 135). Procedural memory "depends on multiple brain systems" (Squire, Knowlton & Musen, 1993, p.471), but is mainly settled in the frontal lobes and basal ganglia (Ullman, 2005).

Focusing on the linguistic items being investigated in the present study, the D/P Model assumes that in healthy native speakers of English irregular verbs are stored in the mental lexicon, as part of the declarative memory system (Alegre & Gordon, 1999; Newman et al., 2007; Ullman et al., 1997, Van der Lely & Ullman, 2001). On the other hand, regular verbs are processed in the mental grammar, as part of the procedural memory system (Alegre & Gordon, 1999; Newman et al., 2007; Ullman et al., 1997, Van der Lely & Ullman, 2001).

Research supporting dual-mechanism models has provided electrophysiological, neuroimaging and behavioral evidence, as well as evidence from developmental disorders. In relation to electrophysiological evidence, Newman et al. (2007) carried out an event related potential (ERP)[1] study of regular and irregular English past tense inflections. Newman et al. (2007) recorded ERPs form 26 native English-speaking American males while they were reading correct sentences or sentences which violated the regular past tense inflection,

[1] ERP´s are obtained by placing electrodes in participants´ scalps and connecting them to an amplifier that records the voltage variation between electrodes (Kaan, 2007). The variation is also known as the Electro-encephalogram (Coles & Rugg, 1995). With the presentation of a stimulus and the recording of the EEG, a waveform, signifying the differences in voltage between electrodes appears in the EEG right after the presentation of the stimulus and is therefore associated to the processing of such stimulus (Coles & Rugg, 1995). It is the variations in voltage, recorded by the EEG after the presentation of a stimulus that is known as the Event Related Potential or ERP (Coles & Rugg, 1995).

the irregular past tense form, the syntactic structure or the lexical structure in English. The results of Newman et al. (2007) showed that regular past tense violations elicited a left anterior negativity (LAN), which is usually found in violations in grammar (Kaan, 2007) followed by a late positivity (P600), which is usually found in "syntactically incorrect or non-preferred continuations of sentences" (Kaan, 2007, p.580). Irregular past violations only elicited a P600 (Newman, 2007). The presence of a LAN component only in the data for the processing of regular verb violations suggests a difference between the processing of regular and irregular verbs in English as L1 (Newman et al., 2007). For syntactic structure violations a LAN and a P600 were elicited again, but an N400, which is expected for words which are semantically strange in relation to the previous context (Kaan, 2007), was elicited for semantic structures violations. In conclusion, the results in Newman et al. (2007) suggest that dissociations exist between lexicon and grammar in first language acquisition.

Contributing with neuroimaging evidence, Rhee, Clark, Casasanto, Ullman, Wagner & Pinker (2001), conducted an fMRI study with the aim of localizing the neural substrates responsible for the processing of regular and irregular verbs. Sixteen native speakers of English were scanned while producing the past tense form of regular and irregular verbs. The results showed activation of Brodmann´s area 44 for the production of regular verbs which, according to Ullman (2004), "plays an important role in the procedural memory system" (p. 239). Moreover, for the production of irregular verbs, the results of Rhee et al. (2001) showed activation of Brodmann´s areas 44 and 45 which, according to Ullman (2004), "play a role in the encoding of new memories and the selection or retrieval of declarative knowledge" (p. 236), and also Brodmann´s areas 9/49 which, according to Rhee et al. (2001), are implicated with the inhibition of the rule application. Therefore, the results found in Rhee et al. (2001) suggest that the production of regular and irregular verbs in English as L1 activate different brain areas associated to procedural memory and declarative memory functioning, respectively (Ullman, 2001).

As regards developmental disorders, as evidence for dual-mechanism models, Ullman et al. (1997) observed the behavior of a population with five different disorders concerning the generation of regular and irregular verbs. Ullman et al. (1997) presented a list of regular, irregular and nonce verbs to a group of 24 Alzheimer patients, 6 posterior aphasics, 28 Parkinson patients, 6 anterior aphasics and 17 Huntington patients, asking them to produce the past tense form of each

item. Ullman et al. (1997) expected to find more difficulty in the production of irregular verbs in Alzheimer patients and posterior aphasics since they normally present impairments of their lexical memory caused by lesions in temporal and temporo-parietal regions (Ullman et al., 1997). On the other hand, difficulty with the production of regular and nonce verbs was expected with Parkinson patients and anterior aphasics since they normally present impairments of motor and grammatical functions because of lesions in the basal ganglia area (Ullman et al., 1997). Finally, with Huntington patients, overregularization of irregular verbs was expected since these patients have lesions in the basal ganglia area as well as Parkinson patients and anterior aphasics, but the lesion in Huntington patients cause an "excess excitation" (Ullman et al., 1997, p.273) in motor and grammatical functions. All the hypotheses were confirmed in this study. Consequently, results from Ullman et al. (1997) suggest that lesions in temporal and temporo-parietal regions cause problems with the production of irregular verbs, while lesions in the basal ganglia cause problems with the production of regular and nonce verbs. These results are understood as evidence that in English as L1

> "the lexicon is part of a temporal-parietal/medial-temporal declarative memory system and that grammatical rules are processed by frontal/basal ganglia procedural system" (Ullman et al., 1997, p. 266).

All studies considered, it can be concluded that the hypotheses presented by the Declarative and Procedural Model are well studied, from different perspectives, with the application of varied and reliable methods and with different populations. In the next sub-section, 2.1.2, studies also providing evidence in favor of the Declarative and Procedural Model will be reviewed from a second language perspective.

2.1.2 Dual-mechanism models: The Declarative and Procedural Model from a second language perspective

In the case of second language learning, a key factor for dual-mechanism models´ theories is the influence of age. The D/P Model makes different claims and predictions for late-learned L2 than for L1 and early-learned L2 (Ullman, 2001, 2004, 2005). After puberty, problems with the acquisition of grammatical structures in procedural memory appear as opposed to the improvements in declarative memory (Ullman, 2004, 2005). This can be explained by the increasing levels of

estrogen in the transition of childhood / adolescence, which inhibit the procedural memory system and enhance declarative memory (Ullman, 2004). As a result of these alterations, young adults who are learning a second language usually rely more on their declarative memory system, memorizing complex linguistic forms, which are commonly computed in L1 (Ullman, 2005). However, this deficiency in procedural memory can be overcome by means of practice and experience with the L2 (Ullman, 2001, 2005). Therefore, proficiency is another key factor in the processing of a second language, since the deficiency in procedural memory caused by age can be gradually overcome with practice and experience in the language.

Focusing again on the linguistic items being investigated in the present study, but this time from a second language perspective, according to the D/P Model, at the beginning stages of the learning of English as a second language, both regular and irregular verbs depend on the declarative memory system. Nevertheless, as proficiency increases, the dissociations between what is stored and what is computed by the rule start to appear. Therefore, advanced learners of English as a second language store only irregular verbs in declarative memory and compute the rule of regular verbs in procedural memory (Ullman, 2001, 2004, 2005).

As evidence for the hypotheses established by the D/P Model for L2 processing, the results of some aphasia studies, like Ku, Lachmann & Nagler (1996) and Fabbro and Paradis (1995) are relevant to be mentioned. Ku et al. (1996) studied a Chinese-English bilingual who suffered from herpes simplex encephalitis which caused lesions in his left temporal lobe. He was impaired to speak or comprehend English but could communicate and understand his first language. This was taken as evidence supporting the hypothesis that L2 depends mostly on declarative memory, which is based on left temporal brain structures. On the other hand, Fabbro and Paradis (1995) reported results from 4 aphasics with lesions in the left basal ganglia. They showed more grammatical problems in their native languages or highly proficient second languages than in their less proficient second languages. This was taken as evidence supporting the hypothesis that the grammar of less proficient second languages rely more on declarative memory and that as proficiency gets higher grammar moves to procedural memory bases.

As neuroimaging evidence to the hypotheses of the D/P Model of L2 processing, Optiz and Friederici (2003) carried out an fMRI study with 17 participants learning an artificial language. At the beginning of

the learning process of the grammar of the artificial language, the hippocampus showed major activation, but as proficiency increased, activation in the left inferior frontal gyrus started to appear. This was interpreted as evidence suggesting that at the beginning stages of grammar learning, declarative memory plays a major role, and that as proficiency increases, grammar starts moving to procedural memory bases.

Electrophysiology also contributed to the D/P Model. Hahne (2001) presented a study in which she collected ERP data from 16 native speakers of German and 16 native speakers of Russian with German as an L2. The participants were presented with semantic and syntactic violations in German. The first kind of violation elicited the N400 component in both language groups and the second kind of violation elicited LANs and P600s in the native speakers but not in the second language learners. In the L2 group there were no LANs elicited and there were P600s but were qualitatively different from the ones found in the native speakers. The results of Hahne´s (2001) study suggest that lexical processing shows no difference in L1 and L2 while grammatical processing does show a difference between L1 and L2 processing. Such results coincide with the D/P Model hypotheses which suggest that

> "ERP components associated with grammatical processing and left frontal structures in L1 should be absent or modified in L2 speakers. In contrast, ERP effects associated with lexical-conceptual processing and temporal lobe structures should differ minimally if at all between L1 and L2" (Ullman, 2001, p. 114).

As regards behavioral measures of cognitive organization of regular and irregular English morphology, Birdsong and Flege´s study (2001) is worth describing. They gathered a group of 30 native speakers of Spanish and 30 native speakers of Korean, all of which were proficient speakers of English as a second language. The participants were presented with 80 multiple-choice sentences with verbs or plural nouns as target items. They found that higher age of arrival to the U.S. affected more irregular items than regular items and that frequency effects were found only in the processing of irregular items. These results are in line with the claims of dual-mechanism models concerning ultimate attainment in English as a second language.

Considering the studies reviewed in this sub-section, it can be concluded that verbal morphological processing from a second language perspective has also been well studied and that the Declarative and

Procedural Model has found evidence in favor of the hypotheses presented in relation to second language verbal morphological processing. In the next sub-section, 2.1.3, the theory and evidence supporting verbal morphological processing will be presented from a single-mechanism model perspective of L1 processing.

2.1.3 Single-mechanism models from a first language perspective

The connectionist perspective, or single-mechanism model to language learning and processing, suggests that rule-based processes and the random process of irregular formation depend on a single computational system, a network of connections based on phonological and semantic proximity (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al., 2009). Therefore, according to this view, there is no distinction between what is stored and what is computed, because even rule-based processes are learned, stored and processed in a single computational associative memory system (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al., 2009). The neural correlate of the learning and processing of the network of connections proposed by single-system models is the Inferior Frontal Gyrus, which is involved in phonological processing (Joanisse & Seidenberg, 2005). Research supporting single-mechanism models have focused on providing simulation evidence. However, there are also some neuroimaging and behavioral evidence, as well as evidence from developmental disorders in favor of single-mechanism models.

Joanisse and Seidenberg (1999) presented a simulation study in response to Ullman et al.´s study (1997) reviewed in sub-section 2.1.1. In this simulation model, Joanisse and Seidenberg (1999) argued against the claim that patients tested in Ullman et al.´s study (1997) had trouble in the generation of regular or irregular verbs because each form was processed in different ways, by rules of grammar and associations of the lexicon. Instead, in Joanisse and Seidenberg´s (1999) view, the patients presented damages in the phonological or semantic representations of a single lexical processing mechanism (Ullman, 2001c). According to Joanisse and Seidenberg (1999), to produce the past form of an irregular verb, the subject needs to recognize the stem of the verb as an irregular lexical item to then produce its past form. If the semantic representation is damaged, then patients suffering from Alzheimer´s Disease or

Posterior Aphasia have trouble in producing irregular verbs because they cannot recognize them as irregular lexical items and then the default transformation of the past tense ,-ed, is applied (Ullman, 2001c). On the other hand, to produce the past form of a regular verb, the semantic representations identify them as a regular lexical item and the phonological representation –ed allows their generation as a regular verb form. However, with damage to phonology, patients suffering from Parkinson´s Disease or Anterior Aphasia have trouble in generating novel verbs since they do not have meaning and "the only way to generate its past tense is by analogy to know their phonological forms" (Joanisse & Seidenberg, 1999, p. 7593).

Joanisse and Seidenberg (1999) simulated damage to the phonological or semantic representations of a single lexical processing system. They found that the system had trouble in producing irregular verb forms when the semantic representation was impaired and that the system had trouble in producing the past form of novel verbs when the phonological representation was impaired. They interpreted this simulation results as evidence supporting single-mechanism models of regular and irregular verbal morphological processing, which is influenced by its semantic and phonological representations.

Joanisse and Seidenberg (2005) obtained fMRI imaging data from 10 English speaking participants. The past tense generation task applied consisted of 60 stimuli of which 16 were nonwords, 16 were regular verbs, 16 were true irregular verbs (irregular verbs which do not have phonological similarities with regular verbs) and 12 were pseudoregulars (irregular verbs which share some phonological characteristics with regular verbs). The participants heard a verb in the infinitive or a nonword and were instructed to think of the past form of that verb.

Results showed that when regular verbs and non words were compared to true irregular and pseudoregular verbs, the only difference of activation appeared in the IFG, which was more activated for the processing of regular verbs and nonwords. These differences of activations in the IFG continued to appear when regular verbs and nonwords were compared only to true irregular verbs. However, when regular verbs and nonwords were compared to pseudoregular verbs, the advantage of activation for regular verbs and nonwords was also reached by pseudoregulars creating a similar pattern of activation. In sum, the imaging results were interpreted by Joanisse and Seidenberg (2005) as supporting connectionist theories of English verbal morphological processing since the greater activation of the IFG was involved in

phonological processing of nonwords, regular verbs and pseudoregular verbs, rather than the application of the past tense regular rule to such forms.

In relation to developmental disorders evidence, Patterson, Lambon Ralph, Hodges & McClelland (2001) provided empirical evidence on the relationship between semantic impairments and problems in the production of irregular verbs and Bird, Lambon Ralph, Seidenberg, McClelland & Patterson (2002) provided empirical evidence on the relationship between phonological deficits and problems in the production of regular verbs. Patterson et al. (2001) applied generation and recognition tasks with 113 regular, irregular and nonce verbs to 11 patients with semantic dementia, characterized by impairments with semantic knowledge. Based on single-mechanism models of regular and irregular verbal morphological processing, Patterson at al. (2001) predicted that these patients would present more problems generating and recognizing irregular verbs than regular and nonce verbs, since irregulars depend on semantic representations for their generation and identification. This is exactly what Patterson, et al. (2001) found. The patients participating in their study presented an accuracy from 10 to 20% when generating and recognizing irregular verbs and an accuracy of 70 % when generating and recognizing regular verbs.

Bird et al. (2002) studied the connection between difficulties in the production of regular verbs and phonological deficiency. They tested 10 non-fluent aphasic patients first in a regular and irregular verbal production, repetition and reading task and then in a same-different recognition task. In the regular and irregular verbal production, repetition and reading tasks, the patients showed better performance for irregular verbs than for regular verbs, with mean accuracy percentages of 37 and 20, respectively for production, 68 and 47, respectively for repetition and 44 and 24, respectively for reading (Bird et al., 2002). In the same-different recognition task, the same 10 patients listened to pairs of stems and their respective regular past forms such as mix/mixed and also to pairs of semantically unrelated words but with the same phonological distinction of past tense regular verbs, such as coal/cold. The patients showed similar difficulties in identifying the difference between the regular verb stem and their past form and between the words semantically and morphologically different. These results were interpreted by Bird at al. (2002) as evidence of a phonological deficiency, not a morphological deficiency leading to difficulties with regular verbs over irregular verbs.

Considering the line of research reviewed in this sub-section, it can be concluded that single-mechanism models also have a sound body of evidence supporting the hypotheses they present as regards first language verbal morphological processing. In the next sub-section, single-mechanism models´ research on verbal morphological processing from a second language perspective will be described.

2.1.4 Single-mechanism models from a second language perspective?

To the best of my knowledge, the line of research presenting evidence in favor of connectionist verbal morphological processing has not presented evidence for second language processing yet. There are some studies that contradict the hypotheses of the D/P Model concerning the dependence of the lexicon and grammar on declarative memory at beginning levels of proficiency in L2 procesing with a proceduralization of grammar as proficiency and experience in the L2 increases.

