COMENIUS UNIVERSITY IN BRATISLAVA FACULTY OF MATHEMATICS, PHYSICS AND INFORMATICS



REGULAR AND IRREGULAR MORPHOLOGICAL INFLECTION

IN BILINGUALS: EVIDENCE FROM HUNTINGTON'S DISEASE

STUDIES

Diploma Thesis

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REGULAR AND IRREGULAR MORPHOLOGICAL INFLECTION IN BILINGUALS: EVIDENCE FROM HUNTINGTON'S DISEASE STUDIES

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Name: Regular and irregular morphological inflection in bilinguals: evidence from Huntington's disease studies.

- Anotation: Recent studies in Huntington's disease patients suggest that the basal ganglia are involved in morphological inflection. However, it is unclear whether the effect is lexical or grammatical. Huntington's disease research provides evidence for two possibilities: an inhibitory role in final selection or an integral role in earlier processing. According to general research in bilinguals, executive control and especially inhibitory functions are strengthened by use of two languages. Analysis of these studies reveals that bilingualism in Huntington's disease patients may provide an enlightening context for clarifying the role of the basal ganglia.
- Aim: Gather together the relevant data from theoretical and empirical research and analyze it in order to understand the nature of morphological inflection in bilinguals. Predict whether bilingual Huntington's disease patients can provide additional insight on the involvement of the basal ganglia in these processes. Create a research plan based on previous studies and do a case study if possible.
- Literature: Roumpea, G., Blesic, M., Georgiev, D., Manouilidou, C. (2019). Regular and irregular forms : evidence from Parkinson's and Alzheimer's disease in Slovene-speaking individuals. *Proceedings of the 22nd International Multiconference INFORMATION SOCIETY* 2019(B): 47-51

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student

vedúci práce

Declaration

I hereby declare that I elaborated this diploma thesis independently using the cited literature.

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Abstrakt

LEBENS, Rebecca Rose: Pravidelné a nepravidelné (morfologické) skloňovanie u bilingvistov: Dôkazy zo štúdií zameraných na Huntingtonovu chorobu. [Diplomová Práca]. – Univerzita Komenského v Bratislave. Fakulta Matematiky, Fyziky a Informatiky; Oddelenie Aplikovanej Informatiky. – Školitel': Mgr. Juraj Bánovský, PhD. – Univerzita v L'ublane, Filozofická fakulta, Oddelenie komparatívnej a všeobecný lingvistiky. – Školitel': Prof. Dr. Christina Manouilidou, PhD. Stupeň kvalifikácie: Magister. Bratislava: FMFI UK, 2020. 67s

Jednou z oblastí záujmu neurolingvistiky sú bazálne gangliá. Výskum rečových porúch zapríčinených Huntingtonovou chorobou priniesol niekoľko teórii o neurologickej podstate flexie a úlohe bazálnych ganglií v týchto procesoch [Ullman *et al* 1997, Kargieman *et al* 2014]. Existujúce štúdie zatiaľ poskytli iba protichodné výsledky vedúce k rozličným názorom na úlohu bazálnych ganglií v lexikálnom vyhľadávaní a spracovávaní gramatických pravidiel [Teichmann *et al* 2005, Longworth *et al* 2005]. Dve hlavné otázky sa týkajú toho, či bazálne gangliá sú potrebné pre vykonávanie gramatických operácii založených na pravidlách, alebo či sa podieľajú na všeobecnej inhibícii navzájom si konkurujúcich lexikálnych foriem. Na testovanie týchto teórii sa používajú úlohy zamerané na flexiu, v ktorých sú gramatické spracovávanie a lexikálne vyhľadávanie disociované, ako napríklad pri porovnávaní pravidelnej a nepravidelnej flexie v angličtine [Ullman *et al* 1997, Tyler 2002, Longworth *et al* 2005]. Kontext pre porovnanie týchto dvoch hypotéz by mohol poskytnúť výskum bilingválnych osôb, keďže v ich prípade je performancia v inhibičných úlohách silnejšia.

Kľúčové slová: morfologické skloňovanie, lexikálnym získavaním, spracovanie gramatickéch pravidiel, Huntingtonova choroba, bilingvalizmus

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Abstract

LEBENS, Rebecca Rose: Regular and irregular morphological inflection in bilinguals: evidence from Huntington's disease studies. [Diploma Thesis]. – Comenius University in Bratislava. Faculty of Mathematics, Physics and Informatics; Department of Applied Informatics. – Supervisor: Mgr. Juraj Bánovský, PhD. – University of Ljubljana, Faculty of Arts, Department of Comparative and General Linguistics. – Supervisor: Dr. Christina Manouilidou, PhD. Qualification Degree: Master. Bratislava: FMPH CU, 2020. 67p

In the field of neurolinguistics, one area of interest is the basal ganglia. Research into the linguistic impairments caused by Huntington's disease has produced several theories regarding the neurological underpinnings of morphological inflection and the role of the basal ganglia in such processes [Ullman *et al* 1997, Kargieman *et al* 2014]. From the existing studies, there are contradictory results leading to differing positions on the necessity of the basal ganglia in lexical retrieval and grammatical rule processing [Teichmann *et al* 2005, Longworth *et al* 2005]. The main two arguments debate whether the basal ganglia are necessary for grammatical rule-based tasks or if they are involved in the general inhibition of competing lexical forms. In order to test these theories, tasks of morphological inflection in which there is a dissociation between grammatical processing and lexical retrieval, such as the comparison of regular and irregular English past tense conjugation, are used [Ullman *et al* 1997, Tyler 2002, Longworth *et al* 2005]. As performance in inhibitory tasks is stronger in bilinguals, the same research in bilinguals could provide a context for comparing these two hypotheses.

Key Words: Inflectional morphology, lexical retrieval, grammatical rule application, Huntington's disease, bilingualism

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Introduction

In a globalizing world, as the population of bilingual and multilingual speakers increases, the importance of related research also grows. However, most interdisciplinary linguistic research focuses on monolingual speakers. One reason for this is the high degree of variation in bilingual performance and competence in contrast to monolinguals. Age of language acquisition, learning methods, usage environment and degree of competency are only a few of the factors which create individual differences that hinder the viability of linguistic tasks and models. In order to create a valid method for studying linguistic processes in bilingual and multilingual contexts, the reliability of existing models and research should be thoroughly evaluated.

One area of relevance for bilingualism studies is the organization and processing of the mental lexicon and the mental grammar. The mental lexicon is comprised of words and their characteristics, such as pronunciation and applicable syntax. The mental grammar is defined as the set of rules and principles that govern those words, allowing them to be used productively and understandably in larger contexts. In terms of processing information stored in the mental lexicon and mental grammar, bilingual speakers are presumed to be weaker than monolinguals [Sandoval *et al* 2010]. In tasks of lexical retrieval, bilinguals experience longer reaction times [Ivanova *et al* 2008]. In tasks of grammatical rule application, bilingual performance depends not only on competence but also on age of acquisition [Ullman 2001]. Additional influential factors include the learning environment and the degree of language use [Martínez-Horta 2018].

In order to understand the processes of lexical retrieval and grammar application in bilinguals, it is necessary to find tasks and situations that create division between them, allowing them to be studied as separate entities, while controlling for the elements that create individual variability. Tasks of morphological inflection allow researchers to compare regular affixation, which is rule based and reliant on the mental grammar, and irregular form retrieval, which depends on the mental lexicon [Tyler, 2002]. Significant differences in the task results occur in the context of certain types of brain damage, as patients are unable to perform one or the other inflection as optimally as healthy controls. One such context is Huntington's disease.

Huntington's disease is a neurological degenerative disease with pathology in subcortical and cortical structures, particularly frontostriatal and frontotemporal regions. It is mainly classified by its effect on motor function, specifically as regards coordination and volition of movement. Different language tests show that linguistic functions may be impaired as a result of Huntington's disease pathology [Azambuja *et al*, 2012]. Further research into these impairments not only serves to improve understanding of the neural structures involved in different aspects of language, but also has the potential to allow for earlier diagnosis of the disease, as evidence suggests that the linguistic impairments precede other symptoms.

Discoveries regarding the neurological processes and psychological underpinnings of language aid in understanding the cognitive significance of language as well as in creating models of language processing. These in turn determine both the scientific and social paradigms of language, which are used to formulate plans for the instruction and use of language within society. This is of particular importance in the case of bilinguals and multilinguals in today's society.

The purpose of the thesis is to examine lexical and grammatical organization in mono- and bilinguals using the context of Huntington's disease pathology and compare theoretical models with evidence from neurological and psychological studies. The first section will focus on the theoretical background, explaining the current context for studying irregular and regular morphology as well as the general knowledge of the disease pathology. The theories of lexical organization in terms of the mental lexicon and mental grammar will be described, followed by theories of lexical organization of multiple languages in one brain. The second section will compare existing studies on the linguistic impairments of Huntington's disease patients and create a plan for future research based on the theoretical background and the available empirical evidence.

1 Theory

To create a cohesive theory of bilingual language processing of the mental lexicon and the mental grammar that accounts for individual variability, three questions must be considered. First, what context allows for the comparison of the mental lexicon and the mental grammar? Regular and irregular morphological inflection in Huntington's disease patients has been chosen due to the availability of comparable studies [Ullman 1997, Teichmann 2005, Longworth 2005, Teichmann 2008, Nemeth 2012]. Second, are the mental lexicon and mental grammar controlled by separate mechanisms? In addition to general theories of lexical organization, Ullman's Declarative/Procedural model will be considered for its relevance to the context. Third, does each language have a separate store for its concepts, lexical items, and grammar, or are these shared between languages? In order to predict the behavior of bilinguals performing the aforementioned tasks, it is necessary to understand how additional languages relate to the first language, as previous research in this area has only been done with monolingual participants.

