

MORPHOLOGICAL PROCESSING IN PATIENTS WITH OBSESSIVE-
COMPULSIVE DISORDER

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COMPULSIVE DISORDER**

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ABSTRACT

MORPHOLOGICAL PROCESSING IN PATIENTS WITH OBSESSIVE- COMPULSIVE DISORDER

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The present study examines how individuals with Obsessive-Compulsive Disorder (OCD) process inflected and derived words during visual word recognition. A second aim is to determine whether procedural memory deficits contribute to differences in morphological processing in OCD. Grounded in Ullman's declarative/procedural (DP) memory model, this study explores how impairments in frontostriatal circuits—associated with procedural memory—affect rule-based morphological decomposition, while medial temporal lobe structures supporting declarative memory remain intact. 36 individuals diagnosed with OCD and 36 healthy controls were tested through a lexical decision task using masked priming paradigm in terms of their processing of Turkish inflected verbs and derived nouns. The results showed that the processing of inflected words in the OCD group was selectively impaired. Patients with OCD demonstrated a statistically significant decreased sensitivity to inflectional morphology although the processing of derived words remained intact – indicating a reliance on declarative memory as a compensatory route. Control group displayed automatic decomposition for both inflected and derived words. These findings provide empirical evidence that morphological decomposition mechanisms are selectively impaired due to the procedural memory deficits in OCD only for the inflected

morphological items. In spite of this impairment, the functioning of the declarative-memory dependent whole-word storage mechanisms remained intact in the OCD group. This study provides insights into the neurobiological bases of language difficulties in OCD by connecting morphological processing to the procedural memory dysfunctions. These findings highlight the significance of language as an indicator of broader cognitive impairments, with possible ramifications for treatment strategies aimed at cognitive rehabilitation and language-oriented therapy.

Keywords: Morphological Decomposition, Procedural Memory Impairment, Obsessive-Compulsive Disorder (OCD), Inflectional and Derivational Morphology, Masked Priming Paradigm

ÖZ

OBSESİF-KOMPULSİF BOZUKLUK TANILI HASTALARDA BİÇİMBİLİMSEL İŞLEMLEME

BELENDİR, Zeynep

Yüksek Lisans, İngiliz Dili Öğretimi Bölümü

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Bu çalışma, Obsesif-Kompulsif Bozukluğu (OKB) olan bireylerin görsel sözcük tanıma sırasında çekimlenmiş ve türetilmiş sözcükleri nasıl işlediğini incelemektedir. Çalışmanın ikinci amacı, OKB’de görülen biçimbilimsel işleme farklılıklarının ardında yatan prosedürel bellek (procedural memory) eksikliklerinin rolünü belirlemektir. Ullman’ın Deklaratif/Prosedürel (Declarative/Procedural – DP) Bellek Modeli temel alınarak yürütülen bu çalışmada, prosedürel bellek ile ilişkilendirilen frontostriatal devrelerdeki bozulmaların kural tabanlı biçimbilimsel ayrıştırmayı nasıl etkilediği incelenirken, bildirimsel belleği destekleyen medial temporal lob yapılarına dair işlevselliğin korunduğu varsayılmıştır. Çalışmaya OKB tanısı almış 36 birey ve 36 sağlıklı kontrol katılmıştır. Katılımcılar, maskeleye yönteminin kullanıldığı sözcüksel karar verme görevi aracılığıyla, Türkçedeki çekimlenmiş fiillerin ve türetilmiş isimlerin işlenmesi açısından değerlendirilmiştir. Sonuçlar, OKB grubunda çekimlenmiş sözcüklerin işlenmesinin seçici olarak bozulduğunu göstermiştir. OKB tanılı bireyler, türetilmiş sözcükleri sağlıklı kontrollerle benzer şekilde işlerken, çekimsel biçimbilgisinin işlenmesine yönelik duyarlılıklarının istatistiksel olarak anlamlı düzeyde azaldığı gözlemlenmiştir. Bu bulgu, OKB’li bireylerin telafi edici bir

strateji olarak bildirimsel belleğe daha fazla dayandığını göstermektedir. Buna karşılık, sağlıklı kontrol grubu hem çekimlenmiş hem de türetilmiş sözcüklerde otomatik biçimbilimsel ayrıştırma gerçekleştirmiştir. Elde edilen bulgular, OKB’de prosedürel bellek eksiklikleri nedeniyle yalnızca çekimlenmiş biçimbirimlerin işlenmesinde seçici bir bozulma olduğunu göstermektedir. Bununla birlikte, deklaratif belleğe dayalı tam sözcük depolama mekanizmalarının OKB grubunda sağlam kaldığı gözlemlenmiştir. Bu çalışma, OKB’de dilsel güçlüklerin nörobiyolojik temellerine ışık tutarak, biçimbilimsel işlemenin prosedürel bellek işlev bozukluklarıyla bağlantılı olduğunu ortaya koymaktadır. Bu bulgular, dilin daha geniş çaplı bilişsel bozuklukların bir göstergesi olarak önemini vurgulamakta ve bilişsel rehabilitasyon ile dil odaklı terapiye yönelik tedavi yaklaşımları için potansiyel çıkarımlara işaret etmektedir.