For instance, Klein (1995), Klein (1999) and Abutalebi and Perani (2005) suggest that the L1 and L2 share the same neural substrates, the lexicon of L1 and L2 rely on left temporal areas and the grammar of L1 and L2 on Broca´s regions. They added that the only reason why some studies have found some variance on the degree of neural activation of Broca´s area is because of differences participants had in age of acquisition or proficiency (Abutalebi & Perani, 2005). However, these pieces of research cannot be taken as evidence for connectionist models since they recognize the dependence of lexicon and grammar on two separate systems. Klein (1995), Klein (1999) and Abutalebi and Perani (2005) just do not agree with the D/P Model in the hypotheses of grammar being dependent on declarative memory at beginning levels of proficiency in the L2. They present evidence suggesting that even at beginning levels of proficiency, grammar is processed in Broca´s area in L2 as well as in L1.

Therefore, research testing the hypotheses made by connectionist theories and presenting evidence in favor of single mechanism-models as regards verbal morphological processing in L1 (see Bird et al., 2002; Joanisse and Seidenberg, 1999; Joanisse and Seidenberg, 2005; Patterson et al., 2001, among others) have not included studies on second language processing. In the next section, studies carried out with the method implemented in the present study, that of frequency effects, will be reviewed from dual and single-mechanism perspectives in L1 and L2.

2.2 Frequency effects studies

A good and widely used method to investigate the distinction between the storage and composition of regular and irregular morphology is that of frequency effects (Bowden, 2007; Bowden, Gelfand, Sanz, & Ullman, 2010; Brovetto, 2002; Pinker & Ullman, 2002). The validity of this method has been demonstrated in several studies suggesting that, in the context of dual-mechanism models, irregular forms of high frequency use would differ from irregular forms of low frequency use as regards accuracy and time response because they are retrieved from memory (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Pinker & Ullman, 2002). Therefore, high frequency irregular forms are retrieved from memory faster and more accurately than low frequency irregular forms. Regulars, being computed and not retrieved from memory, would show no differences in the time response and accuracy with high or low frequency use (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Pinker, 1994; Pinker & Ullman, 2002).

Examples of studies carried out with the method of frequency effects of regular and irregular verbal production investigating the English language as L1which found evidence supporting dual-mechanism models are Van Der Lely and Ullman (2001), Walenski et al. (2007) and Prado and Ullman (2009), among others. Prado and Ullman (2009) investigated the response times of regular and irregular verbal production of 72 native speakers of English. The results showed frequency effects for the production of irregular verbs but not for the production of regular verbs. These results were interpreted by Prado and Ullman (2009) as evidence suggesting that only irregular verbs are stored in declarative memory and that regular verbs are computed online in procedural memory.

Brovetto´s unpublished doctoral study (2002) provided evidence supporting dual-mechanism theories by investigating English as a second language verbal morphological processing. She carried out a behavioral study analyzing frequency effects with two variables: accuracy and response time. Ninety-eight adult participants, being 32 native speakers of Chinese with English as a second language, 33 native speakers of Spanish with English as a second language and a control group of 33 native speakers of English were required to perform sentence-completion tasks in English using an inflected (past or plural) form. Native speakers of Spanish also had to perform the tasks in Spanish. L1 speakers showed frequency effects, only for irregular

inflections, therefore memorizing just this kind of forms. On the other hand, the L2 groups, consisting of late learners, showed frequency effects for both irregular and regular inflected forms, therefore memorizing both forms (Brovetto, 2002).

However, if it is the case that single mechanism models are correct, frequency effects would be found in the processing of both regular and irregular verbs. This is so in that regulars as well as irregular verbs depend on a single computational system, a network of connections based on phonological and semantic proximity (Woollams et al., 2009).

Woollams et al. (2009) provided supporting evidence to the connectionist theory of language processing based on the findings of the Picture Inflection Task in opposition to the findings of the Stem Inflection Task. The latter task, the Stem Inflection Task, consists of the presentation of written or spoken verb stems to elicit the past tense form of the verbs presented. The results of the Stem Inflection Task have shown regularity effects[2], which have been taken as evidence supporting dual-mechanism theories to suggest that regular and irregular verbs depend on distinct cognitive processes. The aim of the study by Woollams et al. (2009) was to analyze if the regularity effects found in the Stem Inflection Task persisted when the stimuli was a motion picture (Picture Inflection Task) rather than a verb stem, i.e., when the past tense is generated from meaning and not from form.

Woollams et al. (2009) obtained data from 24 participants, native speakers of English. They were divided into two groups, so that 12 performed the Stem Inflection Task and 12 performed the Picture Inflection Task. Both tasks consisted of 30 regular verbs, half of which were of high frequency use and half of low frequency use, and 30 irregular verbs, half of which were of high frequency use and half of low frequency use. For both tasks participants were asked to produce the past tense form of either the verb stems or the motion pictures presented.

Dual-mechanism models would predict for the Stem Inflection Task and the Picture Inflection Task, first the activation of the stem verb, then the retrieval of the past tense form of irregular verbs from the lexicon blocking the application of the default or production of the past tense form of regular verbs by application of the rule (Woollams, et al., 2009). Therefore, according to this last view, regularity effects would be present even in the generation of past forms from the pictures. On the other hand, the connectionist theory would predict that the regularity

[2] Regularity effects are "longer response times and/or lower accuracy for irregular than for regular verbs, particularly for lower-frequency items" (Wollams et al., 2009, p. 56).

effects found in previous studies applying the Stem Inflection Task would disappear in the Picture Inflection Task. This is so because as a picture, not a verb stem was provided as stimuli in the Picture Inflection Task, the lexical representation of the stem will not be activated. Therefore, in the Picture Inflection Task, from the connectionist perspective, the semantic representation of the action portrayed in the picture (for example cooking or singing) is activated and then the phonological representation of the past form of the action is activated (for example cooked or sang) (Woollams et al., 2009).

Results showed that the regularity effects found in the Stem Inflection Task disappeared in the Picture Inflection Task corroborating the Connectionist predictions. However, as response times for all verbs in the Picture Inflection Task were significantly slower than for the verbs in the Stem Inflection Task and some motion pictures elicited erroneous verbs, the experiment was carried out again with 24 new participants. The only difference between the two experiments was that a familiarization session was added before the actual experiment, in which the motion pictures used were presented with their respective stem verbs. The results of this familiarization session were reduced response times and reduced confusions in the generation of the past forms of the verbs represented by the motion pictures. Still, regularity effects predicted by the dual-mechanisms model did not appear in the Picture Inflection Task.

From the revision in this section, it can be noticed that dual-mechanism models have received support from studies with the method of frequency effects in favor of the hypotheses they propose as regards English verbal morphological processing in L1 and L2. However, although single-mechanism models have presented sound evidence in favor of their connectionist perspective in L1 verbal morphological processing with a frequency effects approach, there is a gap in their body of evidence since no studies have been published on L2 English verbal morphological processing. In the next section, theory as regards cognitive decline in older people will be described.

2.3 Cognitive aging

As the main objective of the present study was to investigate the influence of age and proficiency on verbal morphological processing of regular and irregular verbs in English as a first and second language in healthy adult participants (from 50 years old onwards), the basics of cognitive aging theoretical background was included in this section.

Cognitive aging is the study of the changes in cognitive processing as a function of age (Bialystok et al., 2004). Therefore, the general question addressed by cognitive aging researchers is "What happens to the cognitive system as we get older? (Park, 2000, p. 3). According to McDowd and Hoffman (2008), the study of cognitive aging started in the 1920s with the applied purpose of understanding the extent to which sensory and motor abilities declined in older workers. Nowadays, the major goal of the study of cognitive aging is to gather data about the characteristics of the aging mind to turn that information into new directions towards preserving and even improving older adults´ quality of life (McDowd & Hoffman, 2008).

According to Luszcz and Lane (2008), executive functioning is the cognitive construct that enables the elucidation of the process of cognitive decline due to aging. Luszcz and Lane (2008) defined executive functions as "a range of mental processes associated with neurological integrity of the brain" (p. 195). Moreover, Diamond (2006) and Bialystok (2006) pointed out the conscious component of executive functions, since they involve intentional processing.

In the current literature, there are three mechanisms or abilities that constitute the cognitive construct of executive functions which decline with age: (1) working memory, (2) inhibitory control and (3) task switching or cognitive flexibility (Craik & Bialystok, 2006; Diamond, 2006; Feng et al., 2009; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000; Park, 2000; Verhaeghen & Cerella, 2008). These different mechanisms of executive control are considered as measures of individual differences of age-related changes since "people grow older at different ways and at different rates" (Hertzog, 2008). This is the reason why, in the design of the present study, with the main objective of investigating the morphological processing of English verbs in older participants, two measures of executive function abilities are included: to eliminate the hypothesis that the results of the frequency effects task would be influenced by individual differences in speed and accuracy of processing.

Studies merging measures of specific cognitive processes and measures of individual differences, as is the case of the present study, are considered by Hertzog (2008) as "desirable but rare" (p. 35). Moreover, the need to include measures of individual differences in studies investigating cognitive processing in middle adulthood is stressed by Old & Naveh-Benjamin (2008), since according to these researchers variation of cognitive processing abilities in this period is subdivided into "stablers", "decliners", and "gainers" (p.152).

In the following sections, the 2 executive functions measured in the present study, inhibitory control and working memory, will be reviewed.

2.4 Inhibitory control

Inhibitory control is one of the executive functions which shows decline with age (Craik & Bialystok, 2006; Diamond, 2006; Ferg et al., 2009; Hasher & Zacks, 1988; Miyake et al., 2000; Park, 2000; Verhaeghen & Cerella, 2008). According to Hasher and Zacks (1988), inhibitory control is the ability to focus on important information and to be able to inhibit irrelevant information. Diamond (2006) described inhibitory control in terms of focusing and inhibiting distraction. Moreover, Diamond (2006) added to the concept of inhibitory control the ability "to resist making one response and instead make another" (p. 70), which is the formula to perform the Simon arrows task, the task chosen to measure inhibitory control in the present study. The Simon arrows task will be described in 3.3.6 in Chapter 3.

As an inhibitory control task, the Simon arrows task, was included in the design of the present study as a measure of individual differences (McDowd & Hoffman, 2006). The purpose was to investigate if there is a correlation between performance in the frequency effects task and performance in the Simon arrows task. In other words, the objective of the inhibitory control task was to investigate if inhibitory control affects performance in the frequency effects task. The existence of a correlation between performance in the frequency effects task and the Simon arrows task would mean that individual differences are influencing the results in the frequency effects task. On the other hand, the lack of correlation between the 2 tasks would mean that the results of the frequency effects task are only influenced by the nature of the English language, not by individual cognitive differences between the participants. To the best of my knowledge, there are no studies on verbal morphological processing taking into consideration the influence of individual differences in the results, as measured by inhibitory control tasks.

2.5 Working memory

As inhibitory control, working memory capacity is considered to be another executive function which shows decline due to age (Craik, 2000; Diamond, 2006; Ferg et al., 2009; Miyake et al., 2000;). Baddeley and Hitch (1974) introduced the concept of working memory as a cognitive construct by means of which human beings have the ability to

store and process information, while executing a complex cognitive task (as cited in Bergsleithner, 2007). This is the concept behind the letter-number ordering task, the task chosen to measure the working memory capacity of the participants of the present study. The letter-number ordering task will be detailed in 3.3.5, Chapter 3.

This task was included in the design of the present study as a further measure of individual differences (Park & Payer, 2006). The purpose was to investigate if there is a correlation between performance in the frequency effects task and performance in the letter-number ordering task. In other words, the objective of the working memory task was to investigate if working memory capacity influenced performance on the frequency effects task. The existence of a correlation between performance in the letter-number ordering task and the frequency effects task would mean that individual differences are influencing the results in the frequency effects task. On the other hand, a lack of correlation between the 2 tasks would mean that the results of the frequency effects task are only influenced by the nature of the English language, not by individual cognitive differences between the participants. To the best of my knowledge, there are no studies on verbal morphological processing taking into consideration the influence of individual differences in the results as measured by working memory tasks.

In the next Chapter, the method designed and followed to carry out the present study will be detailed.

CHAPTER 3
METHOD

A detailed description of the method adopted to carry out the present study will be laid out in this Chapter, which is divided into 6 sections. In section 3.1, the objectives, as well as the research questions and hypotheses of the study are presented. In section 3.2, the participants recruited are described. In section 3.3, the materials applied are addressed. In Section, 3.4, all the procedures followed during the research are explained. In section 3.5, the procedures followed as regards data analysis are described. Finally, in the last section of the Chapter, 3.6, the pilot study carried out to test the instruments that were used in the present study, is reported.

3.1 Objectives and Research questions

The objectives of the present study are: (1) to investigate the effects of age and proficiency on the morphological processing of regular and irregular verbs in English as L1 and L2 in healthy adult participants, analyzing their reaction times in a frequency effects production task, (2) to investigate the role of individual differences, measured by inhibitory control and working memory tasks, in the processing of regular and irregular verbs in English.

So as to accomplish the objectives posed above, the following questions were pursued:

Research question 1: Are frequency effects found in the processing of irregular verbs by:

a. native speakers of American English?

b. advanced speakers of English as a second language, native speakers of Brazilian Portuguese?

c. beginner speakers of English as a second language, native speakers of Brazilian Portuguese ?

Hypothesis 1: Frequency effects for the processing of irregular verbs will be found in the three groups of participants.

This hypothesis is based on both dual and single-mechanism theories of regular and irregular morphological processing. The former model maintains that irregular verb forms in English as L1 and L2 are

stored in declarative memory (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Morgan-Short, Sanz, Steinhauer & Ullman, 2010; Pinker & Ullman, 2002; Ullman, 2005). Likewise, the latter model maintains that irregular verbs are stored in associative memory (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al,. 2009).

Research Question 2: Are frequency effects found in the processing of regular verbs by:

a. native speakers of American English?

b. advanced speakers of English as a second language, native speakers of Brazilian Portuguese?

c. beginner speakers of English as a second language, native speakers of Brazilian Portuguese ?

Hypothesis 2.a. Frequency effects for the processing of regular verbs will only be found in the group of beginners.

This hypothesis is based on dual mechanism theories of regular and irregular morphological processing of English as L1 and L2, which maintain that for late bilinguals at the beginning stage of their learning development, regular past tense forms are not computed in procedural memory but stored in declarative memory (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Morgan-Short at al., 2010; Pinker & Ullman, 2002; Ullman, 2005).

Hypothesis 2.b. Frequency effects will be found in the three groups of participants.

This hypothesis is based on single mechanism theories of regular and irregular morphological processing of English as L1, which maintain that regular verbs, like irregular verbs, are learned, stored and processed in associative memory by means of connections based on phonological and semantic proximity (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al,. 2009).

Research Question 3: Is there a correlation between performance in the frequency effects task, assessed by means of reaction time, and performance in the inhibitory control task?

Hypotheses 3: There will be a positive correlation between performance in the frequency effects task and performance in the inhibitory control task, since the lower the response times for the frequency effects task, the lower the response times in the inhibitory control task.

The latter outcome would mean that individual differences, measured though inhibitory control, influence the processing of verbal morphological processing.

Research Question 4: Is there a correlation between performance in the frequency effects task, assessed by means of reaction time, and working memory capacity?

Hypothesis 4: There will be a negative correlation between performance in the frequency effects task and working memory capacity, since the lower the response times for the frequency effects task, the higher the working memory capacity.

The latter outcome would mean that individual differences, measured though working memory capacity, influence the processing of verbal morphological processing.

In the next section, the participants recruited to perform the battery of tasks designed, programmed and applied for the purposes of the present study will be described in detail.

3.2 Participants:

In order to investigate the research questions and hypotheses presented, data was collected from 31 healthy adult participants, 17 men and 14 women, with a mean age of 58.4, divided into three groups. The first experimental group consisted of 11 late bilinguals, native speakers of Brazilian Portuguese, with advanced level of proficiency in English as a second language. The second experimental group consisted of 11 late bilinguals, native speakers of Brazilian Portuguese, with a beginning level of proficiency in English as a second language. Finally, the third group included in the study was a control group and consisted of 9 adult native speakers of American English.

The Brazilian participants of both experimental groups signed a consent form in Portuguese (Appendix A), answered a background questionnaire in Portuguese (Appendix C), took a proficiency test in English, and performed a frequency effects task, a working memory task, and an inhibitory control task (which will be presented in 3.3.4,

3.3.5and 3.3.6, respectively). The native speakers of American English of the control group signed a consent form in English (Appendix B), answered a background questionnaire in English (Appendix D) and performed the frequency effects task, only. In the next subsections, a detailed description of the three groups that participated in the study will be provided.

3.2.1 The advanced bilingual Brazilian participants

The group of advanced bilingual Brazilian participants consisted of 11 adults with ages ranging from 50 to 83 years, with a mean age of 58.6. Four participants from this group were men and 7 were women.