For the purpose of this paper, bilingualism and multilingualism shall refer to the working knowledge of two or more languages. Native bilingualism shall be used to denote cases where both languages are learned simultaneously from the natural environment during normal first language development.

1.1 Morphology

Morphology studies the forms of words and how they are internally structured. The smallest meaningful unit of language is called a morpheme (e.g. 'play', 'a', and the loanword

'apocalypse') [Francis 1993: pp 41]. A free morpheme, as in the previous examples, is a word on its own. There are also bound morphemes, which must be added to other morphemes in order to form words (e.g. English plural 's'). Morphemes interact through morphological processes such as compounding, derivation and inflection.

Compounding is the process of creating new words by combining free morphemes. Compound words are often semantically semi-opaque in that the meaning of the whole is not the exact sum of its parts [Fabb 2017]. For example, the English compound 'greenhouse' is not a house that is green but a structure for growing plants.

Derivation is the process by which free and bound morphemes are modified to alter the lexical category (e.g. nouns to verbs) or to change the meaning in some significant way [Aronoff & Fudeman 2011: 6.2]. Derivational processes include affixation, reduplication, modification, subtraction and conversion. For example, the derivational affix 'ly' is added to adjectives in English to create adverbs (e.g. 'just' becomes 'justly'). An example of a non-grammatical change is derivation of antonyms through the addition of negative prefixes like 'un' (e.g. 'unjust').

Inflectional processes modify the syntactic form of a word by altering the person, number, case, tense and aspect of words [Aronoff & Fudeman 2011: 6.1]. Like derivation, inflection relies on the addition of affixes, repetition of morphemes, and other morphological modifications [Francis 1993: 205]. For example, in English the plural morpheme '-s' is added to the end of nouns to indicate multiples.

The above examples follow regular rules. For each regular morphological process there are irregular cases that do not follow the rule (e.g. the plural of 'man' is 'men', not 'mans'). There are also what are referred to as subregular forms [Teichmann *et al* 2005]. These follow a structured

rule-like pattern but are less productive and predictable than regular rules. For example, in English 'louse' and 'mouse' become 'lice' and 'mice' following a vowel change pattern. However, there are more examples of similar words following the regular rule than this subregular pattern (e.g. 'house', 'spouse', and 'blouse' are all pluralized by adding 's'). Irregular and especially subregular forms often stem from historical forms or loanwords. The irregular pluralization of 'louse' and 'mouse' being different from 'house' comes from their ancient English counterparts ["I-Mutation"]. In English, words of Latin or Greek origin often retain their original inflections (e.g. 'fungus' is pluralized 'fungi') while in Italian words of English origin are either not inflected in plural form or the original English affix is added (e.g. 'il computer' is pluralized 'i computer' or 'i computers') [Rando 1970: 137-138].

Inflectional morphology is used to study lexical organization because of the potential difference in processing irregular forms compared to regular rules [Tyler 2002, Roumpea *et al* 2019]. Regular rules are structured and presumed to exist as part of the mental grammar while irregular forms, although they may have historically followed a predictable pattern, must be learned individually and thus are assumed to be memorized and stored in the mental lexicon. In several recent studies, subregular patterns were also considered to rely on the mental grammar [Teichmann *et al* 2005, 2006, 2008 & 2008].

In recent years, various laboratories have tested morphological processes in Huntington's disease patients because the basal ganglia, one of the first and primary locations of the disease's pathology, has been indicated for involvement in these automatic linguistic processes [Podoll *et al* 1988, Ullman *et al* 1997, Teichmann *et al* 2008].

1.2 Huntington's Disease

Huntington's disease is a genetic disorder caused by mutations in the HTT gene [Kargieman *et al* 2014]. It is the result of an abundance of repetitions of a DNA (deoxyribonucleic acid) segment CAG, (cytosine, adenine, guanine). In the HTT gene of most humans, this segment is repeated between 10 and 35 times. Having more than 40 repetitions of this pattern often results in the development of Huntington's disease [Roos 2010]. Symptoms of the disease generally appear in adults in their thirties or forties. More than 60 repetitions can result in juvenile onset [Nemeth *et al* 2012, Roos 2010]. Some early symptoms of Huntington's disease include involuntary motion, poor coordination, and difficulty learning [Kargieman *et al* 2014, Roos 2010]. Patients are also likely to become irritable or depressed. As it progresses, it leads to personality changes and dementia, with the majority of patients dying within fifteen to twenty years of original onset [Nemeth *et al* 2012]. In addition to altering motor ability and emotional cognition, it is a disease that damages speech production and comprehension [Azambuja *et al* 2012].

The linguistic impairments in Huntington's disease have been historically presumed the result of motor function degeneration [Podoll *et al* 1988]. For example, the tendency of Huntington's disease patients to speak less frequently was contributed to the concurrent symptom of dysarthria, slowed and slurred speech. By the 1980s it was proposed that the caudate nucleus within the basal ganglia, an area affected by Huntington's disease pathology, is involved in language production [Podoll *et al* 1988]. However, as linguistic functions in spontaneous speech remain largely intact even in advance cases, errors made by Huntington's disease patients could not be strongly correlated to lesions in the basal ganglia [Wallesch and Fehrenbach 1988].

More recent research into the linguistic processing and production mechanisms of mildly or non-symptomatic Huntington's disease patients and healthy control participants provides evidence that the disease does interfere directly with linguistic functions, particularly in tasks of lexical decision making and morpho-syntactic rule following [Azambuja 2012, Kargieman *et al* 2014, Longworth *et al* 2005, Nemeth *et al* 2012, Teichman *et al* 2005, 2006 & 2008, Ullman *et al* 1997 & 2001]. These linguistic errors are unable to be correlated with concurrent motor and general dysfunction [Azambuja *et al* 2012, Longworth *et al* 2005, Ullman *et al* 1997]. There is also evidence that Huntington's disease pathology begins with the basal ganglia and that linguistic errors precede other symptoms [Kargieman *et al* 2014, Nemeth *et al* 2012, Teichmann *et al* 2008]. From these studies, it can be determined whether pathology of Huntington's disease can be correlated with certain linguistic functions and therefore used to better understand these functions.

The research makes use of lexical processes and assume a difference between the mental lexicon and the mental grammar. In order to fully understand the studies and analyze the results, first it is necessary to understand lexical organization in terms of the division, if there is one, between lexical retrieval and rule application.

1.3 Lexical Organization

Models of lexical organization are generally separated into two main types: single mechanism models and dual mechanism models [Ullman 2001]. The single mechanism models suppose lexical and grammatical knowledge to be controlled by one system that stores and processes the relations between word forms, including the derivational and inflectional aspects. Among the single mechanism models, there are those which favor an associative system in which

all known forms are memorized, and others on the opposing side which prefer morphophonological rules as the means for creating inflected forms. Dual mechanism models posit a separation between the associative system and a rule-producing system with distinct computational components. Predominant among current models of lexical organization are the dual mechanism models favoring non-linguistically dedicated components. These are preferred because of demonstrated dissociation between the comprehension and production of lexical information versus grammatical rule-based information seen in various cases of selective linguistic impairment [Ullman *et al* 1997, Teichmann 2005 & 2008]. An important dual mechanism model is the Declarative/Procedural model created by Ullman, Pinker and colleagues [Ullman *et al* 1997].

1.3.1 Declarative/Procedural Model

The Declarative/Procedural model theorizes that similar cognitive functions, in this case those of general memory and learning and of language, may be carried out by the same neural systems [Ullman *et al* 1997]. The declarative system of memory, comprised of medial temporal lobe structures including the hippocampus and related structures, is considered responsible for the associative mental lexicon. The procedural memory system, operated by frontal and basal ganglia structures, is tasked with the learning of skills and mental grammar. This model expects deficiencies in rule following to occur as a result of basal ganglia or frontal cortical damage, as is found in Huntington's disease pathology. It assumes language to consist of both skill-like knowledge and symbolic information.

This model has also been extended to explain multilingual language processing [Ullman 2001]. Ullman posited that a native language would be more reliant on procedural mechanisms in

contrast to a second language. In support of this theory, Ullman examined a variety of PET, fMRI, and ERP studies comparing neural activation patterns during processing of lexical comprehension versus grammar rule comprehension (see Ullman 2001 for full review). In addition to upholding his theory, a sensitivity in the formation of activation patterns appeared in relation to age of acquisition and level of competency in the second language. The neural patterns for monolinguals and for the dominant language of bilinguals (L1) indicated lower levels of activation in general, and particularly in regions associated with the declarative memory system. Regions associated with the procedural memory system showed significant increases in activation in L1 in comparison with non-dominant language use (L2). Ullman (2004) theorized that a higher degree of frontal activation for L2 implies a greater reliance on lexical processing, as grammar may be explicitly memorized rather than implicitly learned. Early language learners as well as highly proficient language users demonstrated neural activation in L2 similar to that of L1 activation in bilinguals and in monolinguals.