Anahtar Kelimeler: Biçimbilimsel Ayrıştırma, Prosedürel Bellek Bozukluğu, Obsesif-Kompulsif Bozukluk (OKB), Çekimsel ve Türetimsel Biçimbilim, Maskelenmiş Hazırlayıcı Paradigması

To My Family



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CHAPTER 1

INTRODUCTION

This introduction chapter involves four sections. The Background section introduces available morphological processing models along with the theoretical background the current study is based on. The second section addresses the main aims and rationale behind this thesis work. The third section discusses the Declarative/Procedural Memory model, which will play a central role in investigating the morphological processing patterns of Turkish-speaking individuals diagnosed with Obsessive Compulsive Disorder (OCD), alongside healthy control participants. The final section presents the research questions and hypotheses of the present study.

1.1. Background to the study

Word processing has long been a pivotal issue in psycholinguistic research. Any comprehensive account of linguistic communication and language processing from a psycholinguistic standpoint necessitates a thorough elucidation of the organizational and procedural aspects governing linguistic input and output. Central to the endeavor of explicating this process within the framework of psycholinguistics is the fundamental concept of the 'mental lexicon'. Generative grammar proposed, in essence, that the language system encompasses a list of words (the mental lexicon) - which has a limited number of items - and works alongside a computational mechanism (the mental grammar) to formulate and comprehend an unlimited number of strings of letters employing certain combinatorial rules (Chomsky, 2014). This construct encompasses the intricate network of representations bridging spoken or written utterances with the corresponding interpretations engendered by the recipient, whether listener or reader.

1.2. Morphological Processing in Healthy Individuals

How the mental lexicon is organized and what mechanisms are used to access words are among the fundamental questions of psycholinguistics. In this context, morphologically complex words (i.e., words comprised of more than one morpheme such as , “*blind-ness*”) are ideal stimuli for understanding whether a morphologically complex word is perceived as consisting of different components (root/stem and affix(es)) and whether it is processed by the reader/listener's language processing system as such. While some studies in the literature have argued that the processing patterns of morphologically complex words favor full-form storage (e.g., Bybee, 1995), others have proposed morphological decomposition as a model that can be empirically supported (e.g., Taft, 1979; Taft & Forster, 1975).

According to the full-form storage approach, words traditionally defined as ‘morphologically complex’ are not represented as parsable units but, rather, as single, unparsed whole words (Marslen-Wilson et al., 1994). In contrast, the morphological decomposition perspective argues that morphologically complex words are represented as distinct morphemic elements. For example, in order to process the morphologically complex word “*blindness*”, the latter view suggests that the processor must parse the word into morphemes (i.e., the root “*blind*” and the suffix “*-ness*”). Therefore, it has been suggested that morphemes play an important role in the organization of complex words in the lexicon (Kazanina et al., 2008). Morphemes, which are defined as the smallest functional units, are hence considered to be the building blocks of the meaning of a morphologically complex word. This notion has gained considerable support from theories positing that morphemes are accessed in the process of retrieving morphologically complex words from the lexicon. For example, there are hypotheses about the effect of the root morpheme (“*blind*”) on the morphologically complex word (“*blindness*”) with which the word is processed (e.g., Bertram et al., 2000; Rastle et al., 2004).

Taft (1979) suggested that morphological parsing is an essential process that occurs in the early stages of processing. Many studies have shown that words consisting of multiple morphemes (e.g., “*beauti-ful-ly*”) are represented in a “decomposed” manner in the visual word recognition system, and that morphologically complex words are

decomposed from their stem representations (e.g., Rastle et al., 2000). Visual lexical decision studies have found that the recognition of stem targets (e.g., “depart”) is significantly and equivalently facilitated by the pre-exposure of semantically transparent (“departure”) and semantically opaque (“department”) masked primes (Rastle & Davies, 2000). It has also been found that the recognition of stem targets (e.g., “broth”) is faster when these targets are preceded by a morphologically structured ‘semantically opaque’ masked prime (e.g., “brother”) than by a non-morphologically structured masked prime (e.g., “brothel”) (Rastle et al., 2004). In other words, findings have been obtained regarding the functioning of a completely structural morphological parsing system in recognition.