According to the answers they provided in the background questionnaire, they all finished college education and only 2 of them were retired. They had just one native language, Brazilian Portuguese, and had not been extensively exposed to any language other than Portuguese before the age of 17. Four participants of this group had lived in the United States, 2 of them in England and 2, both in the United States and England. The average period of time that this group remained in a foreign country was 3.1 years. All of the participants from this group studied English at private English schools and the average number of years of study was 7.9. Only 2 participants of this group were still studying English by the time of data collection.

When asked to self evaluate their performance in English in the four language skills (speaking, listening, reading and writing), all of the participants here grouped as advanced, evaluated their performance as good or very good. Also, all of the participants of this group reported never having been diagnosed with any developmental or neurological disorder, nor having taken any kind of medicine (prescribed or not) to enhance memory in the twelve months prior to data collection. All of them were right-handed.

3.2.2 The beginner bilingual Brazilian participants

The group of beginner bilingual Brazilian participants consisted of 11 adults with ages ranging from 54 to 61 years, with a mean age of 56.3. Six participants from this group were men and 5 were women.

According to the answers they provided in the background questionnaire, they all finished college education and only one of them was retired. They had just one native language, Brazilian Portuguese, and had not been extensively exposed to any language other than

Portuguese before the age of 17. Two participants of this group had lived in the United States, two of them in England and one in Australia and England. The average period of time that this group remained in a foreign country was of 7 months. All of the participants from this group had studied English at a private English school and the average number of years of study is 2.9. Eight participants of this group were still studying English by the time of data collection.

When asked to self evaluate their performance in English in the four language skills (speaking, listening, reading and writing), all of the participants here grouped as beginners, evaluated their performance as fair or bad. Moreover, all of the participants of this group reported having never been diagnosed with any developmental or neurological disorder, nor having taken any kind of medicine (prescribed or not) to enhance memory in the twelve months prior to data collection. All of them were right-handed.

3.2.3 The native speaker participants

The group of native speakers of American English consisted of 9 adults included in this study as a control group for the bilingual Brazilians in the frequency effects task. Their ages ranged from 50 to 75, with a mean of 60.8 and they were 7 men and 2 women.

The participants included in this group were all from the United States of America and at the time of data collection they were residing in Brazil. The average period of time they had been away from the United States was 20 years. They had not been extensively exposed to any language other than English before the age of 17. Finally, despite the fact that all of them reported to use Portuguese on a daily basis, 5 participants from this group stated that they used more English than Portuguese, 2 stated that they used more Portuguese and the other 2 reported to use English and Portuguese to the same extent.

In the next section, the materials by means of which data was collected in the present study will be presented.

3.3 Materials

All of the materials that will be described in this section were piloted. The pilot study will be described in 3.6. The description below details the final version of the materials used in the experimental session.

3.3.1 The background questionnaire for the bilingual Brazilian participants

Based on Scherer (2007) and Kramer (2011), I adapted and applied a questionnaire eliciting the participants' personal, linguistic, clinical and pharmacological information. The questionnaire can be found in Appendix C.

The questionnaire consisted of four brief core sections. The first section was intended to gather personal information about each participant and included questions about name, date of birth, age, nationality, sex, education, occupation and handedness.

The second section of the questionnaire elicited the participants´ linguistic information. Participants were first asked about the number of languages that they spoke. After that, questions about English were introduced assessing the age the participants started to learn English, the contexts in which they studied the language, whether they had lived in any English speaking country, as well as their current activities involving the use of English. In this section, participants were also asked to do a self evaluation of their speaking, listening, reading and writing abilities in English and in any other language they knew. It is important to mention, that this section was not intended to account for the participants´ proficiency level, since this was assessed by means of the proficiency tests described in 3.3.3.

The third section of the questionnaire elicited clinical information. In this section, participants were asked if they or any member of their family were diagnosed with any degenerative illness. Finally, in the last section of the questionnaire, pharmacological information was asked for. Participants needed to inform the medication that they had taken in the last year.

3.3.2 The background questionnaire for the American participants

The questionnaire for the control group of participants was based on Xhafaj´s (2006) questionnaire for native speakers of English. This questionnaire also started eliciting personal information about name, sex, age, nationality, years of education, career, occupation, and handedness. It consisted of 9 questions asking about the amount of time that the participants had been away from the U.S., the amount of time they had been living in Brazil, whether they studied Portuguese before coming to Brazil and which language they used more between English and Portuguese. The participants´ mother tongue was also asked for and

whether they were exposed to any other language besides their native language when they were growing up. Participants were also asked to report how many languages they spoke, when they started to learn each of them and the contexts of learning. As in the questionnaire used with the bilingual Brazilians, Americans were also asked to do a self evaluation of their speaking, listening, reading and writing abilities in any language they knew besides English. Finally, information related to degenerative illnesses and medication taken in the last year was also elicited.

The questionnaire for the Americans is included in Appendix D.

3.3.3 Proficiency Tests

Two proficiency tests were adopted to measure the bilingual Brazilian participants´ proficiency level, which is one of the key variables for this study. The tests are the KET (Key English Test) and the PET (Preliminary English Test), both designed by Cambridge University. They were obtained from the Cambridge website which offers free sample tests.

The KET examination demonstrates that learners who pass this exam are able to deal at basic level with everyday English ("Key English Test: Handbook for Teachers", n.d.). The sample test included in the Key English Test: Handbook for Teachers[3] was the one used for the present study. However, as the test was designed to take an hour and fifty minutes, a short version of the KET was developed to take a maximum of an hour and thirty minutes and was divided into 3 parts: Reading and Writing, Listening and Speaking. The first part, Reading and Writing, consisted of 4 activities. Activity number 1 was a multiple choice focused on vocabulary. Activity number 2 was another multiple choice focused on reading comprehension. Activity number 3 was a cloze exercise focused on grammatical structures. Finally, activity 4 was a guided writing exercise.

The second part of the test, the listening, consisted of 3 activities. The first one was a multiple choice activity requiring the ability to identify key information from 5 short dialogues. The second listening activity was a matching exercise also requiring identifying key information, but this time from just one dialogue longer than the dialogues in activity 1. Finally, the third listening exercise was a gap

[3] http://www.cambridgeesol.org/resources/teacher/pet.html

filling activity in which participants listened to a monologue and needed to write down specific information about the topic addressed.

In the last part of the test, the speaking part, there were 2 activities. In the first part of the speaking session, candidates interacted with the researcher, who asked personal questions. In the second part of the speaking test, the participant interacted with the researcher again since, although the activity was designed for candidates to interact among themselves, the test was taken individually. In this second part, prompt cards were used to foster questions and answers about factual, non personal information.

The PET examination demonstrates that learners who pass this exam are able to deal with every day English at an intermediate level ("Preliminary English Test: Handbook for teachers", n.d.). The sample test included in the Preliminary English Test: Handbook for teachers[4] was the one used for the purpose of the present study. However, as the test was designed to take two hours and ten minutes, a short version of the PET was developed to take a maximum of an hour and thirty minutes and was divided into 3 parts: Reading and Writing, Listening and Speaking. The first part, Reading and Writing, consisted of 4 activities. Activity number 1 was a reading comprehension multiple choice exercise focused on the ability to extract specific information from a text. The second activity was a multiple choice cloze activity focused on vocabulary and grammatical structures. The third activity was a sentence transformation exercise focused on grammatical structures and on the ability to rephrase and reformulate information. Finally, activity number 4 was a guided writing activity.

The second part of the test, listening, consisted of 3 activities. The first one was a multiple choice activity requiring the ability to identify key information from 5 short dialogues. The second listening activity was another multiple choice also requiring identifying specific information from a radio interview. Finally, the third listening exercise was a gap filling activity in which participants listened to a monologue and needed to write down specific information about the topic addressed.

In the last part of the test, the speaking, there were 3 activities. In the first exercise of the speaking session, candidates interacted with the researcher who asked personal questions. In the second and third activities, the participants interacted with the researcher again since, although the activities were designed for candidates to interact among

[4] http://www.cambridgeesol.org/resources/teacher/ket.html

themselves, the test was taken individually. In the second speaking activity a simulated situation was presented in a flash card to foster a discussion and in the third exercise the participant had 3 minutes to talk about and describe the situation presented in a photograph.

The KET was applied to those participants who reported in the questionnaire to have had contact with English for less than five years and in the self evaluation considered themselves to be fair or bad in the four language skills. The PET was applied to those participants who reported in the questionnaire to have had contact with English for more than 5 years and in the self evaluation considered themselves to be good or excellent in the four language skills. Only the participants who scored up to 80% in the KET were considered beginners and only the participants who scored from 90% onwards in the PET examination were considered advanced.

3.3.4 The Frequency Effects Task

According to Ellis (2002), "Frequency is a key determinant of acquisition" (p.144). As previously mentioned, irregular forms, being retrieved from memory, differ as regards accuracy and time response according to the frequency with which they are used (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Pinker, 1994; Pinker & Ullman, 2002). As a consequence of this, high frequency irregular forms are retrieved from memory faster and more accurately than low frequency irregular forms. Regulars, being computed and not retrieved from memory, show no differences in the time response and accuracy with high or low frequency use (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Pinker, 1994; Pinker & Ullman, 2002).

In the present study, data resulting from a behavioral task tackling frequency effects of regular and irregular English verb forms was analyzed. The performance on this task was assessed by means of two variables: time response and accuracy.

For the design and procedures of this task I followed Brovetto (2002), Prado and Ullman (2009), VanderLely and Ullman (2001) and Walenski et al. (2007). As in their studies, a verb in the infinitive, a sentence in the simple present containing the previous verb, and an incomplete sentence in the past were displayed all together at the centre of a screen, eliciting the past tense form of the first verb from the participants.

Examples of sets of stimuli used in the frequency effects task in the present study are:

•Help

Everyday I help my mother.

Yesterday I _____ my mother.

•Take

Everyday I take a pill.

Yesterday I _____ a pill.

The frequency effects task for this research was programmed in E-prime 2.0. This is a psychology software tool which allows researchers to design computerized experiments, as well as to collect data with millisecond precision timing and also to analyze the collected data (Schneider, Eschman & Zuccolotto, 2002). Two high quality microphones, one connected to a Serial Response Box (SRBOX) which recorded the participants' response times, from the presentation of the stimulus to the response, and another one connected to the computer to record the participants' answers, were installed in the computer of the lab where the experiments took place. The collected data from each participant was registered in an E-prime electronic file.

In order to obtain data, the frequency effects task was programmed as follows: first the instructions appeared on the screen in Portuguese for the Brazilian participants and in English for the American participants (Appendix E1). The instructions remained on the screen until the "space" key was pressed. Then, two examples were presented for the participants to learn what the task consisted of. After the learning session, a practice session consisting of five examples was presented for participants to get used to the mechanism of the task. After the practice session, a question appeared on the screen, asking the participants if they were ready to start the experiment or if they wanted to practice again. If they were ready to start, pressing the "space" key would start the experiment and if they wanted to practice again, pressing the "escape" key would make the practice start over. For the practice and the experimental sessions, before every set of stimuli, a fixation cross appeared on the screen for 1 second and a beep was heard for the participants to know that the stimuli was about to appear. After the fixation and the beep, the verb in the infinitive, the present simple sentence and the incomplete past simple sentence appeared at the centre of the screen. The stimulus remained on screen until the participant´s answered. Following the first sound of the answer, the stimulus disappeared and a mask of a blank screen remained for 420 milliseconds. After that time, a new fixation cross appeared for

anticipating the next stimulus. The experimental session was divided into two parts. After thirty two verbs, that is to say, after half of the stimuli were presented there was a pause. When the participant was ready to continue the "space" key was pressed. After the other thirty two stimuli, the task finished.

3.3.4.1 Stimuli for the Frequency Effects Task

As mentioned before, for the design and procedures, the task applied in the present study was based on Brovetto (2002), Prado and Ullman (2009), VanderLely and Ullman (2001) and Walenski et al. (2007). However, only Brovetto (2002) and Walenski et al. (2007) made available the list of stimuli used in their studies. Nevertheless, for the stimuli of the frequency effects task for the present study, Newman et al.´s (2007) list of verbs was used. This decision was taken because the verbs that Newman et al. (2007) used for their study coincided more with the list of verbs presented in the Interchange series (the most widely ESL book series used at UFSC), so there were more possibilities for the participants of this study to be familiar with the verbs from Newman´s study than to know the verbs used in Brovetto´s (2002) or Walenski et al.´s (2007) studies.

Newman et al. (2007) had the same purpose as the present study: to investigate

> "whether regular and irregular forms depend on fundamentally distinct neurocognitive processes (rule-governed combination vs. Lexical memorization), or whether a single processing system is sufficient to explain the phenomena" (Newman et al., 2007, p. 475).

As previously reviewed in Section 2.1.1, Newman et al. (2007) provided convincing evidence from an Event Related Potential (ERP) study of regular and irregular English past tense inflections suggesting that dissociations do exist between lexicon and grammar in first language acquisition.

As Newman and his colleagues worked with ERP´s, their list of stimuli was very extensive. Sixty four regular verbs, half of which were of high frequency use and the other half of low frequency use, and sixty four irregular verbs divided in the same way as regards frequency use were selected to constitute Newman et al.´s (2007) list of stimuli. For the purpose of designing the behavioral task of frequency effects based on regular and irregular English morphology of the present study, thirty

two regular verbs and thirty two irregular verbs were selected from Newman et al.´s list of verbs. Both groups were also divided between verbs of high and low frequency use. The number of verbs for the task was based on the studies carried out by Prado and Ullman (2009), VanderLely et al. (2001), Walenski et al. (2007) and Woollams et al. (2009), who also applied behavioral tasks with similar purposes.

To update the frequency of Newman et al.´s (2007) verbs, all of them were looked up in the Corpus of Contemporary American English (COCA), the largest corpus available for free (four hundred and ten million words at the time of data collection). The list of Newman et al. (2007) is included in Appendix F ordered from the most frequent to the least frequent verbs. A new list, with a different order based on the frequency showed in the COCA, was built with Newman et al.´s (2007) one hundred and twenty eight verbs. From the raw frequencies of the Corpus, a natural logarithm was calculated. Brovetto (2002, p.102) explained that "[T]he natural logarithm is a transformation of the raw frequencies that has been shown to be a better predictor of response times than the raw values". This list of verbs with the raw frequency from COCA and the natural logarithm is included in Appendix G, again ordered from the most frequent to the least frequent verbs.

From that new list, the sixteen most frequent regular verbs and the sixteen most frequent irregular verbs were selected to be part of the frequency effects task of the present study. To select the least frequent verbs a different procedure was followed. The thirty two less frequent regular verbs and the thirty two less frequent irregular verbs were presented to 4 ESL students for them to select the ones they knew. To check that they knew the verbs, I asked these learners to provide the meanings or a sentence using that verb in the correct way. This procedure was carried out because the less frequent verbs needed to be known by the participants of the present study although these forms were found on more rare occasions. From this activity the 16 less frequent regular and irregular verbs (but probably known by ESL students) were selected for the group of regular and for the group of irregular verbs for the frequency effects task in the present study.

The complete list of verbs (16 irregular frequent, 16 irregular infrequent, 16 regular frequent, 16 regular infrequent) used for the design of the frequency effects task in the present study is included in Appendix H, ordered from the most frequent to the least frequent verbs. The order of this list was electronically randomized before including the verbs in E-Prime 2.0 and no more than 4 regular or irregular verbs were presented in a row.

As mentioned before, in the frequency effects task, a verb in the infinitive, a sentence in the present simple and an incomplete sentence in the past were presented in the middle of the computer screen. All sentences were created with the same structure. All of the present simple sentences started with Every day, followed by the pronoun I, the main verb, which was the same verb presented above in the infinitive, and finally the post verbal argument (Brovetto, 2002; Prado & Ullman, 2009; VanderLely & Ullman, 2001; Walenski et al., 2007). All the sentences in the past simple started with Yesterday, followed by the pronoun I, then a blank was left for the participant to know that the sentence was incomplete, and finally the post verbal argument was included (Brovetto, 2002; Prado & Ullman, 2009; VanderLely & Ullman, 2001; Walenski et al., 2007). The sentences were created based on the content of Newman et al.´s (2007) sentences, and the only change made was the post verbal argument. The sentences were read, modified and approved by 2 native speakers of English. The list of sentences used in the frequency effects task for the present study is included in Appendix I.