1.4 Bilingual Language Processing

In addition to understanding the general processing of languages in terms of the mental lexicon and the mental grammar, there is also the question of the relationship between different languages in one brain. In order to predict how the morphological processes of multiple languages will be influenced by Huntington's disease pathology, it is necessary to understand how multiple languages are stored in the brain and how they interact. If a bilingual can be defined as a monolingual of two languages, then there would be little gained in bilingual research compared to monolingual studies. However, existing neurolinguistic research shows that this is not the case [Grosjean 1989]. Various studies and theories have explored the organization of languages in the multilingual brain [Gerard & Scarborough 1989, French & Ohnesorge 1995, Abutalebi 2000].

There are two main hypotheses regarding the interaction between multiple languages in one brain: the independence hypothesis and the interdependence hypothesis [French & Ohnesorge 1995]. The independence hypothesis supports the viewpoint that processing of each language is entirely separate, with each language having separate memory stores. The interdependence hypothesis argues for a single memory store for linguistic information across languages.

If there are two linguistic systems sharing the same mental space, the expectation is that the elements of the languages would mix. When learning a new language, learners often replace an unknown word or grammatical structure with the corresponding one from the dominant language. However, such substitutions are not generally the result of confusion or accidental mixing of languages [Safont Jordà 2005]. When learning two linguistic systems, or learning a second after knowing a first, even young children are able to distinguish between the two languages [Werker & Tees, 1984]. With increased competence substitutions disappear altogether except where mixing is considered acceptable, such as in multilingual communities [Cook 1992, Ramezani *et al* 2020]. This ability of learners to distinguish languages and the general lack of interference initially encouraged the independence hypothesis. However, some case studies on pathological language mixing as well as research on code switching provide evidence for a more integrated model of bilingual language organization, leading to the interdependence hypothesis [Abutalebi 2000, Kong & Abutalebi 2014, Ramezani *et al* 2020].

1.4.1 Independence Hypothesis

Early independence theories argued in favor of the hypothesis that each language has its own conceptual store, a map of real-world concepts and meanings stored in the brain. From this comes the notion of language personalities and the idea that speakers of different languages, culture aside, understand the world fundamentally differently. This has been supported by studies of color conceptualization, among others, which demonstrate that speakers of different languages have distinct categories for color discrimination [Regier & Kay 2009]. Moreover, it has been demonstrated that multilingual speakers behave differently depending on the language context [Ervin 1964]. Despite this evidence, most theories prefer a single conceptual store, regardless of lexical storage organization [Cook 1992, Barac & Bialystok 2012]. One reason for this is the apparent influence of the first language on the second in comprehending new concepts. Additionally, research shows that the first language is also influenced by the second (see Cook 1992 for review). For example, a study on color perception in Koreans, it was found that knowledge of English influenced color categorization [Caskey-Sirmons & Hickson 1977]. The most oft-cited evidence against separate conceptual stores is cross-linguistic priming demonstrated by interlexical priming studies [French & Ohnesorge 1995]. In the case of separate conceptual stores, mixed language studies should not demonstrate evidence of priming between semantic pairs across languages.

All independence theories support the notion that separate languages have separate lexical stores, meaning that the words of each language are organized independently of one another. In order to have separate lexical stores, stimuli from each language needs to be considered by the brain as belonging to a separate entity. It has been shown that by two months infants are able to distinguish between native and non-native languages and within four months between native and

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related languages [Werker & Tees 1984]. The general lack of cross-linguistic interference in pathologically normal bilinguals, in terms of both grammar rules and lexical items, also supports the theory that language stores are separate. That bilinguals are able to reach a degree of fluency in language production that is comparable to that of monolinguals belies the possibility of strong competition between languages, as would be expected if the lexical data of different languages were not separate. Experiments on homographic noncognates, words that are written identically but have unrelated meanings across languages (e.g. ride, 'wrinkle' in French), demonstrate selective activation of one language [French & Ohnesorge 1995, Gerard & Scarborough 1989]. Independent models rely on initial language selection, after which the language in use should remain active until context requires a change. Thus, in independent models, code switching and code mixing would require a high level of attention and language control in order to switch between two separate systems in a single utterance.

Each language requires access to the conceptual store, allowing the linguistic symbols to be linked to a mental representation of their real-world reference. In the case of one shared conceptual store, this access could be distinct or by way of the other language, which could cause language interference. Studies on priming in bilinguals do not support such an interference [French & Ohnesorge 1995, Gerard & Scarborough 1989]. However, there is a greater switch cost when moving from a dominant language into a weaker language [Ramezani *et al* 2020]. This could imply a greater distance between secondary languages and the conceptual store, or it could be the result of the stronger language causing an inhibitory strain.

Neurolinguistic data also gives evidence to support the independence hypothesis. In cases of brain damage in multilinguals, linguistic impairments can vary across the languages of an individual [Dehaene *et al* 1997]. This inequality implies a degree of dissociation between the

languages stored in a single brain. Generally, first languages (L1) show consistent activation across speakers while secondary languages are more varied. In tasks of L1 comprehension, areas of the left temporal region including the superior temporal sulcus, superior and middle gyri, and less commonly the temporal pole as well as the inferior frontal sulcus and precentral sulcus are recruited [Dehaene *et al* 1997, Perani *et al* 1996, Price 1999]. Second languages' (L2) patterns of activation tend towards more widespread left temporal activation and a higher degree of right hemisphere activation [Dehaene 1997]. In terms of language production, L1 and L2 activate distinct regions of Broca's area in late learners, though not in early learners [Kim *et al* 1997]. These studies show that L1 and L2 tend to be neurologically distinct with a high degree of individual variability for L2.

1.4.2 Interdependence Hypothesis

The alternate view is that languages share the same conceptual and lexical stores. Although early research primarily supported separation of languages due to the relative lack of language interference, models of interdependence have gained support in recent research [Cook 1992, Barac & Bialystok 2012, Jacob, Heyer & Veríssimo 2018]. That the knowledge of additional languages does not noticeably hinder performance of individual languages at higher levels of competency does not mean that languages do not interact in the multilingual mind. Compared to monolinguals, bilinguals are often slower and less accurate in lexical decision tasks, which could indicate crosslinguistic interference [Ivanova & Costa 2008, Sandoval 2010]. In addition to these indicators of an integrated lexical store, studies have found that conceptualization in each language is affected by other known languages (see Cook 1992 for review).

Theories of interdependence vary, some hypothesizing that there is one conceptual and one lexical store shared by all languages and others suggesting interactive but not fully integrated stores [Cook 1992, French & Ohnesorge 1995, Cook 2003, Barac & Bialystok 2012]. In interdependent theories, differentiation between languages relies on other mechanisms to avoid cross-language interference, such as executive control functions and contextual activation. Supporting the theory that executive control mechanisms influence language activation, bilinguals, compared to monolinguals, are stronger in executive control tasks, especially in tasks that measure attentional switching and inhibition [Barac & Bialystok, 2012; Bialystok, 2004]. Interdependence theories suppose that this increase in performance is the result of language competition and the necessity of bilinguals to switch between languages and inhibit the non-active language. The active language serves as the context, and executive control mechanisms ensure that the target language is processed and produced correctly. For a parallel example in a single language context, there is no interference between nouns and verbs that share the same form in monolinguals nor between semantically unrelated homophones, despite initial priming of contextually irrelevant meanings [French & Ohnesorge 1995]. The interdependence hypothesis argues that organization in bilinguals behaves in a similar manner, with the language context acting as a control over which language is activated in secondary and tertiary processing. In contrast with the single language tasks on homophonic noncognates [Gerard & Scarborough 1989], mixed language tasks demonstrate that word recognition is influenced by the non-target language [French & Ohnesorge 1995]. That both languages can be activated simultaneously and influence one another implies a relationship of interdependence that could be controlled by mechanisms outside of the lexical store.

Neurolinguistic studies have found that much of the variation in brain activation during linguistic tasks between L1s and L2s is dependent on learning factors such as age of acquisition, level of competence, and degree of language switching. For example, one study confirmed that in highly proficient early learners, there are no significant differences in frontal and temporal activation during language production [Hernandez 2000]. Moreover, the differential effect of age is mitigated by higher proficiency alone [Perani *et al* 1996, Dehaene *et al* 1997]. Crucial differences in temporal activation during L2 comprehension are also not apparent in cases of high proficiency compared to low, regardless of age of acquisition [Perani *et al* 1998].

Evidence from neurological studies also provides indicators of possible control mechanisms. Switching between languages activates Broca's area and the supramarginal gyri, indicating phonological recoding [Price 1999]. The periventricular white matter surrounding the left caudate nucleus was also implicated in a case study on a trilingual patient suffering from pathological language mixing [Abutalebi 2000]. The subcortical lesion resulted in involuntary language mixing within single utterances, though individual phrases were intact (e.g. 'il bambino' not 'the bambino') and morpho-syntactic marking was consistent, with correct morpho-syntactic agreement (e.g. person, number, and gender) across languages. The patient was aware of the deficit and could voluntarily switch languages despite being unable to maintain a single language in spontaneous speech and using non-desired languages in confrontation naming tasks. In another case study of pathological language mixing, lesions in the left frontal lobe and left temporo-parietal areas resulted in a similar executive control impairment [Kong & Abutalebi 2014]. Based on previous findings that language switching is dependent on a prefrontal-caudate-anterior cingulate cortex network, which is responsible for general executive control functions, the authors presumed that a frontal-cortical circuit serves as a language control pathway [Abutalebi et al 2008].