3.3.5 The Inhibitory Control Task

According to Lu and Proctol (1995), Simon tasks in general have been used for investigating attentional processes and executive control functions on the bases of the stimulus- response relationship (as cited in Bialystok, 2006). The task designed to measure the inhibitory control of the participants was a non-linguistic one (Bialystok, 2006; Bialystok et al., 2008) with the objective of measuring the influence of individual differences, like inhibitory control, in the processing of regular and irregular verbs in English as L2.

The task chosen for measuring inhibitory control in this study was the Simon arrows task (Bialystok, 2006; Bialystok et al., 2008). In this task, a series of arrows pointing to the right or to the left were displayed in a computer screen. Participants were asked to press the right bottom of a Serial Response Box when the arrow was pointing to the right, ignoring if the arrow was displayed to the right or to the left of the computer screen. In the opposite condition, participants were asked to press the left bottom of the Serial Response Box if the arrow was pointing to the left, again ignoring if the arrow was displayed to the right or to the left of the computer screen. In other words, the stimuli contained information as regards direction and location, and the

participant was asked to ignore the location and respond only focusing on direction.

When an arrow pointing to the right appeared to the right of the computer screen, the trial was called congruent (Bialystok, 2006). When an arrow pointing to the right appeared to the left of the computer screen, the trial was called incongruent (Bialystok, 2006). Theory, as well as previous studies involving Simon tasks (See Bialystok et al., 2004; Bialystok, 2006; Bialystok et al., 2008; Fernandes et al., 2007), provided evidence that there is a difference in time response between congruent and incongruent trials. To respond to incongruent trials, participants usually require between 20 and 30 milliseconds more than for congruent trials. This difference is called the Simon effect (Bialystok, 2004).

This task was also programmed on E-Prime 2.0 in the following way: first the instructions appeared on the screen in Portuguese (Appendix E3). The instructions remained on the screen until the "space" key was pressed. Then, two examples were presented for the participants to learn what the task consisted of. After the learning session, a practice session consisting of eight stimuli presentations started for participants to get used to the mechanism of the task. Participants needed to answer correctly to the eight stimuli of this practice session. At the end of the practice, the percentage of accuracy was shown on the screen. If participants managed to get a hundred percent on the practice session, they could go on with the experimental session. The practice was repeated until the participant got the hundred percent of accuracy. After the practice session, a question appeared on the screen asking the participants if they were ready to start the experiment or if they wanted to practice again. If they were ready to start, pressing the "space" key would start the experiment. If they wanted to practice again, pressing the "escape" key would make the practice start over. For the practice and experimental sessions before every set of stimuli, a fixation cross appeared on the screen for 1 second and a beep was heard for the participants to know that the stimuli was about to appear. After the fixation and the beep, the stimulus, an arrow, appeared on the screen and remained until one of the keys of the SRBOX was pressed (independently if the answer is correct or not). After thirty two stimuli, the task finished.

3.3.6 The Working Memory Task

The task designed to measure the WM capacity of the participants was a non-linguistic one designed in Portuguese, since only the Brazilian participants performed this task. The objective of including this task in the design of the present study was to measure the influence of individual differences, like working memory capacity, in the processing of regular and irregular verbs in English as L2.

The task chosen for measuring WM capacity in this study was the letter-number ordering task, which measures the storage and processing constituents of WM (Maurits et al., 2006; Tagarelli et al. 2011; Wechsler, 1997). In this task, the participant read from the computer screen and also listened, in their native language, to a series of letters and numbers from two to eight digits. After the presentation of each set of stimuli the participants had to repeat, first the numbers in the increasing order and then the letters in alphabetical order. For example, after the presentation of the set of stimuli "S – 9 – 3 – A", the participant needed to repeat "3 – 9 – A – S" (Maurits et al., 2006; Tagarelli et al. 2011; Wechsler, 1997).

For each set repeated in the correct order, the participant received one point with the maximum of twenty one points. Unlike Maurits et al.´s study (2006), the participants of the present study went to the end of the task even if they missed three sets in a row. This methodological decision was taken based on the pilot study which showed that some participants could repeat in the correct order a set of stimuli even after having missed the three previous sets in a row.

This task was also programmed in E-Prime 2.0 as follows: first the instructions appeared on the screen in Portuguese (Appendix E2). The instructions remained on the screen until the "space" key was pressed. Then, two examples, one with two items and another one with three items, were presented for the participants to learn what the task consisted of. After the learning session, a practice session consisting of six examples was presented for participants to get used to the mechanism of the task. Examples one and two had two items; examples three and four had three items and examples five and six had four items. After the practice session, a question appeared on the screen asking the participants if they were ready to start the experiment or if they wanted to practice again. If they were ready to start, pressing the "space" key would start the experiment. If they wanted to practice again, pressing the "escape" key would make the practice start over. For the practice and the experimental sessions the items of each set of stimuli were

programmed to be seen at the centre of the screen and also to be listened to in Portuguese through a pair of headphones. After all the items of a set of stimuli were displayed, a set of question marks appeared at the centre of the screen for the participant to know that the set finished and that an answer needed to be given. With the same example used before, after the presentation of the set of stimuli "S – 9 – 3 – A", four question marks appeared at the centre of the screen eliciting the following answer: "3 – 9 – A – S". The question marks remained on the screen until an answer was given and the "space" key was pressed for the next set of stimuli to start. After 21 sets of stimuli, the task finished.

3.3.6.1 Stimuli for the Letters-Numbers Ordering Task

The stimuli for the WM task for the present study were obtained from the supplementary material of Maurits et al.´s study (2006). In this supplementary material they presented the complete list of stimuli which is part of the WAIS-III Intelligence Scale (Wechsler, 1997).

For the design of the task for the present study, some parts were added to the list of stimuli used by Maurits et al. (2006). As they only included the twenty one sets of the real experiment in the supplementary material, 2 sets for the learning session and six sets for the practice session were added.

There were also some changes to the list that they used in their study in 2006 since they used the W and the K letters, which were recently included in the Brazilian Portuguese alphabet. Therefore, these two letters were replaced by letters that already appeared in Maurits et al.´s (2006) stimuli list. The complete list of stimuli used for the purpose of the present study is included in Appendix J.

In the following section, the procedures followed during data collection will be presented.

3.4 Procedures

In the present study, data was collected individually with each participant at the Laboratorio da Linguagem e Processos Cognitivos, located in room 511, CCE (Centro de Comunicação e Expressão) at UFSC. The first procedure followed was to present the participant with a consent form, in Portuguese for the Brazilian participants and in English for the American Participants. Both consent forms are included in Appendix A and B, respectively.

After the participant signed the consent form, the questionnaires described in 3.3.1 and 3.3.2 were completed. Then, the proficiency test started (only for the bilingual Brazilians) with the listening and the reading and writing sessions. After that, the frequency effects task, the working memory task and the inhibitory control task were applied to the corresponding groups of participants. The speaking session of the proficiency test finished the data collection encounters.

In the data collection sessions, the participant and the researcher were seated in a quiet room equipped with a computer screen, an SRBOX and two microphones placed in front of the participant. The researcher read out loud the instructions from the computer screen in front of them in Portuguese or in English, depending on the participant. The tasks were not interrupted until the end. However, during the programmed pauses, the participants were told that they would have all the time they needed to rest.

In the next Section, data analysis will be described.

3.5 Data Analysis

The data analysis of the present study was carried out with the Statistical Package for Social Sciences (SPSS) version 20. The first test carried out was the Shapiro-Wilk to analyze whether the data was normally distributed. This test of normality was chosen since it is considered to be a robust test for small sample sizes, with less than 50 participants (Larson-Hall, 2009), which is the case of the present study. Table 3.1 presents the results of the Shapiro-Wilk test. These results show that the data from the frequency effects task does not present a normal distribution ($p < .001$, $p = .000$).

Table 3.1

Test of Normality: Shapiro-Wilk

Language groups	N	Regularity	Frequency	Statistics	Df	p-value
Native speakers	**9**	**Irregular**	**High**	**.847**	**128**	**0.000**
			Low	**.870**	**144**	**0.000**
		Regular	**High**	**.855**	**135**	**0.000**
			Low	**.807**	**137**	**0.000**
Advanced bilinguals	**11**	**Irregular**	**High**	**.811**	**150**	**0.000**
			Low	**.715**	**99**	**0.000**
		Regular	**High**	**.916**	**154**	**0.000**
			Low	**.557**	**164**	**0.000**
Beginner bilinguals	**11**	**Irregular**	**High**	**.857**	**130**	**0.000**
			Low	**.859**	**66**	**0.000**
		Regular	**High**	**.948**	**176**	**0.000**
			Low	**.868**	**157**	**0.000**

Note: N=number of participants

A descriptive analysis of the data from the different tasks applied in the present study was also conducted. The values presented in the descriptive analysis are the medians, not the means, because as the data was not normally distributed, the medians were considered to be better suited for the data analysis.

For the frequency effects task, first, the medians of reaction times (RT) and accuracy (ACC) of the answers of the three groups of participants to all of the stimuli (high and low frequency irregular and regular verbs all together) were calculated. Then, the medians of reaction times (RT) and accuracy (ACC) of the answers of the three groups of participants divided into irregular and regular verbs were also considered. Finally, the medians of reaction times (RT) and accuracy (ACC) of the answers of the three groups of participants divided into irregular verbs of high and low frequency use and regular verbs of high and low frequency use were analyzed.

To analyze whether there were frequency effects in the response times of the production of high and low frequency regular verbs and high and low frequency irregular verbs within each group, the Mann-Whitney test was applied. The choice of the Mann-Whitney test over the t- test was a result of the data not being normally distributed. Therefore,

the Mann-Whitney non-parametric test was used to compare the medians between the different variables of the present study (ex: the median of the response times of high frequency irregular verbs and the median of the response times of low frequency irregular verbs in the group of advanced bilinguals).

For the inhibitory control task, first, the medians of reaction times (RT) and accuracy (ACC) of the answers of the two bilingual groups (the control group did not perform this task) to the 32 experimental stimuli were calculated. Then the median of reaction times (RT) and accuracy rates (ACC) of the answers to the congruent and incongruent trials in the two experimental groups were analyzed separately. The Simon effect for each of the experimental groups was also calculated.

Regarding the working memory task, the medians of accuracy (ACC) of the answers of the two bilingual groups (the control group did not perform this task) to the 21 experimental stimuli of the task were calculated. Notice that in this task, reaction time is not a variable since participants had all the time they needed to process the stimuli.

Finally, a Pearson correlation was run between the response times of the frequency effects task and the accuracy rates of the working memory task and the response times of the inhibitory control task, respectively.

Finally, in the following Section, the pre-experimental steps, corresponding to the pilot study, will be described.

3.6 The pilot study

The materials developed for the purpose of the present study were piloted before data collection. In the first phase of the pilot study, 10 participants were recruited. Five of them were Master students of the Graduate Program in English at UFSC, pre-selected as being advanced speakers of English as a second language. The other 5 were students of the second semester of the Letras course, pre-selected as being beginner participants. Age was not controlled since the first phase of the pilot study was intended to investigate if the materials would reach the objectives. The consent form, the questionnaire, the complete version of the proficiency tests KET and PET and the three tasks were applied in this first phase of the pilot study. No changes were necessary in the consent form and the questionnaire. However, the proficiency tests had to be shortened since each session with each beginner participant lasted 3 hours and thirty minutes and 4 hours with each advanced participant. The frequency effects task and the inhibitory control task ran properly.

However, a methodological change was made in the working memory task. As previously explained, Maurits et al.´s (2006) interrupted the task after the participant had made 3 mistakes in a row. However, we decided to apply the task until the end in the first phase of the pilot study to analyze the participants' results. Since some of them were able to repeat correctly a set of stimuli even after having missed the 3 previous sets in a row, we decided to carry out the second phase of the pilot and data collection to the end of the task.

In the second phase of the pilot study, the new adjusted version of the materials was tested again. The difference was that this time, age was considered and participants were over the age of 50 in order to verify how they reacted to the materials of the study. Four volunteers, who were then not included in data collection, were recruited to participate in this phase of the pilot study. Two of them were pre-selected from the advanced extracurricular course at UFSC and the other 2, beginners, were pre-selected from the fourth semester of the extracurricular course at UFSC. Based on this second phase of the pilot study, minor modifications were made as regards the size of the font used for the consent form, the questionnaires, the proficiency tests and the instructions of the tasks.

CHAPTER 4
RESULTS AND DISCUSSION

The objective of this Chapter is to present and discuss the results obtained from the experiments carried out in order to answer the research questions introduced in Chapter 3, section 3.1. This Chapter is divided into 4 sections; section 4.1 presents the descriptive and inferential statistics related to the frequency effects task; section 4.2 reports the descriptive and inferential statistics for the inhibitory control task (the Simon arrows task); section 4.3 presents the descriptive and inferential statistics for the working memory task (the letter-number ordering task); finally, section 4.4 addresses the 4 research questions pursued in the present study.

4.1 Results and discussion: the frequency effects task

This section is divided into 2 subsections. Subsection 4.1.1 consists of the presentation and discussion of the descriptive statistics of the data collected by means of the frequency effects task. Subsection 4.1.2 consists of the presentation and discussion of results of the Mann-Whitney test applied to the data collected through this task.

4.1.1 The frequency effects task: Descriptive statistics

Tables 4.1, 4.2 and 4.3 show the descriptive analysis of the data from the frequency effects task applied in the present study. As previously mentioned, the values presented in tables 4.1, 4.2 and 4.3 are the medians, not the means of the raw scores, since the data was not normally distributed. Table 4.1 informs the medians of reaction times (RT) and accuracy scores (ACC), as well as the standard deviation (SD) of the responses of the three groups of participants to all of the stimuli (high and low frequency irregular and regular verbs all together).

Table 4.1

Descriptive Statistics for the frequency effects task- Median Reaction Time and Accuracy by language group

Language groups	N	RT (in ms)	Accuracy (%)
Native Speakers	**9**	**930(645.7)**	**93**
Advanced bilinguals.	**11**	**831(532.6)**	**89.1**
Beginners Bilinguals	**11**	**1239(900.8)**	**81.5**

Note. N=number of participants; Standard deviations (SD) are in parentheses; RT=Reaction Time; ms=milliseconds.

As can be seen in Table 4.1, the median of response times of the native speakers is slightly higher (930 ms) than the median of the advanced participants (831 ms). This can be an effect of the sentential context in which the verbs were presented during the task, since it was observed that native speakers read the whole sentences presented in the task before verbalizing the past tense form of the verb presented, even though they were asked in the instructions to say the verb in the past as quickly as possible. This reading effect was not observed in the advanced bilingual participants, who upon seeing the verb in the infinitive form, immediately produced the past tense form, without reading the sentence where the blank they had to fill in was. As expected, the median of the reaction times of the beginners was the highest of the three groups of participants (1239 ms) and this may be related to low proficiency and to a reading effect of the sentential context as well.

As regards accuracy of response, the expected pattern can be observed in Table 4.1, with the highest accuracy rate achieved by native speakers (93%), followed by advanced bilinguals (89.1%). The lowest accuracy rates were those of the beginner bilinguals (81.5%).

Table 4.2 reports the medians of reaction times (RT) and accuracy rates (ACC), as well as the standard deviation (SD) of the responses of the three groups of participants divided into irregular and regular verbs.

Table 4.2

Descriptive Statistics for the frequency effects task – Median Time Response and Accuracy by language group and regularity

Language groups	N	Irregular verbs		Regular verbs	
		RT (in ms)	Accuracy (%)	RT (in ms)	Accuracy (%)
Native Speakers	**9**	**971(581.5)**	**89.8**	**911.5(699.6)**	**95.8**
Advanced Bilinguals	**11**	**879(483.8)**	**73.5**	**795(564.2)**	**93.7**
Beginner bilinguals	**11**	**1265(829.6)**	**55.05**	**1200(940.7)**	**92**

Note. N=number of participants; Standard deviations (SD) are in parentheses; RT=Reaction Time; ms=milliseconds.

As can be seen in Table 4.2, when the medians of response times and accuracy are divided according to regularity, the same pattern shown in Table 4.1 appeared. Advanced bilinguals achieved the lowest response times for both irregular and regular verbs (879 ms and 795 ms, respectively), followed by native speakers (971 ms and 911.5 ms, respectively) and finally by beginner bilinguals (1265 ms and 1200 ms, respectively). As regards accuracy of response, again, native speakers presented the highest scores for irregular and regular verbs (89.8% and 95.8%, respectively), followed by advanced bilinguals (73.5% and 93.7%, respectively) and finally by beginner bilinguals (55.05% and 92%, respectively).

Finally, Table 4.3 presents the medians of reaction times (RT) and accuracy of response (ACC), as well as the standard deviation (SD) for the processing of irregular verbs of high and low frequency use and regular verbs of high and low frequency use.

Table 4.3

Descriptive Statistics for the frequency effects task – Median Time Response and Accuracy by language group, regularity and frequency

Lang. Groups	N	Irregular verbs				Regular verbs			
		High Freq.		Low Freq.		High Freq.		Low Freq.	
		RT (ms)	Acc (%)	RT (ms)	Acc (%)	RT (ms)	Acc (%)	RT (ms)	Acc (%)
Nat.	**9**	**970.5 (564.2)**	**88.8**	**1002 (597.9)**	**90.9**	**896 (775.9)**	**96.5**	**917 (612.1)**	**95.1**
Adv	**11**	**894 (370.6)**	**85.2**	**853 (601)**	**61.9**	**724 (253.3)**	**94.3**	**879 (735.7)**	**93.1**
Beg	**11**	**1323.5 (735.4)**	**73.8**	**1238.8 (987.9)**	**36.3**	**1004 (849.1)**	**94.8**	**1495 (982)**	**89.2**

Note: Lang groups= language groups; Nat.= native speakers; Adv.= advanced bilinguals; Beg.=beginner bilinguals; N= number of participants; Standard deviations (SD) are in parentheses; RT=Reaction Time; Acc.= accuracy; ms=milliseconds.

In Table 4.3, with the data divided into verb regularity and frequency, the pattern present in Tables 4.1 and 4.2 appeared again. The lowest medians of response times were those of advanced bilinguals (894 ms for high frequency irregular verbs, 853 ms for low frequency irregular verbs, 724 for high frequency regular verbs and 879 ms for low frequency irregular verbs). The native speakers followed the advanced bilinguals as regards time response (970.5 ms for high frequency irregular verbs, 1002 ms for low frequency irregular verbs, 896 ms for high frequency regular verbs and 917 for low frequency regular verbs). Finally, beginner bilinguals obtained the highest scores of response times (1323.5 ms for high frequency irregular verbs, 1238.8 ms for low frequency irregular verbs, 1004 ms for high frequency regular verbs and 1495 ms for low frequency regular verbs).

When it comes to accuracy, once more, native speakers presented the highest rates (88.8% for high frequency irregular verbs, 90.9% for low frequency irregular verbs, 96.5% for high frequency regular verbs and 95.1% for low frequency regular verbs). Advanced bilinguals followed the native speakers in accuracy of response (85.2% for high frequency irregular verbs, 61.9% for low frequency irregular verbs, 94.3% for high frequency regular verbs and 93.1% for low frequency regular verbs). Finally, beginner bilinguals obtained the lowest accuracy

scores (73.8% for high frequency irregular verbs, 36.3% for low frequency irregular verbs, 94%, for high frequency regular verbs and 89.2% for low frequency regular verbs).

The repeated pattern observed in Tables 4.1, 4.2 and 4.3 of the descriptive statistics, advanced bilinguals presenting lower response times than native speakers can be related to the nature of English as an L1 and English as an L2. For the task applied in the present study, all participants were instructed to produce the past tense form of the verbs that were presented. As already mentioned, a verb in the infinitive, a sentence with that verb in the present tense and an incomplete sentence in the past tense were presented to the participants, who were required to produce the past tense form of the verbs as quickly as possible. The sentential contexts were presented to help specifically bilingual participants to retrieve the past tense form of the verbs. However, the native speakers were the ones who were observed to read the sentences in the present and past before producing the past tense form of the verb presented. Four native speaker participants reported informally that for them it was strange to produce the past tense form of a verb without having a context or communicative purpose, reason why they read the sentential contexts provided before producing the target structure. If we think of it, the production of past tense forms from verbs in the infinitive is a common practice in L2 formal language contexts, not first language contexts. Therefore, advanced bilinguals were faster at providing the past tense forms than native speakers, probably because they are familiar with practicing past tense forms without any communication purpose or sentential context in L2 formal learning contexts. However, this is not common in English as a first language context. This may be the reason why, although being instructed to produce the past tense form of the infinitive verbs as quickly as possible, native speakers took more time to read the sentential contexts provided.

Comparing the response times of both experimental groups, the advanced and beginner bilinguals, it can be noticed the influence of proficiency on the speed of processing in lexical tasks in a second language. In all cases, with the data merged together (Table 4.1), with the data divided by regularity (Table 4.2) and with the data divided by regularity and frequency (Table 4.3) beginners took longer to provide a response to the stimuli presented than advanced participants. In general, beginners took, in average, 405 ms more than advanced bilinguals to respond to the stimuli presented in the frequency effects task.

4.1.2 The frequency effects task: the Mann-Whitney test

The main objective of the frequency effects task of regular and irregular English verbal morphology, was to investigate if regular and irregular verbs in English as a second language are processed by two distinct cognitive processes, rule application and memorization, respectively, or whether a network of connections in associative memory, based on phonological and semantic proximity, would suffice to explain the processing of both verbal forms.

Dual-mechanism models, more specifically the Declarative and Procedural Model, would predict that in a regular and irregular verbal production task, like the one applied in the present study, the production of irregular verbs, being retrieved from declarative memory, would present frequency effects in the three groups of participants. Presenting frequency effects means that significant differences between the response times of irregular verbs of high frequency use and irregular verbs of low frequency use are found in the data, indicating that irregular verbs more frequently used are retrieved significantly more rapidly than less frequently used irregular verbs.

On the other hand, regular verbs, being computed online in procedural memory, would not present frequency effects in the groups of native speakers of English and the group of advanced bilinguals. The lack of frequency effects means that no significant differences between the response times of regular verbs of high frequency use and regular verbs of low frequency use are found in the data, indicating that regular verbs are not stored in the mental lexicon, but that a rule is applied online for their production, no matter whether they are of high or low frequency use. Finally, in the group of beginner bilinguals, the production of regular verbs would present frequency effects, implying that these forms are stored as part of the mental lexicon at beginning stages of the learning of English as an L2.

Single-mechanism theories would predict that in a regular and irregular verbal production task, like the one applied in the present study, the production of both regular and irregular verbs, being stored, retrieved and processed in an associative memory, would present frequency effects. Presenting frequency effects means that significant differences between the response times of regular and irregular verbs of high frequency use and regular and irregular verbs of low frequency use are found in the data, meaning that both regular and irregular verbs more frequently used are retrieved significantly more rapidly than less frequently used regular and irregular verbs.

As can be observed in Table 4.4, frequency effects were found in the production of regular verbs in the three groups of participants investigated in this study, $p < .001$, $p = .000$. Frequency effects were also found in the production of irregular verbs in the group of native speakers of English and the group of beginner bilinguals, $p < .001$, $p = .000$. However, frequency effects were not found in the production of irregular verbs in the group of advanced bilinguals, $p > .001$, $p = .178$.

Table 4.4

Mann-Whitney test

Language Groups	N	Regularity	p-value
Native Speakers	**9**	**Irregular**	**0.000**
		Regular	**0.000**
Advanced Bilinguals	**11**	**Irregular**	**0.178**
		Regular	**0.000**
Beginner Bilinguals	**11**	**Irregular**	**0.000**
		Regular	**0.000**

Note: N= number of participants

In relation to the different predictions made by single and dual-mechanism models of inflectional morphology, the results reported in the present study for the specific group of participants here investigated, seem to support single-mechanism models. The fact that frequency effects were found in the processing of regular verbs in the three groups of participants is the clearest evidence against dual-mechanism models, such as the Declarative and Procedural Model. This is so in that, although Ullman (2001) states that "even compositional forms could in principle be memorized" (p. 105), he predicts double dissociations between regular and irregular verbal processing at least for native speakers of English (Ullman et al., 1997, 2001, 2004, 2005).

A key factor in the data here analyzed is that of the native speakers of English. If the study did not have the control group, it could be argued that the frequency effects found in the processing of regular verbs in the two experimental groups were a consequence of lack of proficiency in the L2 which could cause regular verbs to be stored in declarative memory instead of being computed in procedural memory. However, the frequency effects found in the processing of regular verbs in the control group are counter-evidence for that hypothesis.

Going on with the analysis of the data obtained in the present study, both single and dual-mechanism models predict frequency effects for the processing of irregular verbs. In the data here reported, frequency effects were found for the processing of irregular verbs in the groups of native speakers of English and the group of beginner bilinguals investigated. Therefore, it can be concluded that these two groups process English inflectional verbal morphology as L1 and as L2 respectively, through only one cognitive system, an associative memory system.

However, the data presented an outlier to both single and dual-mechanism models. The fact that frequency effects were absent in the processing of irregular verbs in the group of advanced bilinguals was not predicted by single or by dual-mechanism models. This absence of frequency effects could be understood as some sort of rule being applied online at the moment of the processing of irregular verbs.

Stockall and Marantz (2006) predict this rule application for the processing of regular and irregular verbs in English. The basis of their proposal is the idea that complex words are originated by means of a single psycholinguistic computational online system, a rule system that concatenates the stem and the affix (Stockall & Marantz, 2006). Stockall and Marantz (2006) and Joanisse and Seidenberg (1999, 2005) suggest that irregular verbs in English have some kind of subtle subregularities and that speakers are able to perceive such partial rules in the irregular morphology of a language. Examples of such subregularities in English irregular verbs are the groups of verbs like ring – rang, sing – sang; grow – grew, throw – threw and bleed – bled, feed – fed (Stockall & Marantz, 2006). This can be taken as evidence suggesting that irregular verbs could be a product of a rule computation that first activates the stem and after the stem has been activated and identified as a specific subregularity, the past tense form is concatenated (Stockall & Marantz, 2006).

In the data here analyzed this rule application only affects the processing of irregular verbs in the group of advanced bilinguals and this may be the reason why the full decomposition model described by Stockall and Marantz (2006) does not entirely describe the pattern found in the data of the present study. This outlier in the data, the lack of frequency effects in the processing of irregular verbs in the group of advanced bilinguals, does not mean that the study diverges from single-mechanism models which are clearly sustained with the results from the control group; it could be an effect of the age of the participants

involved in the study and the proficiency in English of the group of advanced bilinguals.

Beginner bilinguals, knowing just a few irregular past forms, (they obtained 55.05% of accuracy for the production of irregular verbs), can rely on the associative memory to learn, store and retrieve them, even though this cognitive construct is weaker because of age (Light & Albertson, 1989; Light & Singh, 1987 and Light & La Voie, 1993 as cited in Old and Naveh, 2008). However, advanced bilinguals, knowing more irregular past forms (they obtained 73.5% of accuracy for the production of irregular verbs), need to rely on some kind of rule to account for the production of such forms. Native speakers, despite also being adults and knowing a large number of irregular forms, do not need to rely on the application of a rule for the production of irregular past forms due to the decline of associative memory, since their knowledge of such forms comes from childhood and are well established in their mental lexicon.

4.2 Results and discussion: Inhibitory control, the Simon arrows task

There were 2 objectives in introducing this task in the design of the present study. The first one was to investigate to what extent ESL learners above the age of 50 count on the cognitive resource of inhibition to unimportant stimuli. The second was to investigate whether individual differences, measured through inhibitory control, influence verbal morphological processing. To achieve the first goal of the task, the descriptive statistics will be analyzed and discussed in subsection 4.2.1 and to reach the second objective, the correlation between the response times of the regular and irregular verbs in the frequency effects task and the response times of the stimuli of the Simon arrow task will be analyzed and discussed in subsection 4.2.2.

4.2.1 The Simon arrows task: descriptive statistics

Table 4.5 shows the descriptive analysis of the data from the Simon arrows task applied in the present study. This table first informs the medians of the reaction times (RT) and accuracy scores (ACC), as well as the standard deviation (SD) of the responses of the two groups of participants to all of the stimuli, congruent and incongruent trials all together. Table 4.5 also presents the medians of the reaction times (RT) and accuracy scores (ACC), as well as the standard deviation (SD) of

the responses of the two groups of participants to the congruent and incongruent trials individually. In addition, it informs the Simon effect of each of the two groups of bilinguals.

Table 4.5

Descriptive Statistics for the Simon arrows task- Median Reaction Time and Accuracy by language group

				Congruent		Incongruent		
Language groups	**N**	**RT (ms)**	**Acc (%)**	**RT (ms)**	**Acc (%)**	**RT (ms)**	**Acc (%)**	**Simon effect**
Advanced bilinguals	**11**	**670.5**	**95**	**665**	**95.6**	**676**	**89.3**	**11**
Beginner bilinguals	**11**	**659**	**90.6**	**640**	**94.3**	**673**	**90**	**33**

N= number of participants; RT=Reaction Time; Acc.= accuracy; ms=milliseconds.

As can be observed in Table 4.5, the median of the response times to all the stimuli with no distinction between congruent and incongruent trials was higher for advanced participants than for beginner participants (670.5 ms and 659 ms, respectively), meaning that advanced participants took longer time to response to the stimuli than beginner participants. However, when taking into consideration accuracy scores, advanced participants outperformed the beginner participants (95% and 90.6%, respectively). The fact that longer time was needed for advanced bilinguals in comparison to beginner bilinguals and that in this way, advanced bilinguals managed to respond correctly to a higher number of stimuli, could mean that advanced bilinguals were more focused on being accurate than on being quick.

The same pattern is repeated when analyzing congruent trials individually. Advanced bilinguals took longer to respond to congruent trials than beginner bilinguals (665 ms and 640 ms, respectively) but advanced bilinguals were more accurate than beginner bilinguals (95.6% and 64.3%, respectively). On the other hand, analyzing incongruent trials individually, advanced participants took longer time to respond to these trials and scored lower accuracy rates than beginner bilinguals (676 ms with 89.3% of accuracy and 673 ms and 90% of accuracy, respectively).

However, the superficial deficiency of advanced bilinguals as regards time response, in comparison to beginner bilinguals, is reversed

when the Simon effect was calculated for both groups. Let us remember that the Simon effect is the millisecond increase in the response time of incongruent trials in comparison to the response time of congruent trials (Bialystok et al., 2004; Bialystok, 2006; Bialystok et al., 2008). This difference in time response is considered to mean that reacting to incongruent trials costs more (the cost of cognitive inhibition is greater) than to react to congruent trials (Bialystok et al., 2004; Bialystok, 2006; Bialystok et al., 2008). Table 4.5 shows that the Simon effect for advanced participants is 11, while for beginner participants, the Simon effect is 33. Therefore, although being faster in the reaction to congruent and incongruent trials, beginner bilinguals need to make a greater cognitive effort to inhibit the unimportant information about location, focusing only on the information about direction of incongruent trials than advanced participants.

Based on the evidence that bilingualism prevents adults from cognitive decline, we expected to see an advantage of advanced bilinguals over beginner bilinguals in the Simon arrows task, as regards speed of processing (time response) and inhibition. As regards speed of processing (time response), Birren (1965) and Salthouse (1996), in Old and Naveh-Benjamin (2008), explain that age affects negatively this cognitive function. Therefore, the fact that we did not find a positive effect of bilingualism on the time response of advanced bilinguals could be taken as evidence that age has a strong influence when it comes to speed of processing in non-linguistic tasks and that not even bilingualism, at least not late bilingualism, could protect this cognitive function. However, our data also suggests that when it comes to inhibition, proficiency in a second language is stronger than age in that we found a positive effect of bilingualism on the Simon effect of advanced bilinguals.

4.2.2 The Simon arrows task: the Pearson correlation

To find out whether there is a correlation between the response times in the frequency effects task and the response times in the Simon arrows task, a Pearson correlation was run. The objective was, as previously explained, to investigate if individual differences, in this case measured by inhibitory control, would influence the performance on the frequency effects task.

The expected outcome was to find a positive correlation between the response times in the frequency effects task and the response times in the Simon arrows task. This result would imply that in the same

group with lower response times in the frequency effects task because of proficiency, lower response times would be also found in the Simon arrows task because of a high level of proficiency. Table 4.6 presents the correlation results between the variables response times of the frequency effects task and the response times of the Simon arrows task.