Contrasting with the control effect of the subcortical lesion in the case study of Abutalebi (2000), the patient with cortical lesions also created neologisms and was described as producing 'fluent unintelligible jargon' [Kong & Abutalebi 2014]. Subcortical structures such as the putamen and caudate head have been implicated in mental coordination while activation of the anterior cingulate gyrus may be due to its role in controlling attention in language translation tasks [Price 1999].

Language control and inhibitory mechanisms are more necessary in interdependent models, which require continuous attention to the language context, although that attention is considered to be automatic and unconscious [Ramezani *et al* 2020]. Evidence from code-switching studies is more strongly in support of overlapping storage, as there is a cost that is dependent on competence, implying that both languages are active and dominant languages are more difficult to inhibit (see van Hell & Litcofsky 2015 for review).

The differences correlated to age of acquisition and level of competence may indicate the degree to which an L2 is integrated into the natural language network in the brain, as opposed to being merely stored symbolic data. This aligns with the observations of Ullman (2001 & 2004) that L2s tend to depend more on the associative memory of the mental lexicon while L1s and early learned or highly competent L2 users rely on the procedural processes of the mental grammar. This finding implies that the division between the mental lexicon and mental grammar is more based on individual learning patterns in addition to which linguistic data can become procedural, such as morphological inflection rules, and what information must be individually memorized, as in the case of unpredictable irregular forms. Thus, in the L2 of bilinguals there may be a less strict distinction between the mental lexicon and mental grammar dependent on the many factors that influence L2 acquisition [Ullman 2004]. In order to research the mental lexicon and mental

grammar in bilinguals, both languages should be taken into account, as well as concurrent learning factors, in order to compare L1 and L2, as the individual patterns for L2 are likely to vary.

2 Research

2.1 Regular & Irregular Morphology in Monolingual Huntington's Disease Patients

Huntington's disease pathology begins in striatum and caudate nucleus of the basal ganglia, later including cortical frontal areas [Kargiemann 2014]. As the linguistic symptoms also precede other symptoms, several studies have been performed in order to understand the role of the basal ganglia in morphological processing [Ullman *et al* 1997, Longworth *et al* 2005, Teichmann *et al* 2005 & 2008, Nemeth *et al* 2012].

Study 1 – Ullman et al 1997

In order to study the mental lexicon and mental grammar as separate components, Pinker, Ullman and colleagues created a task based on conjugation of irregular and regular past tense morphology [Ullman *et al* 1997]. They presumed the application of the regular past tense suffix 'ed' to be the result of a formative rule, while irregular retrieval as in 'taught' would rely on associative memory processes. The task was to read aloud a pair of sentences, one having the verb in present tense and the other requiring the participant to produce the proper past tense form of the verb. In addition to irregular (e.g. dig) and regular (e.g. look) verb types, they also tested regular suffixation of novel words (e.g. plag). The participants were 17 symptomatic Huntington's disease patients and 8 healthy controls, in addition to Alzheimer's disease and Parkinson's disease patients as well as posterior and anterior aphasiacs.

Huntington's disease patients suffered significant impairment in both types of inflectional morphology compared to healthy controls. In irregular past tense morphology, they tended to over-regularize (e.g. 'dig' became 'digged') while in regular and non-verb examples they produced errors of multiple affixation and syllabic suffixation (e.g. 'look' became 'lookeded' or 'look-id'). Parkinson's disease patients saw a similar degree of errors in past tense morphology. However, Ullman and colleagues proposed different causes for these errors. They postulated that the pathways responsible for lexical retrieval and grammatical rule processing are not dedicated to linguistic tasks, but instead shared between cognitive functions. The damaged dopaminergic pathways in the basal ganglia of Huntington's disease patients which fail to inhibit frontal areas, producing chorea, also result in over-active rule use. Conversely, the damage to the basal ganglia of Parkinson's disease patients leads to suppression of both motor function and rule use, resulting in increased irregularity.

Study 2 – Teichmann et al 2005

Focusing on early Huntington's disease pathology, Teichmann and colleagues performed a similar study using verb conjugation, sentence comprehension, and arithmetic tasks in French [Teichmann 2005]. With 30 Huntington's disease patients in early stages of the disease progression and 20 matched control participants, they tested rule use and lexical access in two linguistic domains, morphology and syntax, as well as one non-linguistic domain, mathematics.

In the first task, they compared regular and irregular conjugation of real verbs, testing both rule use and lexical retrieval, with regular and subregular non verb conjugation, which relies only on proper application of grammatical rules. The participants were required to conjugate the verbs into third person singular present and future forms following a verbal tense cue, such as 'aujourd'hui, il' (today he) and 'demain, il' (tomorrow he), and given the infinitive form, for example, 'arriver' (to come). Errors of phonetic substitution, incorrect tense, or repetition of the infinitive were prompted up to three times to repeat their response. Huntington's disease patients saw a higher percentage of irregular verb errors which was not statistically significant. Most errors were not errors of overregularization. However, the results showed a dramatic difference in their conjugation of subregular non verbs, particularly in overregularization and overaffixation errors.

The second task was a sentence-picture matching task which tested syntactic processing of canonical and non-canonical, plausible and implausible sentences. The participants were required to determine whether a spoken sentence matched a presented image. In comprehension of canonical sentences, Huntington's disease patients performed similarly to control participants for both plausible sentences like 'The girl watered the flower' and , and non-plausible sentences such as 'The flower watered the girl'. These sentences may be comprehended using syntactic, semantic, pragmatic, and lexical processing. Huntington's disease patients performed significantly worse on non-canonical sentences with a very strong effect of plausibility. Plausible sentences like 'The flower was watered by the girl' were easier for them than non-plausible sentences which rely only on intact syntactic processing, such as 'The girl was watered by the flower'. Performance in syntactic processing was also found to correlate with disease progression.

The final task compared application of rules and factual knowledge in correctness judgment of mathematic operations. As multiplication relies on factual knowledge while subtraction depends on application of mathematical rules, examples of multiplication and subtraction problems with either correct or incorrect answers were given. A variety of error types were tested, but the only significant difference was found between subtraction and multiplication, with Huntington's disease patients performing significantly worse on subtraction problems.

Teichmann and colleagues concluded that the relative preservation of regular and irregular verbs contradicted the previous study by Ullman *et al* (1997) regarding the role of the basal ganglia in rule application. However, they also noted that the inability of Huntington's disease patients to conjugate subregular non verbs could support the theory that the rule system is impaired as a result of basal ganglia/striatal dysfunction. The sentence matching task also demonstrated intact lexical access and impaired syntactic rule operations. Finally, the arithmetic task demonstrated a dissociation between rules and facts in a non-linguistic domain, with rule application being impaired while factual knowledge was spared.

Study 3 – Longworth et al 2005

Supporting an alternate dual mechanism model of non-language specific competition and inhibition, Longworth and colleagues also studied HD patients using two past tense elicitation tasks and a lexical decision-making task [Longworth *et al* 2005]. They considered the degree of errors in irregular and regular past tense morphology in Ullman's 1997 study and the nature of Huntington's disease and Parkinson's disease pathology insufficient to substantiate the claim that the striatum is required for rule-based language processing. Instead, they posited that the production-specific linguistic impairment of Huntington's disease patients supports a model of inhibition of competing alternatives. Their study compared 10 genetically verified mild and moderate Huntington's disease patients with 8 healthy controls, along with 7 subcortical lesion

patients and 15 Parkinson's disease patients. The HD patients were undergoing a variety of treatments and were also considered depressed based on their Beck Depression Inventory scores.

The participants completed the Ullman 1997 elicitation test as well as a similar test that is auditory rather than read aloud. Healthy controls performed these tasks at or near 100% accuracy, but the majority of patients suffered some degree of impairment. In contrast with the findings of Ullman *et al* 1997, Longworth and colleagues found that although mild Huntington's disease patients showed significantly higher incorrect responses for irregular inflection on one of the elicitation tasks, a single patient was responsible for the majority of those errors. For most participants, the chief errors were repetition the cue or substitution a semantically similar word. In the case of novel words, the most common error was replacement of the target word with an existing phonologically similar word.

Additionally, the participants, excluding moderate Huntington's disease patients, completed an auditory lexical decision task that tested priming of morphological, semantic, and phonological similarity. In this task, target words and non-words are preceded by related or unrelated prime words, and the participant must decide whether the target word exists or not. In healthy controls, phonologically similar words do not produce a priming effect, in contrast to morphologically and semantically related words. The results of this test showed few abnormalities between groups, with positive priming for irregular and regular past tense verbs. Additionally, automatic comprehension of regular past tense forms was intact irrespective of word frequencies. The inability of moderate Huntington's disease patients to complete the task was not explained, and items with high error rates were removed.

Longworth and colleagues concluded that comprehension of regular past tense and formation of the same are not dependent on the basal ganglia. They considered their results to support a theory of inhibition of competing forms more strongly than the Declarative/Procedural model.

Studies 4-6 – Teichmann et al 2006, 2008, 2008

In a further attempt to clarify their previous findings, Teichmann and colleagues conducted several additional studies [Teichmann *et al* 2006, Teichmann *et al* 2008, Teichmann *et al* 2008]. Examining the role of the striatum in sentence processing, they tested idiomatic sentences with idiom-derived sentences, replacing syntactic structure or lexical items. For example, the idiomatic sentence 'Paul has kicked the bucket' was modified into 'Paul was kicked by the bucket' and 'Paul has crushed the bucket'. Using these sentences, they examined lexical access to the meaning of the whole sentence with target words like 'death' and to the meaning of individual words with target words like 'bail'. For a control condition, they also tested unrelated words. Huntington's disease patients performed worse in comprehending syntactically modified sentences, supporting the findings of Teichmann *et al* (2005).