Table 4.6

Pearson correlation between the response times of the frequency effects task and the response times of the Simon arrows task

Language groups	N	Correlation	p-value
Advanced bilinguals	**11**	**-0.61**	**0.060**
Beginner bilinguals	**11**	**-0.50**	**0.110**

Note: N= number of participants

As can be observed in table 4.6, the correlation coefficients are negative, not positive as expected (r = -.61 for advanced bilinguals and r = -.50 for beginner bilinguals). If we take into consideration the response times for advanced and beginner bilinguals in the frequency effects task from Table 4.1, 831 ms and 1239 ms, respectively, and the response times of the 2 groups in the Simon arrows task presented in Table 4.5, 670.5 ms and 659 ms, respectively, the negative correlation makes sense. This is so, in that the group with lower response times in the frequency effects task, previously analyzed as being a result of high proficiency in English as a second language, is actually the group with higher response times in the arrows task, previously analyzed as probably a focus on accuracy rather than on time. Moreover, the relationship between reaction times in the frequency effects task and the Simon arrow task is not only negative, but also not significant with p-values higher that 0.001 (p = .060 for advanced participants and p = .110 for beginner participants), meaning that no significant correlation was found between the variables analyzed. Therefore, it can be concluded that individual differences, measured by means of inhibitory control with the Simon arrows task, are not influencing the results obtained in the frequency effects task.

4.3 Results and discussion: working memory: the letter-number ordering task

There were 2 objectives in introducing this task in the design of the present study. The first one was to investigate to what extent ESL learners above the age of 50 count on working memory capacity. The second was to investigate whether individual differences, measured through working memory capacity, influence verbal morphological processing. To achieve the first goal of the task, the descriptive statistics will be analyzed and discussed in subsection 4.3.1 and to reach the second objective, the correlation between the response times of the regular and irregular verbs in the frequency effects task and the working memory capacity addressed in the letter-number ordering task will be analyzed and discussed in subsection 4.4.2.

4.3.1 The letter-number ordering task: descriptive statistics

Table 4.7 shows the descriptive analysis of the data from the letter-number ordering task applied in the present study. This table reports the medians of the accuracy rates (ACC) of the answers of the two groups of participants.

Table 4.7

Descriptive Statistics for the number and letters ordering task- Median Accuracy by language group

Language groups	N	Accuracy (%)
Advanced Bilinguals	**11**	**54.7**
Beginner Bilinguals	**11**	**57.5**

Note: N= number of participants

As observed in table 4.7, in terms of working memory capacity, beginner bilinguals outperformed advanced bilinguals (57.5% and 54.7%, respectively). However, based again on the claim that bilingualism prevents adults from cognitive decline, we expected to see an advantage of advanced bilinguals over beginner bilinguals in the letter-number ordering task. Therefore, the fact that we did not find a positive effect of bilingualism on working memory capacity could be taken as evidence that age has a strong influence when it comes to

working memory in non-linguistic tasks, and that not even bilingualism, at least not late bilingualism, can protect this cognitive function.

4.3.2 The letter-number ordering task: the Pearson correlation

To find out whether there is a correlation between the response times in the frequency effects task and the working memory capacity, a Pearson correlation was run. The objective was to investigate whether individual differences, this time measured by means of working memory capacity, influences or not verbal morphological processing. The expected outcome was to find a negative correlation between the response times in the frequency effects task and working memory capacity. This result would imply that in the group with lower response times in the frequency effects task because of proficiency, higher working memory capacity would be found because of a high level of proficiency in a second language. And the conclusion would be that individual differences, measured by means of working memory capacity, influenced the results obtained with the frequency effects task. Table 4.8 presents the correlation results between the variables response times of the frequency effects task and working memory capacity.

Table 4.8

Pearson correlation between the response times of the frequency effects task and working memory capacity

Language groups	N	Correlation	p-value
Advanced Bilinguals	**11**	**0.47**	**0.168**
Beginner Bilinguals	**11**	**-0.08**	**0.805**

Note: N= number of participants

As presented in Table 4.8, the correlation coefficient for advanced participants is positive, contrary to expectation, (r = .47), while for beginner participants, the correlation coefficient is negative, as expected, (r = -.08). Again, this pattern makes sense combining the results of the response times for the frequency effects task and the results for the letter-number ordering task. The median of response time for advanced bilinguals in the frequency effects task was 831 ms, the lowest response time of the three groups, but they had 54.7% of accuracy in the letter-number ordering task, lower than beginners. Then

the positive correlation for the advanced participants is explained since to lower response times in the frequency effects task, lower accuracy in the letter- number ordering task.

In the case of beginners, the relation between the response times of the frequency effects task, 1239 ms, higher than the advanced participants, and the scores of the letter-number ordering task, 57.5, again higher than the advanced participants´ response times, does not explain the negative correlation coefficient. However, what is significant about this coefficient is the fact that being so close to 0, (r = -.08), it actually means that there is almost no correlation at all. Nonetheless, the relation between reaction times in the frequency effects task and working memory capacity is not significant with p-values higher that 0.001, (p = 0.168 for advanced participants and p = 0.805 for beginner participants), meaning that no correlation was found between the variables analyzed. Therefore, it can be concluded that individual differences measured through working memory are not influencing the results of the frequency effects task.

4.4 Answers to the 4 research questions

Research question 1: Are frequency effects found in the processing of irregular verbs by:

b. native speakers of American English?

b. advanced speakers of English as a second language, native speakers of Brazilian Portuguese?

c. beginner speakers of English as a second language, native speakers of Brazilian Portuguese ?

Hypothesis 1: Frequency effects for the processing of irregular verbs will be found in the three groups of participants.

This hypothesis is based on both dual and single-mechanism theories of regular and irregular morphological processing. The former model maintains that irregular verb forms in English as L1 and L2 are stored in declarative memory (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Pinker & Ullman, 2002;Ullman, 2005). Likewise, the latter model maintains that irregular verbs are stored in associative memory (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005; McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al,. 2009).

Answer to research question 1: Frequency effects were found in the processing of irregular verbs in the group of native speakers of American English and in the group of beginner speakers of English as a second language, native speakers of Brazilian Portuguese. This means that in the groups of native speakers and beginner bilinguals of the present study, irregular verbs are stored in associative memory. On the other hand, frequency effects were not found in the processing of irregular verbs in the group of advanced speakers of English as a second language, native speakers of Brazilian Portuguese. This means that in the group of advanced bilinguals, the combination of age and proficiency causes an overload in associative memory. As a result of this overload, advanced bilinguals rely on the application of a rule to process irregular verbs, first activating the stem and after the stem has been activated and identified as a specific subregularity, the past tense form is concatenated (Stockall & Marantz, 2006).

Research Question 2: Are frequency effects found in the processing of regular verbs by:

a. native speakers of American English?

b. advanced speakers of English as a second language, native speakers of Brazilian Portuguese?

c. beginner speakers of English as a second language, native speakers of Brazilian Portuguese ?

Hypothesis 2.a. Frequency effects or the processing of regular verbs will only be found in the group of beginners.

This hypothesis is based on dual-mechanism theories of regular and irregular morphological processing of English as L1 and L2, which maintain that for late bilinguals at the beginning stage of their learning development, regular past tense forms are not computed in procedural memory but stored in declarative memory (Bowden, 2007; Bowden et al., 2010; Brovetto, 2002; Ellis & Schmidt, 1998; Pinker & Ullman, 2002; Ullman, 2005).

Hypothesis 2.b. Frequency effects will be found in the three groups of participants.

This hypothesis is based on single-mechanism theories of regular and irregular morphological processing of English as an L1, which maintain that regular verbs, like irregular verbs, are learned, stored and processed by means of connections based on phonological and semantic proximity (Joanisse & Seidenberg, 1999; Joanisse & Seidenberg, 2005;

McCelland & Patterson, 2002; Plunket & Marchman, 1993; Rumelhart & McClelland, 1986; Woollams et al,. 2009).

Answer to research question 2: Frequency effects were found in the three groups investigated in the preset study.

This means that regular verbs are also stored in associative memory. Moreover, these results, the presence of frequency effects in the processing of regular verbs in the 3 groups of participants, confirm hypothesis 2.b supporting single-mechanism theories of regular and irregular verbal morphological processing in English and invalidate hypothesis 2.a based on dual-mechanism theories of regular and irregular verbal morphological processing in English.

Research Question 3: Is there a correlation between performance in the frequency effects task, assessed by means of reaction time, and performance in the inhibitory control task?

Hypotheses 3: There will be a positive correlation between performance in the frequency effects task and performance in the inhibitory control task, since the lower the response times for the frequency effects task, the lower the response times in the inhibitory control task.

The latter outcome would mean that individual differences, measured through inhibitory control, influence the processing of verbal morphological processing.

Answer to research question number 3: No correlation was found between the response times of the frequency effects task and the response times of the Simon arrows task. This is interpreted in the present study to mean that individual differences, measured by means of inhibitory control, did not influence the results obtained in the frequency effects task. Therefore, it can be concluded that individual differences do not influence verbal morphological processing.

Research Question 4: Is there a correlation between performance in the frequency effects task, assessed by means of reaction time, and working memory capacity?

Hypothesis 4: There will be a negative correlation between performance in the frequency effects task and working memory

capacity, since the lower the response times for the frequency effects task, the higher the working memory capacity.

The latter outcome would mean that individual differences, measured though working memory capacity, influence the processing of verbal morphological processing.

Answer to research question number 4: No correlation was found between the response times of the frequency effects task and the accuracy rates of working memory. This could mean that individual differences, measured by means of working memory, did not influence the results obtained in the frequency effects task. Therefore, it can be concluded that individual differences do not influence verbal morphological processing.

In the next Chapter, 5, conclusions based on the results described in Chapter 4 will be presented.

CHAPTER 5
FINAL REMARKS

The objective of this Chapter is to reconsider the results and discussion presented in the previous Chapter to reach to conclusions as regards the main aspects addressed in this investigation. This Chapter will be divided into 3 sections; section 5.1 will present the conclusions of the study; section 5.2 will acknowledge the limitation of the study and elaborate on suggestions for further research; finally, section 5.3 will present the methodological and pedagogical implications that this study provides.

5.1 Conclusions:

This section will be divided into 5 subsections. On the basis of the results obtained from data collection, each subsection will present conclusions on the 5 main topics of the investigation, namely, verbal morphological processing, the past tense debate, the effects of proficiency on verbal morphological processing, the effects of age on verbal morphological processing, and the role of individual differences in the processing of English verbal morphological processing as a second language.

5.1.1 Verbal morphological processing in the English language

From the results presented and discussed in Chapter 4, in 4.1.1 and 4.1.2, we conclude that the native speaker participants of the present study store regular and irregular verbs in associative memory. This conclusion remits to the results of the Mann- Whitney test, by means of which frequency effects were found in the processing of regular and irregular verbs in the group of native speakers (p = .000).

In the case of the advanced bilingual participants of the present study, the conclusion is that they also store the regular verbs in associative memory, but they compute irregular verbs online, applying subregularities present in irregular English verbs (Joanisse & Seidenberg, 1999, 2005; Stockall & Marantz, 2006). This conclusion also comes from the results of the Mann-Whitney test which shows that there are frequency effects in the processing of regular verbs (p = .000)

but there are not frequency effects in the processing of irregular verbs (p = .178) in the group of advanced bilingual participants.

Finally, the conclusion as regards the verbal morphological processing of the beginner participants of the present study is that, like the native speakers, they store regular and irregular verbs in associative memory. Again, this conclusion is sustained by the results of the Mann-Whitney test showing frequency effects for the processing of regular and irregular verbs (p = .000) in the group of beginner bilinguals.

5.1.2 The past tense debate

Once again, from the results presented in Chapter 4 and from the conclusions presented in 5.1.1, further conclusions can be drawn in the context of the past tense debate. To start with, the native speakers of American English included in the present study process regular and irregular verbs according to single-mechanism theories of verbal morphological processing of English as a first language. This conclusion comes from the fact that single-mechanism models of verbal morphological processing predict that regular and irregular verbs are processed in associative memory and that in a production task like the one applied in the present study, frequency effects would be found for the processing of regular and irregular verbs, as were found in the data of the present study.

The case of advanced bilingual participants is different from that of the native speakers. According to single-mechanism theories, advanced bilinguals also process regular verbs storing them in associative memory and showing frequency effects. However, irregular verbs, which should be processed in the same way as regular verbs, follow subregularities present in irregular verbs in the English language. This may be the reason why frequency effects were not found in the data. As previously mentioned, this is an outlier to both single and dual-mechanism models of verbal morphological processing. However, having found frequency effects in the processing of regular verbs in this group of advanced bilinguals, the data is in opposition to dual-mechanism models. Therefore, we attribute this deviation from single-mechanism models to the variable of age. This influence of age will be further explained in sub-section 5.1.4.

Finally, the beginner bilingual participants process regular and irregular verbs as native speakers do which can be interpreted as evidence that, according to single-mechanism models, they store both kinds of items in associative memory thus showing frequency effects.

As mentioned in the review of the literature in sub-section 2.1.4, the line of research providing evidence in favor of single-mechanism models did not present any study or theories in a second language context. However, with the data collected in the present study, we can conclude that single-mechanism models seem to apply to first language and second language verbal morphological processing in the same way. That is, as in L1 processing, in L2 processing, regular and irregular verbs seem to be stored in a single system, a network of connections in associative memory, based on phonological and semantic proximity. Nevertheless, when variables like proficiency in the L2 and the age of the L2 speakers are included, variations in the morphological processing of regular and irregular verbs appear creating a more complex pattern of processing in L2 contexts than in L1 contexts.

5.1.3 The effects of proficiency on English verbal morphological processing

Being proficiency a key variable in the present study, some conclusions were drawn as regards its influence on the results found. Proficiency in the language under investigation, English, played a key role in the accuracy scores of the frequency effects task. This influence of proficiency on accuracy of response can be observed in the accuracy scores from the 3 groups of participants, being the native speakers the group with higher scores (93%), followed by advanced bilingual participants (89.1%) and finally, by the beginner bilingual participants (81.5%).

Time response in the frequency effects task was also influenced by proficiency in English. This influence of proficiency in time response can be observed in the medians of time response of advanced bilinguals being lower than the time response of beginner bilinguals. Advanced bilinguals processed the stimuli in the frequency effects task with a median of 405 ms. less than beginner bilinguals. In the case of time response, native speakers were not the fastest of the three groups due to the reading of the contextual sentences of the task before vocalizing the past form of the verbs presented as a consequence of the nature of English as L1 and L2.

5.1.4 The effects of age on English verbal morphological processing

Besides proficiency in English, age is another decisive variable influencing the results of the present study. From the conclusions

reached in 5.1.1, that the bilinguals of the present study process regular and irregular verbs in English as second language in associative memory, with the exception of irregular verbs in advanced bilinguals, we can arrive to a further conclusion related to age. If adults studying a second language make use of associative memory to process regular and irregular items in a second language, we could conclude that associative memory, which declines with age, is stimulated through the learning of a second language.

Moreover, from the conclusion also presented in 5.1.1, that the advanced participants, having associative memory overloaded, make use of a back up resource, the application of subregularities for the processing of irregular verbs in English as a second language, another conclusion can be brought to this discussion in relation to cognitive aging. If adults knowing a second language to an advanced level find associative memory overloaded and make use of other available cognitive resource, like the identification of subregularities to overcome the deficiency caused by age, we could conclude that through the learning of a second language, adult bilinguals could be cognitively stimulated to use different kinds of back up resources when facing decline in other cognitive constructs.

5.1.5 The role of individual differences in the processing of English verbal morphological processing as a second language

Two measures of individual differences were included in the present study, inhibitory control and working memory capacity. Let us remember that the 2 tasks measuring individual differences, the Simon arrows task and the letter-number ordering task, were only applied to the bilingual participants. To start with inhibitory control, one of the conclusions reached is that adult bilinguals benefit from the proficiency in a second language when using the cognitive function of inhibiting unimportant information. This conclusion is based on the Simon effect values of beginner and advanced bilingual participants. Advanced bilingual participants responded to incongruent trials on average with 11 ms more than when responding to congruent trials, while beginner bilingual participants took on average 33 ms more when responding to incongruent trials than when responding to congruent trials. Therefore, the learning of a second language to an advanced level stimulates inhibitory control.

The second, and most important conclusion as regards inhibitory control is related to the fact that no significant correlation was found

between the response times of participants in the frequency effects task and the response times in the Simon arrows task (r = -.612, p = .060 for advanced participants and r = -.508, p = .110 for beginner participants). Therefore, we can conclude that individual differences, measured through the inhibitory control function with the Simon arrows task, did not influence the results obtained in the frequency effects tasks.