In order to understand the contrary results of earlier studies and in particular the role of the striatum, Teichmann and colleagues repeated their study [Teichmann *et al* 2005] with the addition of PET imaging. 31 Huntington's disease patients and 20 control participants completed the same three tasks in conjugation, sentence comprehension and arithmetic, testing for impairments in rule application and lexical retrieval. They repeated their earlier results of relative rule conservation but a breakdown of sub-rules. In the sentence-picture matching task, there was no plausibility

effect, in contrast to their earlier finding, but a canonicity effect suggested impaired movement rules while the general performance of Huntington's disease patients compared to controls suggested either an impairment in formation rules or lexical access. Finally, the arithmetic task showed consistent rule impairment. These results were correlated with striatal regions through PET scans of metabolic activity. Significant correlations were found between low performance and low levels of metabolic activity in specific striatal regions [Teichmann *et al* 2008].

Each task showed different patterns of metabolic activity with most correlations being lateralized to the left, primarily in the ventral striatum and caudate head. Lower metabolism in the ventral portions of the caudate head, ventral striatum and putamen correlated with poor performance conjugating regular non verbs while subregular non verbs correlated with only the ventral portions of the caudate head and the ventral striatum. Irregular conjugation errors and difficulty comprehending non-plausible canonical sentences both correlated solely with low activity in the dorsal regions of the caudate head. In syntactic rule-based non-canonical sentences, errors correlated generally with a lack of activity in the right ventral striatum and plausible sentence errors correlated additionally with the left-lateralized ventral regions of the striatum, putamen, and pallidum. Similarly, rule-based subtraction errors correlated left-laterally with the ventral striatum, putamen, and pallidum. Poor performance in multiplication tasks, presumed to rely on factual knowledge, correlated only with lower levels of activity in the left ventral striatum.

Teichmann *et al* (2008) concluded, based on their results, that rule-based tasks and lexiconbased tasks rely on mechanisms differentially located in distinct areas of the striatum. Performance was more significantly impaired on tasks that relied more strongly on rule application and ventral portions of the striatum, such as non-canonical sentence comprehension and non verb conjugation.

Study 7 – Nemeth et al 2012

Examining the methods and results of Ullman *et al* (1997), Longworth *et al* (2005), and Teichmann *et al* (2005, 2006), Nemeth and colleagues hypothesized that linguistic impairments might precede all other symptoms of HD given their connection to early pathology in the basal ganglia [Nemeth *et al* 2012]. To test for over-active rule processing in early pre-symptomatic Huntington's disease patients, they recruited 7 genetically confirmed Huntington's disease gene carriers and 7 age and education matched control participants. They created stimuli using regular and irregular noun morphology in singular and plural forms, nominative and accusative cases in Hungarian. Plural is marked by the additional suffix '(V)k', V being an optional vowel following vowel harmony rules. Accusative case is created by adding '(V)t'. The rule for suffixation is agglutinative, with pluralization preceding case markers. For example, the nominative singular word 'kert' (garden) is pluralized by adding the suffix 'ek' 'kertek' (gardens) and made accusative with the additional 'et' suffix 'kertet' (accusative singular) 'kerteket' (accusative plural). Irregular nouns are those with stem changes, including epenthetic (e.g. 'kéreg' to 'kérg'), shortening (e.g. 'madár' to 'madar'), and v-insertion (e.g. 'ló' to 'lov').

On a nominative singular naming task, all participants achieved 100% accuracy. Across conditions, control participants made no errors. Huntington's disease gene carriers, despite being otherwise asymptomatic and undiagnosed, produced significant over-suffixation errors and over-regularization errors in both inflection processes, in particular for irregular nouns. The over-suffixation errors were typically a combination of plural and accusative suffixes where only one was required. Reported substitution errors were lexical rather than semantic or phonological.

2.2 Huntington's Disease & Bilingualism

Studies on the bilingual subset of the Huntington's Disease population are few and not directly related to lexical organization and morphological processing. Still, they provide valuable perspective regarding the interactions between bilingualism and Huntington's disease pathology in terms of the general effects of the disease on the control and use of multiple languages.

Study 8 – Martínez-Horta et al 2018

Martínez-Horta and colleagues conducted a study in order to examine the possibility of neuro-protective effects of bilingualism on disease pathology. In particular, bilingualism has been linked with better conflict monitoring, shifting, and inhibitory control, likely due to the necessity of monitoring and controlling which language is used [Green & Abutalebi 2013].

They recruited thirty Catalan-Spanish bilinguals confirmed to carry the Huntington's disease gene that were in the early stages with mild symptoms. Degree of bilingual language use was computed using survey questions and language competency was measured for writing, speaking, and comprehension. Cognitive function was also assessed through several tasks, including phonetic and semantic fluency tests, the symbol digit modality test, and the Stroop test. These scores were compared with Magnetic Resonance Imaging (MRI) of gray matter volume and Positron Emission Tomography (PET) scans of brain glucose metabolism.

Bilingual competence was not found to correlate with any of the results. A higher degree of bilingual use, meaning that the two languages are used more equally and switching between languages is more frequent, correlated significantly with better performance on the Stroop wordcolor interference task. This also correlated with a slightly greater volume of gray matter in the right inferior frontal gyrus and higher glucose metabolism in the dorsal anterior cingulate cortex, part of the monitoring and control network [Green & Abutalebi 2013]. Higher bilingual use was also associated with higher glucose metabolism in other fronto-temporal regions, including the superior and ventromedial orbital prefrontal cortices, right inferior temporal gyrus and left inferior frontal gyrus. Thus, deficits in response inhibition and action monitoring correlated with damage to the dorsal anterior cingulate cortex were mediated by a lifetime of bilingual language switching.

The study found no evidence for a bilingual effect on the caudate nucleus or the putamen but recognized that this could be due to atrophy in these areas beginning as early as fifteen years prior to the onset of symptoms. A comparison with healthy controls was not included, nor was a monolingual group tested.

Study 9 – Calabria et al 2018

Another study conducted by Calabria, Martínez-Horta and colleagues tested the effects of Huntington's disease on language inhibition and cross-language interference.

The Spanish-Catalan bilingual participants were 12 Huntington's disease patients, either pre-symptomatic or with mild symptoms, and 14 age and education-matched healthy controls. They were highly proficient early language acquirers and reported their degree of bilingual language use through a questionnaire. In addition to general cognitive tests, they performed two linguistic tasks.

The first task consisted of pictures of non-cognate items that needed to be named in a specified language. Conditions included single blocks of one language and mixed blocks of repeat trials, where the language did not change, and switch trials, where it did. Switch trials are used to test the speed and accuracy of performance when switching between two languages. In healthy bilinguals, switch trials result in greater response times unless preparation time is given [Costa & Santesteban 2004]. In order to test this in Huntington's disease patients, a condition was included for preparation time. Either the target language and the picture were given simultaneously, or the target language was indicated 1000ms before the picture.

The results showed a correlation between the type of block and reaction time, with switch tasks requiring more time from all participants. The effect of preparation time, which eliminated the switch cost in healthy controls, was not apparent in Huntington's disease patients. This was proposed to be the result of subcortical dysfunction. It also shows a difference in reactive control, necessary for immediate switching, compared with proactive control, which should occur when extra preparation time is given. The performance of Huntington's disease patients was not significantly impaired in the mixed trials in terms of accuracy.

The second task was a STROOP word-color interference task with single and mixed language conditions. The participants were required to name the colors in their dominant language while ignoring the distractor words. Three types of distractor words were given, either in the same language or in the non-dominant language. They were neutral adjectives (e.g. cute), congruent color words (e.g. blue, green) or incongruent color words (e.g. green, purple). Statistical analysis

of the results showed no significant difference in language condition and no group significance. Huntington's disease patients were generally slower, and all participants suffered in accuracy on the incongruent condition compared to the neutral and congruent conditions.

2.3 Analysis

2.3.1 Monolinguals

In review of these studies, it can be supposed that Huntington's disease patients, like others with basal ganglia damage, can expect difficulties in the application of morphological, syntactic and non-linguistic rules. Early pathology of Huntington's disease affects bilinguals in their ability to maintain inhibition or activation of one language but does not result in pathological switching or mistakes in language choice. In general, they may have greater resilience against the effects of the disease. Most of the research shows the linguistic symptoms but does not analyze the precise sources. Based on the typical development stages of the disease, different morphological processes appear to be governed, or at least partly substantiated, by the basal ganglia. Conflicting information between these studies should be resolved on a theoretical basis before further testing.

In Huntington's disease patients, Ullman *et al* (1997) concluded that a lack of inhibition on the application of the rule resulted in inappropriate overuse of it, as seen in regularized irregular past tense conjugation in English (e.g. teached). This conclusion was supported by Nemeth *et al* (2012) and in part by the results of Teichmann *et al* (2005, 2008). In the case of Teichmann and colleagues' research, it was found that while in some syntactic and non-linguistic cases the rules failed to be applied, lexical rules were over-applied. The primary source of contention comes from the evidence provided by Longworth *et al* (2005). In this study, the most significant errors were repetition errors and word substitutions, including semantically and phonologically similar substitutions. Research shows that semantic and phonological properties have a priming effect on similar words, leading to a possibility of competition between related words in lexical decision tasks [Moreno & Orden 2001]. Longworth and colleagues considered these errors to support a hypothesis of competing activation, where damage to the striatal-cortical communication results in a lack of inhibition on competing forms. They did not agree with the conclusions of Ullman (1997) regarding the precise role of the basal ganglia but suggested that concurrent cortical damage resulted in an interruption of the general executive control network.

In the case of cue repetition and phonetic substitution, the decision by Teichmann *et al* (2005) was to repeat the instructions up to three times, taking the first response to follow the instructions or the last response given. It is not stated how many such cases occurred, however the subsequent insignificance of such errors in the Teichmann *et al* (2005) results suggests that these errors may have been the result of a non-pathological attentional difficulty. On the other hand, repetition errors could be evidence of competition in the lexical retrieval process or a lack of inhibition on the original morpheme. In either case, the disappearance of these results may indicate an intact inflectional process but impaired automaticity. Repetitions also suggest activation of the phonological loop, which has been described in another study as a possible compensatory agent for lexical generation in Huntington's disease patients [Azambuja 2012]. However, Longworth *et al* (2005) also reported errors of repetition in healthy control subjects, which gives rise to doubt regarding the clarity of the instructions given to participants. Additionally, the phonological substitutions reported in Longworth *et al* (2005) were most common in non-word cases, which

suggests a natural preference to real words. The insignificance of these errors after repetition of the cue word (Teichmann *et al* 2005, 2008) and the lack of such errors in other studies [Ullman 1997, Nemeth *et al* 2012] does little to support the arguments of Longworth *et al* (2005).

The other common error reported by Longworth *et al* (2005) was semantic substitution, which could also indicate impaired inhibition of competing forms, as Longworth *et al* (2005) supposed. As semantically similar words are concurrently primed and undesired choices are inhibited in normal conditions [Moreno & Orden 2001, Copland 2003], this finding could indicate an interruption of the inhibitory mechanism by Huntington's disease pathology. However, there was no significance of semantic substitutions found in any other study. Repetition of this result would be necessary to determine its importance for Huntington's disease pathology and models of lexical retrieval.

Teichmann *et al* (2005, 2006, 2008, 2008) found in linguistic and non-linguistic capacities that rule application was significantly affected in contexts requiring grammatical information more than lexical access, including conjugation of subregular novel verbs and mental decomposition of syntactic movement rules in non-canonical sentence comprehension.

In the case of subregular novel verbs, despite relatively intact regular conjugation for both real and novel verbs, performance approached chance levels. These verbs follow consistent conjugation rules in singular third person present and future conjugation, and the created non verbs were reliably conjugated by university students prior to the study and by the control group within the study. However, it is not clear whether subregular verbs operate by means of a grammatical rule or by way of lexical retrieval.

Like English use of the 'ed' past tense suffix, French 'er' verb construction is predictable and productive in the singular third person, as was used in the studies [Teichmann et al 2005, 2006, 2008 & 2008]. Even neologisms are quick to accept this inflection. For example, as 'to google' becomes 'googled' in English past tense, 'googler' and 'googliser' become 'googlera' and 'googlisera' in French future tense. The same properties of simplicity and productivity, however, may be a detriment to their usefulness as measures of rule use. Assuming that each individual rule is not governed by a localized strand of striatum, and that therefore striatal loss affects the general execution but not the specific existence of individual rules, it might be concluded that as the functional capability of the striatum diminishes, rules become less effective relative to their computational unimportance. Supporting this theory, despite being one of the earliest symptoms [Kargieman 2014, Nemeth 2012], most Huntington's disease patients demonstrate a lack of awareness of their linguistic difficulties [Azambuja 2012]. They are able to apply regular rules; the error occurs in the application of regular rules to irregular words and in adding additional suffixes to regular words. This type of error is easily ignorable-it also happens under stress, fatigue, and legal drug conditions.

In contrast to the regularity of 'er' verbs, subregular 'ir' and 'oir' verb constructions are less predictable and less common. It could be argued that this means they are more likely to exist in memorized forms, or it could indicate that the rules exist but are more complex and require more intact basal ganglia. Teichmann *et al* (2005, 2008) did not study existing subregular verb conjugation, but only used it as the basis for creating subregular non verbs. Therefore, their study only tested the possible rule application, not the possibility of memorized lexical forms. In this task, the significantly poor performance of Huntington's disease patients can only be reliably correlated to a failure in rule application on the assumption that a rule exists. If there was no rule to begin with, then the significant difference in subregular non verbs compared to irregular verb conjugation is the lack of a memorized form in the mental lexicon, which is to be expected considering that the words are made up.

It should also be taken into consideration that the subregular non verbs were normalized with the help of university students, who exist in a context of learning and seeking to understand. The educational environment encourages problem-solving and pattern-finding, and students might find subregular non verb conjugation to be a stimulating task. It is not unreasonable to doubt that such individuals are representative of the larger population in any society. The argument that the control population, matched for age and education, also performed well on the task is valid but not strong. While Huntington's disease patients partake in research primarily in the hopes of ultimately finding a cure for their disease, healthy participants voluntarily join studies either due to external incentive, such as money, or internal motivation, such as personal interest in academia. In the first case, they might represent the average individual, but in the second case they are more likely to share the mindset of university students. As such, it is possible that Huntington's disease patients regarded the task as absurd or unhelpful and did not attempt to understand it, which would account for their performance at near chance levels. It would also plausibly explain their comparatively strong performance in regular non verbs, as in both cases the simplest answer would be to apply the most common conjugation rule.

The significant impairment in comprehension of non-canonical sentences, which rely on syntactical movement rules for proper processing, does indicate a failure in rule application. However, the failure is in the rule not supporting comprehension, regardless of the availability of pragmatic information, as opposed to being over-active as was the case on the lexical task. Teichmann *et al* (2008) correlates this difference with specific areas of the striatum, indicating that

syntactic and morphological rule mechanisms are overlapping but distinct enough to behave differently. The study reliably demonstrated evidential support for the claim made by Ullman *et al* (1997) that the basal ganglia are implicated in the application of procedural-type linguistic rules. Nemeth *et al* (2012) was also in favor of the hypothesis that the linguistic errors found in Huntington's disease patients are the result of overactive rules rather than a general competition between forms.

2.3.2 Bilinguals

The two studies on bilingual Huntington's disease patients indicate, at least in the early stages, intact language control mechanisms. These mechanisms were affected in terms of speed but not accuracy, and there was no evidence of pathological switching. In terms of language competence, the tasks used were simple and only relied on lexical retrieval and language control. Huntington's disease patients demonstrated a difficulty of general lexical interference, possibly indicating impaired inhibitory circuitry. That there was no evidence of a correlation with the damage to the basal ganglia does not refute the theory of Ullman *et al* (1997) that the basal ganglia are involved in rule production, as no rules were tested.

The neurological findings also support the theory that competition of lexical information, in this case the non-congruent words interfering with production of the color word, creates difficulties for Huntington's disease patients. This result was not compared with healthy control participants or monolinguals, and thus could be a general effect of bilingualism on Stroop task performance and unrelated to the disease pathology. The lack of a language effect could be due to the use of the patients' preferred language as the target language. It could also indicate separation between the two languages, either in storage or in activation mechanisms.

2.3.3 Review

The literature from existing studies shows that there is evidential strength in the argument that there are linguistic failures separate from the general cognitive difficulties, such as functional and motor impairments. These linguistic impairments appear early in Huntington's disease gene carriers, allowing them to be studied before other cognitive impairments create conflicting difficulties. With the progression of the disease this distinction becomes less clear. However, in asymptomatic patients and those with mild symptoms it is possible to test these linguistic impairments. Correlations between basal ganglia activity and performance on lexical tasks indicate that Huntington's disease pathology can be utilized to seek clarification for the neurological distinctions between the mental grammar and the mental lexicon.

The research shows that Huntington's disease patients recognize the correct inflectional forms but are not reliably able to produce them [Longworth *et al* 2005, Nemeth *et al* 2012]. It is plausible that the existence of the rule or an alternative option is blocking their lexical retrieval of the irregular forms. In the case of regular and subregular morphology, non words do not exist in the lexicon and therefore comparisons between existing and novel words might provide further insights into the dissociation between lexical retrieval and rule use.

The assumption of Teichmann *et al* (2005, 2008) was that the French subregular non verbs are rule based (e.g. the 'oir' conjugation pattern). This is not a foregone conclusion, as it depends on the behavior of real subregular verbs. Do they correlate with regular morphological processes, or are they treated as irregulars and memorized? In English, the most common subregular morphology comes from loanwords, such as nouns from Latin which have retained their native plurals. For example, the Latin ending 'us' is pluralized to 'i', as in fungi, cacti, and syllabi. This morpheme might be considered productive by some, particularly those who ignore the Greek origin of octopus and incorrectly pluralize it to octopi. However, English also has words like campus, which despite being of Latin origin is never pluralized to campi. For all such 'us' ending words, the regular plural suffix 'es' is acceptable and often preferred (e.g. syllabuses). Other English nouns with subregular tendencies, such as the Latin 'um' in datum and curriculum and the Greek 'on' in criterion and phenomenon are generally Anglicized or considered to be irregular cases rather than members of a pattern-forming group.