Taking into consideration both measures of individual differences, an unexpected outcome was the fact that beginner bilinguals were faster than advanced bilinguals when providing the responses to the stimuli presented in the inhibitory control task and that beginner bilinguals performed better that advanced bilinguals in the working memory task. These results were surprising in that advanced bilinguals, being more experienced with the second language would have been the ones who benefited more, cognitively speaking, from bilingualism. However, analyzing the questionnaire, I noticed that only 2 of the 11 advanced bilinguals were still studying English, while 8 of the 11 beginner bilinguals practiced English regularly in formal English classes. This leads us to the conclusion that it could be the process of acquiring a second language rather that the product of being proficient, the factor influencing the cognitive advantages of bilinguals in speed of processing and working memory capacity.

Finally, the second and most important conclusion in relation to working memory capacity is the fact that no significant correlation was found between the response times of participants in the frequency effects task and working memory capacity (r = .472, p = .168 for advanced bilingual participants and r = -.085, p = .805 for beginner bilinguals). Therefore, we can conclude that individual differences, measured through the working memory capacity function with the letter-number ordering task, did not influence the results obtained in the frequency effects tasks.

5.2 Limitations of the study and suggestions for further research

Although the present study followed strict methodological conditions and controlled for many possible influential variables, there are some limitations that need to be admitted so that readers treat the data with the necessary caution.

The results of this study cannot be generalized to the population of second language learning since we are aware of the fact that the participants included in the present study are a very small sample of bilinguals and native speakers. Furthermore, because of the small

number of participants, analysis of the role of sex differences in the processing of regular and irregular verbs in English and the relationship of these with the of inhibitory control and working memory capacity could not be pursued.

Aiming at sharing some of the experiences that conducting this kind of research left, it is worth mentioning the difficulty that gathering even a small number of adult participants represented. Being an experimental study with different methodological steps that needed to be followed in data collection, each data collection session took from 2 to 3 hours, including the questionnaire, the proficiency test and the completion of the 3 tasks. Trying to control for environmental factors, data collection was conducted always at the same laboratory room at UFSC. Therefore participants needed to be willing to go to UFSC and this might be one of the reasons why many possible participants refused to volunteer for the study.

Finally, a further limitation of this study is that, because of time constraints, it was not possible to include groups of young beginner bilinguals, young advanced bilinguals and young native speakers. These groups would have been an interesting comparison sample to the adult groups as regards verbal morphological processing as well as inhibitory control and working memory capacity functions.

For further research, with more time to devote to data collection so as to gather a bigger number of participants, comparisons between the processing of men and women would be interesting. Also, comparisons between different age groups, for instance, young participants and older participants would provide valuable data. Moreover, a study focused on the differences as regards inhibitory control, working memory capacity and proficiency in a second language would be interesting to be carried out in order to improve our knowledge of the impact of these variables on L2 processing.

5.3 Methodological and pedagogical implications

One significant methodological implication of the present study is the design and programming of the 3 experimental tasks applied. Each task was designed consulting several previous studies, complete corpus and reliable statistical tests. For the programming of the tasks, E-Prime 2.0, a reliable tool to create experimental tasks was used. This practice of creating experiments taking into consideration the kind of study, the context and the participants, although being time consuming is completely recommendable to ensure reliable data. Moreover, I consider

that the present study makes available a detailed description of all the steps followed in the design and programming of each task, which can be considered as a contribution for further studies replicating this study or even studies analyzing the creation of new experiments.

Another implication concerning method is related to the pre-pilot and pilot sessions. These steps prior to data collection were important to check if the tasks were running as expected and to see how adult participants would react to the tasks. These sessions avoided invalidating data from participants in the data collection phase due to eventual mistakes or problems with the task.

Also, the procedures for data collection are another contribution for methods in L2 research in Brazil. In the present study, each session of data collection was carried out by the researcher in charge of the study with each participant individually. The sessions were always in the same room, at UFSC, to ensure the optimal environmental conditions. Instead of the keyboard, an SRBOX was used to capture the responses of the participants to the stimuli, which is considered to be more precise for experiments capturing response times. Each session followed the steps described in 3.4 with no exception.

In terms of pedagogical implications, this study offers sound and reliable data reporting that adult bilinguals, either beginning the process of learning English as a second language, or at advanced levels of proficiency, train the use of associative memory and therefore could improve this memory system and slow down the decline due to aging of such indispensable cognitive resource. Moreover, the study presents the possibility that it might be the process of acquiring a second language, rather that the product of advanced proficiency the reason for cognitive advantages in bilinguals, Taking into consideration the advantages of bilingualism on associative memory and the advantages of the process of learning a second language on cognitive ability, it would be important to foster public language policies to create ESL classes that suit the needs of older adults. Such policies should inform the society about the advantages of early and late bilingualism to motivate adults who already know a second language or are learning one, to continue the process to benefit from the cognitive advantages of bilingualism, as well as to motivate monolingual adults to start the process. Finally, it is crucial to prepare qualified language teachers to deliver classes specially planned for older students.

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APPENDIX A
Consent form in portuguese

Formulário do consentimento livre e esclarecido

Título do projeto: "Efeitos da idade e da proficiência no processamento morfológico verbal em inglês como L1 e L2."
Gostaria de lhe convidar a participar de um projeto de pesquisa sobre aquisição de segunda língua. Se você aceitar participar, porfavor leia este consentimento e, se concordar com a informação aqui apresentada, assine onde indicado. Uma cópia ficará comigo, sendo a pesquisadora responsável pelo projeto, e outra com você.

Objetivo da pesquisa: o objetivo deste estudo é analisar o processamento morfológico verbal do inglês como l2 em falantes nativos do português brasileiro. Os dados coletados neste estudo serão utilizados na minha dissertação de mestrado que tem como orientadora a prof. Dra. Mailce Borges Mota (UFSC/CCE/DLLE/PPGI – mailce@cce.ufsc.br).

Procedimentos: se você aceitar participar deste estudo, você será solicitado a realizar os seguintes passos: responder uma entrevista, fazer uma prova de proficiência e completar três tarefas cognitivas no computador. Todas as atividades referentes a este projeto serão feitas no CCE "B", sala 511, fora de horário de aula, em horário no qual você e a pesquisadora tenham disponibilidade.

Riscos da pesquisa: não há riscos em participar deste estudo. Antes da realização de cada tarefa, você terá o tempo que for necessário para praticar o procedimento da tarefa e para tirar todas as dúvidas fazendo as perguntas que quiser. Ao finalizar a pesquisa, os resultados do estudo serão tornados públicos, mas garantimos que a sua identidade será absolutamente preservada e que unicamente a pesquisadora e a sua orientadora terão acesso aos dados coletados.

Natureza voluntária do estudo: sua decisão de participar ou não deste estudo não afetará sua relação com a universidade de nenhuma forma. Você pode decidir desistir a qualquer momento. Peço apenas que você me notifique, você não precisará se justificar.
Pesquisadora responsável: mariana beatríz perrino (perrino_mariana@hotmail.com; (48) 9944-6530)

Declaração de consentimento:

Declaro que li a informação acima. Quando necessário, fiz perguntas e recebi esclarecimentos. Eu concordo em participar deste estudo.

Nome:
_____.

Data: _____/_____/_____.

_____
assinatura do participante

_____
Assinatura da pesquisadora responsável

APPENDIX B

CONSENT FORM IN ENGLISH

Consent Form

Project title: "The effects of age and proficiency on verbal morphological processing in English as L1 and L2."
I'd like to invite you to take part in a research Project about second language acquisition and processing. You are being invited to participate in this research for being a native speaker of English. Please, read this consent form and if you agree with the information presented here and you are willing to take part in the study, sign where appropriate.

Objective of the study: The objective of this study is to analyze the morphological verbal processing of English as a second language in native speakers of Brazilian Portuguese. As a native speaker of English you will contribute with data which will be used in a comparison with the data collected by Brazilian speakers of English as a second language. The data collected in this study will be used in my M.A. thesis which is being advised by Dr. Mailce Borges Mota (UFSC/CCE/DLLE/PPGI – mailce@cce.ufsc.br).

Procedures: If you accept to participate in this research you will be asked to do the following: to answer a questionnaire and to complete three cognitive tasks in the computer. In order to gather the data from these tasks you will have to meet the researcher at UFSC on a date and at a time that bests suits you. The completion of the two tasks should not take longer than 40 minutes.

Risks and benefits of the study: There are no risks in taking part in this research. Before performing the tasks you will have time to get familiarized with them and ask questions until you feel comfortable with them. At the end of the research the results of the study will be made public but your identity will be preserved and no information will be provided that might make your identification possible. Only the researcher and her advisor will have access to the data collected.

Volunteer nature of the study: Your decision in taking part or not in this study will not affect you or your relation with the University in any way. If you decide to participate and later on decide to give up, there's no problem, you can quit at any moment. I just ask you to notify me, no justifications are needed.

Researcher: Mariana Beatriz Perrino (perrino_mariana@hotmail.com; (48) 9944-6530)

I declare I have read the above information. When necessary I made questions and received clarifications. I agree in taking part of this study.

Name: _____

Date: _____

_____ _____

Participant's signature Researcher's signature

APPENDIX C

QUESTIONNAIRE APPLIED TO BILINGUAL BRAZILIANS

UNIVERSIDADE FEDERAL DE SANTA CATARINA
CCE - DLLE
Programa de Pós Graduação em Inglês e Literatura Correspondente

Seção 1: Informações gerais do participante:

1. Data da entrevista: ____/____/_____
2. Horário: _____:_____
3. Nome do participante: _____
4. Data de nascimento: ____/____/_____
5. Idade: _____ anos.
6. País de nascimento: _____
7. Nacionalidade: _____
8. Sexo: ( ) M ( ) F
9. Grau de escolaridade

( ) Nenhuma escolaridade
( ) Ensino Fundamental: de 1º à 4º série
( ) Ensino Fundamental: de 5º à 8º série
( ) Ensino Médio
( ) Superior Incompleto.
( ) Superior Completo.

10. Formação: _____
11. Ocupação atual: _____
12. Informações para contato:

Telefones: _____
E-mail: _____

13. Você é destro ou canhoto? _____

Seção 2: Informações sobre a Segunda Língua:

1) Quantas línguas você fala?

_____

2) Quais são?

_____

3) Com que idade você começou a aprender inglês?
_____

4) Com que idade você percebeu que já tinha o domínio do inglês?
_____

5) Em que contexto (s) você aprendeu a língua inglesa? (Ex.: curso, morou no exterior)
_____
_____

6) Você já morou num país onde você ficou exposto à língua inglesa?
( ) Sim ( ) Não

Se 'sim', responda as perguntas abaixo:
a. Em quais?
_____
b. Que idade você tinha quando foi morar nesses países?
_____
c. Quanto tempo você ficou?
_____
d. Durante o tempo em que você morou no exterior, em que contexto (s) você utilizou a língua inglesa? (Ex.: em casa, na escola)_____
_____

7) Você frequentou aulas de inglês num curso de línguas?

( ) Sim ( ) Não
Se 'sim', quanto tempo você frequentou as aulas?
_____

8) Você continua tento aula de inglês?

( ) Sim ( ) Não

Se 'sim', qual o seu nível?
_____

9) Faça uma avaliação do seu desempenho na língua inglesa e alguma outra línguaque você saiba. Abaixo de cada habilidade escreva (1) para muito bom (2) para bom (3) regular e (4) ruim

Idiomas	Fala	Entendimento Oral	Leitura	Escrita
Inglês				
Outro:				
Outro:				

Seção 3: Informações Clínicas:

1. Você ou alguém da sua família (pai, mãe e irmãos) já foi diagnosticado como portador de alguma doença degenerativa como o Alzheimer, Parkinson ou Huntington?

Sim ( ) Não ( )

Se 'sim', responda as perguntas embaixo:

a. Quem?

_____

b. Que doença?

_____

c. Data de Diagnóstico

_____

d. Tratamento

_____

Seção 4: Informações Farmacológicas:

1. Informe os medicamentos utilizados por você nos últimos 12 meses (pílula, comprimido, injeção, etc). Incluir (1) remédios com prescrição, (2) remédios sem prescrição como remédio para resfriado e (3) remédios alternativos como fitoterápicos e ervas medicinais.

Tipo de medicamento	Nome do medicamento	Data de início (ano)	Duração do tratamento	Observações: reações alérgicas, overdoses, etc
Com prescrição				
Com prescrição				
Com prescrição				
Com prescrição				
Com prescrição				
Com prescrição				
Sem prescrição				
Sem prescrição				
Sem prescrição				
Sem prescrição				
Sem prescrição				
Alternativos				
Alternativos				
Alternativos				
Outro				
Outro				

APPENDIX D

Questionnaire applied to the Americans

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PROFILE QUESTIONNAIRE:

Name: _____
Male ( ) Female ( )
Age: _____
Handedness:_____
Country of birth: _____
Nationality: _____
Education: _____ Career: _____
Professional activity (if any)_____
E-mail address:_____

1. How long have you been away from the U.S.?
_____

2. How long have you been living in Brazil?
_____

3. Have you studied Portuguese before you arrived in Brazil? (Either formally or by yourself) For how long?
_____

4. Currently, in your daily life, do you speak more Portuguese or English? Or you would say you speak about the same amount of each?
_____

5. What is your mother tongue?
_____

6. When you were growing up, were you exposed to another language, besides English, at home? If yes, which one?
_____

7. a. How many languages do you speak? Which ones?

_____

b. How old were you when you started learning each one of them?

_____

c. In which contexts did you learn them?

_____

8. If you have some knowledge in another language(s), please complete the chart bellow specifying the language and writing (1) excellent, (2) for good, (3) for regular, (4) for weak for each one of the skills.

Language	Speaking skill	Listening skill	Reading skill	Writing skill

9. Have you, or any of your relatives (mother, father, sisters or brothers) been diagnosed with any degenerative illness, like Alzheimer, Parkinson or Huntington?

Yes ( ) No ( )

If yes, please answer the questions bellow:
e. Who?

_____

f. Which illness?

_____

g. Year of diagnosis:

_____

h. Treatment:

_____

APPENDIX E

1. INSTRUCTIONS FOR THE FREQUENCY EFFECTS TASK

In Portuguese:

“Bem vindo ao teste de "EFEITOS DE FREQUÊNCIA".
Primeiramente será apresentado um verbo em inglês. Após cada verbo, será apresentada uma sentença no presente e uma sentença que você deverá completar oralmente com o verbo no passado.
ATENÇÃO: você deverá produzir em voz alta somente o verbo conjugado no passado.
Tente ser o mais rápido possível, pois estamos medindo o seu tempo de resposta.”

In English:

“Welcome to the "FREQUENCY EFFECTS" task.
You will be presented with an English verb. After each verb will be a sentence in the present tense, and that sentence in the past tense with the verb missing. Speak the past tense conjugation of the verb to move on to the next sentence.
ATTENTION: Speak ONLY the verb in the past tense, and be sure to speak loudly.
Try to respond as quickly as possible as we will be measuring your response time.”

2. INSTRUCTIONS FOR THE WORKING MEMORY TASK

“Bem vindo à tarefa "ORDENAÇÃO DE LETRAS E NÚMEROS".
Neste teste você escutará uma série de letras e números.
Você deverá repetir, primeiramente os números em ordem crescente, e depois as letras em ordem alfabética.
Começaremos o teste com dois itens e iremos aumentando gradativamente.
Vamos aprender como o experimento funciona?”

3. INSTRUCTIONS FOR THE EXECUTIVE CONTROL TASK

“Bem vindo ao teste “SIMON FLECHAS”. Neste teste você verá uma seqüência de flechas e deverá pressionar o botão 1 ou o 5 conforme o modelo embaixo:
Pressione a tecla 1 quando vir
Pressione a tecla 5 quando vir
Tente ser o mais rápido possível, pois estamos medindo seu tempo de resposta
Pressione espaço para ver como o experimento funciona.”