Although this makes English subregulars difficult to normalize and study, it provides interesting insight into the regular and irregular distinction. They do not behave in a strictly bound manner but are dependent on the experiences of the individual and especially the socio-linguistic environment. For academics and intellectuals, proper use of Latin and Greek plurals is expected. In contrast, the average English speaker, in America at least, is not aware that those plurals exist and uses regular English pluralization. Thus, in the first case, the 'i' plural morpheme may behave as a productive rule, while in the second case any known examples (e.g. fungi) would be memorized irregulars. It is possible that the same is true of the French 'ir' and 'oir' verb conjugation. The metabolic activity from Teichmann *et al* (2008) shows that performance in irregular verbs, subregular non verbs and regular non verbs correlates with overlapping regions in the left striatum. How the results should be interpreted is contingent on the natural behavior of subregular forms.

The existing research on bilingual Huntington's disease patients indicates that in the early stages there is no evidence of interference between languages. There does seem to be impairment in inhibitory mechanisms for lexical retrieval, but it remains to be seen whether rule application is

equally affected. According to the theory by Ullman (2001), secondary languages depend on lexical retrieval mechanisms, overseen by the associative memory system, more than on rule application, controlled by the procedural memory system. Ullamn (2001 & 2004) correlated this relationship to age of acquisition and competence, with early learners' and highly competent language users' secondary language neural activation resembling that of their dominant language, and that of monolinguals. If this theory is accurate, then bilinguals should demonstrate varying degrees of reliance on rule application in their second language compared to their first language. Overactive rule use in bilingual Huntington's disease patients should therefore correlate with higher competence and early learning. If overall performance, not specifically on rule-based tasks, correlates with competence, this would be contrary to the expectation of the declarative/procedural model for bilingual lexical organization [Ullman 2001]. It could indicate that either the theory of competition is more accurate or that bilinguals' reliance on rule application does not depend on competence. On the other hand, general language competence will correlate with accuracy on a task that requires some in-depth knowledge of the language. Recognition of a correct form, particularly in secondary languages, does not guarantee the ability to produce that form in natural circumstances, let alone in a laboratory. It would therefore be difficult and likely unrewarding to test individuals with low competence.

However, as in the experiment by Martínez-Horta *et al* (2018), degree of use in competent bilinguals could be studied and compared, testing the hypothesis that increased exposure and use of a language encodes previously learned information into skill-like implicit knowledge. Age of acquisition could also be a variable where is does not correlate strongly with competence, allowing for a comparison of the relative importance of acquisition age and language use.

3 Future Research

The specific role of the basal ganglia in morphological processing remains unclear. Basal ganglia-related aphasia studies give differing results and often conclude that linguistic impairments are likely due to concurrent cortical damage or disrupted communication between cortical areas and the basal ganglia [Podoll *et al* 1988, Copland 2003].

3.1 Questions & Hypotheses

What will be the pattern of errors in bilingual Huntington's disease patients on tasks of lexical retrieval and morphological inflection? If Huntington's disease seriously affected the bilingual language control mechanism, it would not go unnoticed. Based on the lack of such research and the evidence provided in the two recent studies [Calabria *et al* 2018, Martínez-Horta *et al* 2018], bilingual Huntington's disease patients are able to perform linguistic tasks, though not as well as healthy bilinguals, much as monolingual patients compare to healthy monolinguals. It is possible that there is a bilingual advantage which may result in significant differences between monolingual and bilingual patients. The types of errors produced, either in regular rule application or in irregular retrieval, should indicate whether bilingual patients are relying more on the mental grammar or the mental lexicon, providing evidence for either implicit versus explicit knowledge or inhibition of competing forms. I predict that the results will support the expectation of Ullman (2001) and the existence of a bilingual advantage in inhibition, demonstrating impaired rule following with a similar degree of over-regularization as is found in monolingual patients.

Do the results of previous Huntington's disease studies of linguistic impairments (see above) translate into any language? The previous studies were carried out in English, French and Hungarian, three languages of differing morphological typology. English is an analytic language, meaning that it relies very little on inflection. The meanings of words are encoded in syntactic structural rules (e.g. adjectives precede the nouns they modify) and auxiliary words. French is a fusional language, which relies on inflection that encompasses multiple meanings. For example, in the conjugation of 'er' verbs, a single ending denotes tense, aspect, mood, person, and number. Hungarian is an agglutinative language, having a separate affix for each grammatical category. Despite these morphological differences, the results in these three languages were consistent. From this, I presume that the results will translate into any language.

Does subregular morphology behave more like regular morphology, or irregular morphology? Does this behavior vary between individuals? For monolinguals, subregulars which are common and for which the morphological process is predictable (e.g. pluralization of stress-ending words and loanwords in Italian) can be expected to behave in a rule-governed fashion. The correlation will be gradable, with a higher degree of irregularity corresponding to greater reliance on lexical retrieval. In bilinguals, language use will be of more importance than language competence in terms of creating rules, which relies on implicitly known skill-like aspects of language. Thus, in the case of less used secondary languages, bilinguals will treat subregulars as irregular and their errors will follow the same pattern as irregular errors, while in native bilinguals and those who use L1 and L2 equally, subregular and regular rule errors will be more similar to the results of previous monolingual studies.

Can dissociation between these types of morphological processes provide insight to the question of how the brain processes linguistic rules as opposed to lexical information? Dissociation in morphological processes will be more evident in the bilingual brain. Less natural use of a secondary language will correlate with more intact lexical retrieval and reduced rule use,

particularly in the uncommon subregulars. The distinction will not be as obvious in the application of regular rules, as these are learned early and repeated often, existing as both rules and lexical knowledge. The subregular forms and novel versions of each condition will show a clearer distinction between the mental grammar and the mental lexicon.

3.2 Methods

Following the methods of previous studies (Ullman *et al* 1997, Longworth *et al* 2005, Teichmann *et al* 2005 & 2008, Nemeth *et al* 2012), irregular, subregular and regular morphology should be tested and compared to discover how the brain deals with subregular morphology and to investigate bilingual processing of lexical and rule-based morphological inflection.

3.2.1 Materials

Compared to the plethora of irregulars found in English, Italian is a language that closely observes its rules. Regular pluralization morphology (shown in Table 1) is highly productive and predictable. Italian irregular plurals may be divided into those of Latin origin (Table 2) and subregular plurals (examples given in Table 3). While the irregulars are unproductive and unpredictable and could not generate any sort of testable non word, Italian subregular plurals are mostly predictable (see Table 3 for exceptions). For regular and subregular Italian nouns, phonologically acceptable novel nouns could be derived and tested for predictability of the pluralization following the example of Teichman *et al* (2005, 2008).

Table 1: Italian Regular Pluralization Rules					
Masculine		Feminine	Feminine		
singular	plural	singular	Plural		
-0	-i	-a	-е		
il cavallo	i cavalli	la sedia	le sedie		
-a	-i	-o (abbreviations)	-		
il problema	i problemi	la foto	le foto		
-ista	-isti	-ista	-iste		
il dentista	i dentisti	l'artista	le artiste		

Table 2: Italian Irregular Nouns						
Gender switch		Traceable Roots		Others	Others	
Singular	Plural (f)	singular	plural	singular	plural	
(m)						
braccio	braccia	dio	dei	ala (f)	ali	
budello	budella	(iddio)	(iddei)	bue (m)	buoi	
centinaio	centinaia	principio	principi	mano (f)	mani	
cervello	cervella	(principium)	principii	uomo (m)	uomini	
ciglio	ciglia		principî			
corno	corna	tempio	tempî			
dito	dita	(templum)	tempi			
fondamento	fondamenta	(templo*)	templi			
ginocchio	ginocchia					
labbro	labbra					
lenzuolo	lenzuola					
membro	membra					
miglio	miglia					
migliaio	migliaia					
muro	mura					
OSSO	ossa					
paio	paia					
sopraciglio	sopraciglia					
uovo	uova					

[For the irregulars with clear connections to the original Latin, the Latin roots are given in parenthesis. *Denotes archaic forms.]

Table 3: Subregular Pluralization Patterns						
Final stress		Final (Loanwords)	Final consonant (Loanwords)		Phonological h-insertion	
singular	plural	singular	plural	singular	plural	
città (f)	città	computer (m)	computer/s	amica (f)	amiche	
papà (m)	papà	film (m)	film/s	buca (f)	buche	
re (m)	re	manager (m)	Manager/s	lago (m)	Laghi	

[Unlike the first example, which follows a predictable rule, and the second, which is flexible between two acceptable rules, the subregular pattern of phonological h-insertion is not observed in all words with -go/co or -ga/ca endings. Either the subregular examples must be memorized as exceptions to the normal conjugation rule (e.g. amiche), or the exceptions to the subregular conjugation rule must be memorized (e.g. amici). It is also possibly that they are all memorized.]



Pluralization of final-stress nouns is completely predictable in Italian, with no inflection, and loanwords are acceptably left uninflected or inflected following the English '-s' rule [Rando 1970]. It is technically more effortful to add a suffix, even a regular one, than to leave it unchanged. Thus, adding a regular ending is more indicative of over-active rule use than of an overloaded system seeking the simplest response. Inclusion of the article would demonstrate that participants are not repeating the cue word but are accurately (or not) denoting the plural form in their response. H-insertion is not predictable and may be treated as a rule with exceptions or as individual exceptions to the regular rule. It would be interesting to see whether there is a trend towards rule creation or exception memorization.