APPENDIX F

Newman et al.´s (2007) complete list of stimuli ordered from the most to the least frequent verbs

Regular verbs		Irregular verbs	
Frequent	**Infrequent**	**Frequent**	**Infrequent**
Look	Pour	Think	Ring
Seem	Urge	Feel	Shoot
Ask	Plan	Take	Spend
Call	Share	Tell	Sing
Walk	Roar	Run	Spin
Used	Snap	Write	Bear
Try	Sign	Bring	Sink
Stop	Tie	Keep	Teach
Pass	Beg	Lose	Cling
Work	Owe	Speak	Stride
Drop	Weigh	Break	Eat
Watch	Care	Grow	Swear
Play	Score	Catch	Steal
Stay	Strain	Seek	Bend
Stare	Stripp	Swing	Creep
Pull	Dare	Hold	Feed
Serve	Sail	Drive	Deal
Wish	Whip	Ride	Weep
Fail	Sway	Build	Swim
Raise	Stir	Send	Hide
Talk	Frown	Throw	Grind
Help	Dry	Win	Fling
Cause	Drown	Buy	Bind
Roll	Fan	Sell	Lend
Join	Scrawl	Mean	Bleed
Hope	Spray	Strike	Dig
Step	Glue	Sweep	Sling
Jump	View	Fly	Freeze
Change	Store	Fight	Wring
Slip	Spy	Sleep	Sting
Cry	Dye	Stick	String
Sigh	Vie	Slide	Breed

APPENDIX G

1. Newman et al.´s (2007) complete list of verbs reorganized according to the raw frequencies from coca, ordered from the most frequent to the least frequent

Reg. stems	COCA	Reg. past	COCA	Irreg. stems	COCA	Irreg. past	COCA
Look	197064	Used	186292	Think	579698	Told	172012
Help	145576	Called	166028	Take	302834	Took	157331
Use	135009	Asked	152431	Tell	173781	Thought	157140
Work	131786	Looked	124138	Mean	158947	Felt	103445
Talk	105066	Seemed	80278	Keep	140346	Lost	78101
Try	100449	Tried	70914	Feel	134573	Held	75395
Call	97163	Worked	67951	Run	77559	Brought	69232
Ask	95411	Played	50400	Bring	76777	Spent	57318
Play	78622	Changed	48240	Buy	55739	Kept	56861
Stay	65982	Passed	44058	Hold	53707	Wrote	52256
Stop	64943	Helped	44000	Speak	44188	Won	49975
Seem	64558	Walked	42296	Win	43721	Sent	46697
Change	60065	Stopped	41782	Write	41276	Built	44066
Watch	45403	Talked	38759	Eat	40079	Ran	41556
Hope	45358	Raised	38150	Spend	39643	Caught	38763
Serve	37136	Pulled	37717	Build	37791	Meant	36843
Walk	36458	Served	32881	Lose	36173	Sold	32613
Care	30908	Watched	32763	Send	35316	Grew	32226
Pass	28792	Dropped	28356	Sell	32692	Spoke	31856
Share	28489	Caused	26905	Grow	31497	Bought	30592
Raise	28066	Joined	26526	Deal	29730	Shot	28293
Pull	25980	Failed	25661	Break	26745	Taught	25100
Join	25777	Signed	22415	Drive	26318	Broke	22419
Wish	24953	Stayed	19272	Fight	24140	Drove	18756
Cause	22227	Stepped	17785	Teach	23958	Struck	17779
Drop	16625	Planned	15801	Catch	21681	Sought	16984
Plan	15293	Tied	15439	Seek	19611	Threw	15312
Step	14328	Stared	15233	Sleep	18527	Stuck	15023
Sign	13287	Shared	14362	Throw	18163	Fought	13415
Fail	11931	Hoped	13738	Fly	15536	Fed	11367
Stir	11453	Viewed	12989	Shoot	14529	Ate	10465
Roll	10980	Scored	12683	Sing	13371	Bound	10085
View	10481	Rolled	12599	Bear	12678	Flew	9876
Jump	10184	Jumped	11667	Hide	11659	Bent	9223

Cry	9509	Cried	10646	Stick	11141	Slept	8446
Pour	8151	Slipped	9952	Ride	10904	Swept	7516
Slip	5943	Wished	8037	Feed	10453	Dealt	7070
Tie	575	Sghed	7146	Strike	8198	Slid	6716
Stare	5334	Urged	6987	Dig	5721	Sang	6706
Score	5238	Poured	6840	Steal	5698	Rode	5997
Dare	5225	Snapped	6521	Slide	4838	Rang	5443
Owe	4919	Cared	5790	Swim	4461	Swung	5272
Weigh	4538	Stored	5028	Swear	4373	Dug	5092
Store	4388	Weighed	4043	Swing	3958	Stole	4925
Dry	4291	Frowned	3907	Ring	3940	Spun	3784
Snap	3529	Stripped	3454	Freeze	3873	Sank	3661
Urge	3004	Stirred	3338	Bend	3817	Bore	3660
Beg	2957	Dried	3313	Sink	3655	Hid	3418
Fan	2301	Owed	3190	Lend	3587	Flung	2438
Sail	2244	Begged	2585	Spin	3031	Froze	2390
Spray	1920	Dared	2537	Sweep	2349	Crept	2221
Strain	1679	Whipped	2359	Bind	1668	Swam	2067
Drown	1673	Sailed	2358	Breed	1528	Clung	2010
Whip	1668	Drowned	2317	Cling	1458	Swore	1953
Strip	1596	Roared	2057	Grind	1369	Lent	1759
Sway	1021	Strained	1786	Bleed	1319	Strode	1752
Vie	935	Sprayed	1496	Weep	1099	Wept	1730
Glue	856	Glued	1489	Creep	1044	Bred	1707
Spy	829	Swyed	1465	Sting	578	Ground	1693
Roar	625	Fanned	965	Fling	527	Strung	1516
Sigh	455	Spied	907	String	492	Stung	1498
Frown	338	Dyed	681	Wring	460	Slung	1151
Scrawl	60	Scrawled	676	Stride	402	Bled	978
Dye	5	Vied	231	Sling	174	Wrung	422

2. Newman et al.´s (2007) list of verbs reorganized according to the natural logarithm of the raw frequencies from coca, ordered from the more frequent to the least frequent

Reg. stems	NL	Reg. past	NL	Irreg. stems	NL	Irreg. past	NL
Look	12,191	Looked	11,729	Think	13,270	Thought	11,964
Help	11,888	Helped	10,691	Take	12,620	Took	11,966
Use	11,813	Used	12,135	Tell	12,065	Told	12,055
Work	11,7889	Worked	11,126	Mean	11,976	Meant	10,514
Talk	11,562	Talked	10,565	Keep	11,851	Kept	10,948
Try	11,517	Tried	11,169	Feel	11,809	Felt	11,546
Call	11,484	Called	12,019	Run	11,258	Ran	10,634
Ask	11,465	Asked	11,934	Bring	11,248	Brought	11,145
Play	11,272	Played	10,827	Buy	10,928	Bought	10,328
Stay	11,097	Stayed	9,8664	Hold	10,891	Held	11,230
Stop	11,081	Stopped	10,640	Speak	10,696	Spoke	10,368
Seem	11,075	Seemed	11,293	Win	10,685	Won	10,819
Change	11,003	Changed	10,783	Write	10,628	Wrote	10,863
Watch	10,723	Watched	10,397	Eat	10,598	Ate	9,255
Hope	10,722	Hoped	9,5279	Spend	10,587	Spent	10,956
Serve	10,522	Served	10,400	Build	10,539	Built	10,693
Walk	10,503	Walked	10,652	Lose	10,496	Lost	11,265
Care	10,338	Cared	8,663	Send	10,472	Sent	10,751
Pass	10,267	Passed	10,693	Sell	10,394	Sold	10,392
Share	10,257	Shared	9,572	Grow	10,357	Grew	10,380
Raise	10,242	Raised	10,549	Deal	10,299	Dealt	8,863
Pull	10,165	Pulled	10,537	Break	10,194	Broke	10,017
Join	10,157	Joined	10,185	Drive	10,178	Drove	9,839
Wish	10,124	Wished	8,991	Fight	10,091	Fought	9,504
Cause	10,009	Caused	10,200	Teach	10,084	Taught	10,130
Drop	9,718	Dropped	10,252	Catch	9,984	Caught	10,565
Plan	9,635	Planned	9,667	Seek	9,883	Sought	9,740
Step	9,569	Stepped	9,786	Sleep	9,826	Slept	9,041
Sign	9,494	Signed	10,017	Throw	9,807	Threw	9,636
Fail	9,386	Failed	10,152	Fly	9,650	Flew	9,197
Stir	9,346	Stirred	8,113	Shoot	9,583	Shot	10,250
Roll	9,303	Rolled	9,441	Sing	9,500	Sang	8,810
View	9,257	Viewed	9,471	Bear	9,447	Bore	8,205
Jump	9,28	Juped	9,364	Hide	9,363	Hid	8,136
Cry	9,159	Cried	9,272	Stick	9,318	Stuck	9,617
Pour	9,005	Poured	8,830	Ride	9,296	Rode	8,699
Slip	8,689	Slipped	9,205	Feed	9,254	Fed	9,338
Tie	8,663	Tied	9,644	Strike	9,011	Struck	9,785
Stare	8,581	Stared	9,631	Dig	8,651	Dug	8,535
Score	8,563	Scored	9,448	Steal	8,647	Stole	8,502
Dare	8,561	Dared	7,838	Slide	8,484	Slid	8,812
Owe	8,500	Owed	8,067	Swim	8,403	Swam	7,633

Weigh	8,420	Weighed	8,304	Swear	8,383	Swore	7,577
Store	8,386	Stored	8,522	Swing	8,283	Swung	8,570
Dry	8,364	Dried	8,105	Ring	8,278936	Rang	8,602
Snap	8,168	Snapped	8,782	Freeze	8,26178468	Froze	7,779
Urge	8,007	Urged	8,851	Bend	8,24722005	Bent	9,129
Beg	7,991	Begged	7,857	Sink	8,20385137	Sank	8,205
Fan	7,741	Fanned	6,872	Lend	8,1850714	Lent	7,472
Sail	7,716	Sailed	7,765	Spin	8,01664788	Spun	8,238
Spray	7,560	Sprayed	7,310	Sweep	7,76174498	Swept	8,924
Strain	7,425	Strained	7,487	Bind	7,41938058	Bound	9,218
Drown	7,422	Downe	7,748	Breed	7,33171497	Bred	7,442
Whip	7,419	Whipped	7,765	Cling	7,28482091	Clung	7,605
Strip	7,375	Stripped	8,147	Grind	7,22183583	Ground	7,434
Sway	6,928	Swayed	7,289	Bleed	7,18462915	Bled	6,885
Vie	6,840	Vied	5,442	Weep	7,00215595	Wept	7,455
Glue	6,752	Glued	7,305	Creep	6,95081477	Crept	7,705
Spy	6,720	Spied	6,810	Sting	6,35957387	Stung	7,311
Roar	6,437	Roared	7,629	Fling	6,26720055	Flung	7,798
Sigh	6,120	Sighed	8,874	String	6,19847872	Strung	7,323
Frown	5,823	Frowned	8,270	Wring	6,13122649	Wrung	6,045
Scrawl	4,094	Scrawled	6,516	Stride	5,99645209	Strode	7,468
Dye	1,609	Dyed	6,523	Sling	5,1590553	Slung	7,048

APPENDIX H

Complete list of verbs (sixteen irregular frequent, sixteen irregular infrequent, sixteen regular frequent, sixteen regular infrequent) used for the design of the frequency effects task, ordered from the most frequent to the least frequent verbs

Regular Verbs		Irregular Verbs	
Stem	**Past Tense**	**Stem**	**Past form**
Look	Looked	Think	Thought
Help	Helped	Take	Took
Use	Used	Tell	Told
Work	Worked	Keep	Kept
Talk	Talked	Feel	Felt
Try	Tried	Run	Ran
Call	Called	Bring	Brought
Ask	Asked	Buy	Bought
Play	Played	Hold	Held
Stay	Stayed	Speak	Spoke
Stop	Stopped	Write	Wrote
Change	Changed	Eat	Ate
Watch	Watched	Spend	Spent
Hope	Hoped	Lose	Lost
Serve	Served	Sell	Sold
Walk	Walked	Grow	Grew
Roll	Rolled	Sing	Sang
View	Viewed	Hide	Hid
Jump	Jumped	Ride	Rode
Cry	Cried	Feed	Fed
Pour	Poured	Dig	Dug
Tie	Tied	Steal	Stole
Stare	Stared	Slide	Slid
Score	Scored	Swim	Swam
Store	Stored	Swear	Swore
Dry	Dried	Ring	Rang
Beg	Begged	Freeze	Froze
Sail	Sailed	Bend	Bent
Spray	Sprayed	Sink	Sank
Glue	Glued	Lend	Lent

Spy	Spied	Spin	Spun
Dye	Dyed	Bleed	Bled

APPENDIX I

The list of sentences used as contexts for the frequency effects task

Regular Verbs	Irregular Verbs
Every day I look at birds. Yesterday I ...	Every day I think about work. Yesterday I ...
Every day I help my mother. Yesterday I …	Every day I take a pill. Yesterday I …
Every day I use my computer. Yesterday I …	Every day I tell a joke. Yesterday I…
Every day I work from home. Yesterday I …	Every day I keep a secret. Yesterday I …
Every day I talk to Sue; Yesterday I…	Every day I feel very happy. Yesterday I ...
Every day I try new things. Yesterday I …	Every day I run five kilometers Yesterday I …
Every day I call my father. Yesterday I…	Every day I bring a gift. Yesterday I…
Every day I ask a question. Yesterday I…	Every day I buy some chocolate. Yesterday I …
Every day I play a game. Yesterday I…	Every day I hold my baby. Yesterday I …
Every day I stay well informed. Yesterday I …	Every day I speak with her. Yesterday I ...
Every day I stop at McDonalds. Yesterday I…	Every day I write a paragraph. Yesterday I ...
Every day I change my clothes. Yesterday I …	Every day I eat a banana. Yesterday I …
Every day I watch a movie. Yesterday I…	Every day I spend my money. Yesterday I ...
Every day I hope for success. Yesterday I …	Every day I lose my keys. Yesterday I ...
Every day I serve hot tea. Yesterday I…	Every day I sell some flowers. Yesterday I ...
Every day I walk four blocks. Yesterday I …	Every day I grow a little. Yesterday I ...
Every day I roll the dice. Yesterday…	Every day I sing a song. Yesterday I …

Every day I view the mountains. Yesterday I…	Every day I hide my wallet. Yesterday I…
Every day I jump really high. Yesterday I …	Every day I ride my bike. Yesterday I …
Every day I cry a lot. Yesterday I…	Every day I feed my dog. Yesterday I …
Every day I pour some milk. Yesterday I	Every day I dig up dirt. Yesterday I …
Every day I tie my shoes. Yesterday I…	Every day I steal a kiss. Yesterday I…
Every day I stare at you. Yesterday I…	Every day I slide on ice. Yesterday I…
Every day I score some points. Yesterday I …	Every day I swim a mile. Yesterday I ...
Every day I store some candy. Yesterday I …	Every day I swear in traffic. Yesterday I…
Every day I dry the dishes. Yesterday I…	Every day I ring the doorbell. Yesterday I …
Every day I beg for food. Yesterday …	Every day I freeze some vegetables. Yesterday I
Every day I sail my boat. Yesterday I…	Every day I bend my back. Yesterday I …
Every day I spray my roses. Yesterday I …	Every day I sink into snow. Yesterday I …
Every day I glue things together. Yesterday I …	Every day I lend six dollars. Yesterday I ...
Every day I spy on people. Yesterday I …	Every day I spin my wheels. Yesterday I ...
Every day I dye some fabric. Yesterday I …	Every day I bleed too much. Yesterday I...

APPENDIX J

Complete list of stimuli and expected correct answers for the working memory task

Stimuli	Correct answers
L – 2	2 – L
6 – Q	6 – Q
C – 5	5 – C
F – 7 – L	7 – F – L
R – 4 – A	4 – A – R
G – 1 – 8	1 – 8 – G
S – 9 – A – 3	3 – 9 – A – S
J – 1 – X – 5	1 – 5 – J – X
7 – R – 4 – L	4 – 7 – L – R
8 – A – 6 – G – 1	1 – 6 – 8 – A – G
L – 2 – C – 7 – S	2 – 7 – C – L – S
5 – Q – 3 – X – 9	3 – 5 – 9 – Q – X
J – 4 – C – 7 – Q – 2	2 – 4 – 7 – C – J – Q
Z – 8 – J – 5 – F – 3	3 – 5 – 8 – F – J – Z
6 – G – 9 – A – 2 – S	2 – 6 – 9 – A – G – S
R – 3 – A – 4 – Z – 1 – G	1 – 3 – 4 – A – G – R – Z
5 – S – 9 – J – 2 – X – 7	2 – 5 – 7 – 9 – J – S – X
F – 1 – L – 8 – R – 4 – C	1 – 4 – 8 – C – F – L – R
5 – G – 9 – S – 2 – L – 6 – A	2 – 5 – 6 – 9 – A – G – L – S
C – 1 – R – 9 – A – 4 – J – 3	1 – 3 – 4 – 9 – A – C - J – R
7 – J – 2 – S – 6 – F – 1 – Z	1 – 2 – 6 – 7 – F – J – S – Z