Testing Huntington's disease patients in two languages will make it possible to determine whether there is any language mixing, which would indicate failure of the language control mechanism, and to measure quantitatively the effects of Huntington's disease pathology on morphological inflection of L1 and L2. In addition to testing the conclusion of Longworth *et al* (2005) that the basal ganglia plays an inhibitory role in later language processing, which should be less impaired in bilinguals given the executive control advantage, testing both languages will provide a context in which to examine the hypothesis of Ullman (2001) that L2 is less ruledependent than L1.

The selected stimuli are Italian nouns and noun plurals, which allow for clear comparison between regular, subregular, and irregular noun morphology. In Slovenian the morphological process is the same, though the stimuli come from verbs as well as nouns (from Roumpea *et al* 2019). This difference should prevent irrelevant errors, such as language crossover due to inattention or the similarity of the tasks.

3.2.2 Tasks

The task itself is a single language sentence completion task. The participants are shown a PowerPoint presentation with instructions for the task followed by the sentence pairs, one sentence on each slide. Sentence pairs are given with the target word missing from the second of each pair, for which the participants are required to verbally provide the target word. The task is not timed. For Italian, the target noun is first given in singular and the second sentence is altered to require the plural form of the same word. The Italian nouns follow regular rules, subregular patterns, or are irregular. For Slovenian, target nouns must be inflected to represent the correct number, singular or plural, while target verbs require either present tense inflection or perfective/imperfective aspect inflection (from Roumpea *et al* 2019). The Slovenian nouns and verbs are either regular or irregular.

3.2.3 Participants

Participants will be highly proficient bilinguals of Italian and Slovenian with preference to early learners to minimize intersubject variability. The participants will be tested for conflicting cognitive impairment following the methods of previous studies [Roumpea *et al* 2019]. Healthy control participants will be tested for comparison.

To date, one asymptomatic patient performed with 100% accuracy on the Slovenian task and one symptomatic patient declined to perform the task. This could indicate support for the theory of Ullman *et al* (1997) and the hypothesis that the bilingual advantage in inhibition acts as a protective against the effects of the disease, especially in early stages. It could also mean that this particular patient's neuropathology is not currently interfering with their linguistic abilities. Additional patients could not be seen due to the current pandemic, and given the risk factors for potential participants, it is not known when data collection will be possible.

3.3 Potential Conflicts with Reliability and Validity

The difficulties posed by bilingual studies are numerous. The many variables—age of acquisition, degree of use, method of study, psychological reasons for learning the language, general education, competence, and socio-linguistic environment—are difficult to control in recruiting a sufficient number of participants. As not all studies include such information as age of acquisition, degree of competence, length of study, or manner of language use, comparison with other studies is also difficult. There is no set definition for early versus late acquisition, though early tends to be 7 +/- 2 years. A variety of tests and tools are used to measure competency. There is often a correlation between early age of acquisition and higher competency, which may be the result of a critical period, a higher degree or duration of language exposure, or other unrelated but cooccurring factors. These factors tend to influence bilinguals' knowledge and performance in both L1 and L2 and can influence the reliability of results and validity of analysis.

It is possible that subregular morphological forms in Italian are less or more rule-governed than those found in French. It may also vary between speakers, dependent on their linguistic background. Additionally, it is possible that the inflexed forms of real words are stored and thus regular and subregular morphological processes are able to compensate the loss of rule function by relying on information in the mental lexicon. The inclusion of novel words for each morphological type allows for differentiation between lexical reliance and genuine rule-following. In order to ensure validity, it would be necessary to test a varied population with both monolingual and bilingual patients and controls.

Discussion

It is assumed by most models of linguistic processing that there must be one manner by which languages are processed in the brain. However, diversity in neural activity indicates that it is not so simple. To implicate age of acquisition would require there to be some important difference in order-that a language learned first is processed differently from others-or in brain capacity at certain stages of development. Case studies on children who were not exposed to linguistic stimuli until later and subsequently failed to develop language supported the idea of a critical age period [Vyshedskiy et al 2017]. The hypothesis was that during a certain period of normal development, conditions in the brain and in the environment coincide to create an optimal context for learning language, particularly in terms of syntax. Assuming a fundamental difference between languages acquired naturally as children and those learned later, bilingualism studies have generally focused on populations of early dual language speakers and used tasks from monolingual research. Although it is true that some functions are lost if they are never activated and this may also be the case with language [Cayea 2006], there are also examples of late learning that do not confirm such a limitation [Vargha-Khadem et al 1997]. In fact, it is possible, as happens with some immigrant populations, to become more comfortable in a second language than in the first [Abutalebi 2000]. The first language possesses a psychologically bestowed importance, not an innate one.

If order of learning is not important in terms of the brain's capacity to process a language, then the neural patterns that are typical of a first language are the result of environmental criteria and linguistic constraints. Automaticity in language is a social expectation; although some tasks are difficult to perform simultaneously, there is a general attitude that conversation can occur alongside almost any other action. In a native environment, it is possible that linguistic information is repeated to such an extent that it becomes automatic like a skill despite being merely knowledge. However, it is more likely that certain aspects of language are implicitly acquired as skills given the neurological and psychological data (see Ullman 2001 & 2004 for review). For example, grammatical rules that are intuitively used yet not explainable by native speakers are learned from contextual examples rather than explicit instruction. The only obstacle against similar rule formation in general second language learners should be insufficient examples and the lack of necessity for automatic processing. The Declarative/Procedural model, whether intentionally or not, leaves room for this interpretation in their bilingual version (see Ullman 2001).

There is also nothing in the Declarative/Procedural model that forbids the regular rule system and irregular lexical retrieval from being competitive or inhibiting one another. If they operate in parallel and each offers a choice, then it makes sense that one would be chosen in a competitive or inhibitory fashion. In the case of normal linguistic functioning, one or the other would be made stronger through exposure to correct examples. While this could explain overactive rule use despite intact lexical retrieval in Huntington's disease patients, it does not explain the failure of rule application in syntactic and non-linguistic contexts. Thus, in order to reasonably apply the results of syntactic and non-linguistic contexts to that of morphological processes, it is necessary to create a context of rule application that is not influenced by potential interference from the lexical retrieval process. Additionally, the results need to be comparable; much as all healthy controls demonstrate similar results, all monolinguals rely on rules and the lexicon to similar degrees. However, if Ullman (2001) presents an accurate theory of the division between lexical retrieval and rule application in bilinguals' second language use, then it should be possible to analyze correlations between dependence on rules and errors in bilingual Huntington's disease patients. Additionally, subregular rules provide another condition where differentiation between individual error patterns may allow for the separation of failure of rule application from lexical dependence.

In bilinguals, an additional important question is whether they would suffer from non-target language interference, resulting in inappropriate code-switching or an increase in errors due to greater inhibitory costs. This did not occur in the two recent Huntington's disease bilingual studies, but that does not guarantee that there would be no effect in rule application. If the multiconceptual interdependent theories are correct in the assumptions that multiple languages share the same mental space and neural components and that the same subcortical and cortical structures affected by Huntington's disease are part of the network that commands language control, interference is a real possibility. It is presumed that the strength of bilinguals on executive control tasks, particularly inhibitory and switch tasks, is due to the higher necessity for such control, making them resilient against related errors. The neural variation in L2 activation in healthy bilinguals makes it difficult to make conclusions regarding the exact relation between L1s and L2s, and even more so in the variability of multilingual aphasia impairment and recovery patterns. Still, it can be theorized that if the basal ganglia are related to the formation of regular (and subregular) morphological inflection, then this monolingual impairment will appear in bilinguals, influenced by the nature of the basal ganglia's role. If it is inhibitory, the impairment will be less apparent in bilinguals. In contrast, if it is related to the procedural memory system, there may be less of a bilingual advantage.

Conclusion

The research to date on Huntington's disease pathology and its effects on morphological processing leaves several open questions in its attempts to understand the role of the basal ganglia in the application of rules and the retrieval of lexical information. In order to clarify the nature of the dissociation between the mental lexicon and mental grammar, further clarification is necessary. Current research indicates that Huntington's disease patients suffer imbalanced impairment in morphological tasks dependent on grammatical rules and the lexicon. The fresh context of bilingualism allows for the examination of the effect of the inhibitory advantage bestowed by language switching the relation between competence and dependence on the mental lexicon versus the mental grammar. Moreover, it is a new context in which to study the relation between languages in the multilingual mind.

In recent years, qualitative differences between native and non-native languages have been disappearing from academia. And yet, much of the world views them as distinctly separate phenomena. Despite the fact that nearly every human has learned a language, it is common to hear people complain that learning languages is hard, much more so than in the case of other skills, tools, and information. The prevalent assumption that it is easier for children is often accompanied by a paradoxical belief that having multiple languages in one brain is too confusing. Psychology suggests that language is a tool, which should be relatively easy to learn, a skill, which is harder to acquire, or a corpus of related information, which requires concentrated effort to memorize and space for storage. That everyone's brain can learn language gives support to all three viewpoints, as does neurological evidence of dissociation between linguistic functions. But while the components of a native language might organize themselves in the most efficient way, differences in secondary language competence suggest that this is not the case in all language learning.

This psychological difference results in neurological variation, as seen in the inconsistency of bilingual neural activation patterns, especially in comparison to monolingual and dominant language neural activation. The division between the mental lexicon and the mental grammar is only one area in which it might be possible to understand the differences between bilinguals' secondary language use, but it importantly highlights dissociation between skill-like and information-based linguistic functions and may provide insight for the debate on the psychological nature of language. Understanding the neurological and psychological underpinnings of language sheds light on not only language function, but also on the relation between psychological and neurological treatment of language.

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