It has been reported for many languages, including Turkish, that words that appear to be morphologically complex, but are in fact not (e.g., “kamuş”- “reed”), are processed by healthy individuals as if they were morphologically complex and are automatically parsed into non-existent morphemes (“ka-muş”). This automatic parsing mechanism, which has been suggested to be ‘blind’ to the morphemic status of linguistic structures, is now accepted by many as a fundamental element of word recognition processes in healthy adults. Although different approaches have been developed with regard to how words are parsed in the early visual perception stage (Stockall & Marantz, 2006; Taft, 2004; Schreuder & Baayen, 1995; Caramazza, 1991; Caramazza et al., 1988) or the late visual perception stage (Giraudo & Grainger, 2000, 2001), the common conclusion reached by most studies to date has been in line with an automatic morphological parsing mechanism in healthy adults.

There are a few morphological processing studies conducted with healthy adults in Turkish (Kırkıcı & Clahsen, 2013; Jacob & Kırkıcı, 2016; Jacob et al., 2019; Uygun & Clahsen, 2021). The common feature of these studies is that they used the masked morphological priming paradigm, which is the most frequently used paradigm in morphological processing studies and was also used in the present study. In all of these studies conducted on Turkish, it was reported that complex words with both derived and inflected suffixes were processed by the participants in accordance with the decompositional pattern summarized above.

1.3. Rational of the study

Numerous cross-linguistic studies conducted with healthy adults have shown that healthy adults process inflected and derived complex words by automatically decomposing them into morphemes during reading (Kırkıcı & Clahsen, 2013). Likewise, words that appear to be morphologically complex, but are actually not, are also processed by healthy individuals as if they were morphologically complex and are automatically parsed into their ‘constituents’. This ‘blind’ morphological decomposition pattern was reported for many typologically-distinct languages, including Turkish, and is now accepted as a fundamental element of the word recognition processes of healthy adults.

How this automatic parsing mechanism develops in child learners, whether and how it is manifested in second language learners, and whether it is involved in the native language processing processes of atypical populations has been increasingly attracting attention, especially in the recent years. Although studies with children and second language learners were reported in the literature, there are very few studies with patient groups and none are known for Turkish. For this reason, the current study focused on the morphological processing patterns of Turkish-speaking individuals diagnosed with Obsessive Compulsive Disorder (OCD).

The present study was designed based on Ullman's declarative/procedural memory model (Ullman, 2001; 2004), which is built upon the distinction between the brain structures underlying the procedural memory (the mental grammar) and the declarative memory (the mental lexicon). Ullman proposed that the declarative memory processes the meanings and content of language, while the procedural memory is responsible for processing language structures and rules. Taking the declarative/procedural memory model as a theoretical basis, it was hypothesized in the present study that the procedural memory deficits of OCD patients reported in the literature may lead to differences in morphological processing as a result of the interaction between these two memory systems. The aim was to examine the morphological processing patterns of adult Turkish native speakers diagnosed with OCD using complex derived (e.g. “*hasta-lık*”) and inflected (e.g. “*git-miş*”) Turkish words through masked priming experiments.

The results of this study will primarily show whether automatic word parsing mechanisms, which were consistently and cross-linguistically reported to exist in adult individuals, exist in patients with OCD and whether the participants will exhibit comparable processing patterns to that of healthy controls. The present study thus aimed to fill the existing research gap regarding the language processing deficits of individuals diagnosed with OCD. The results of the study could potentially lead to a better understanding of the neurological underpinnings and language processing processes of individuals diagnosed with OCD and allow for the development of future diagnostic and intervention approaches. The results of this study could also provide substantial information about the effects of possible procedural memory deficits on language processing and reading processes of individuals diagnosed with OCD.

1.4. Contribution to Research

As indicated earlier, the fundamental patterns of morphological processing in a native language are now relatively well understood for healthy adults. Cross-linguistic studies agree that morphological processing in the native language is a process that can often be described as “automatic morphological parsing”. However, almost no studies have been carried out to date with a population that is known to have difficulties in both procedural processes and different cognitive domains (such as decision making, set switching); however, it is imperative to consider both the developmental processes and the repercussions in clinical and atypical populations in order to check the reliability and validity of the language processing models developed.

Therefore, in the current study, morphological processing processes were tested for the first time in individuals with OCD. This offered the unique opportunity to test whether and how morphological processing processes in Turkish are affected by memory differences/deficiencies. Since no research was reported in the relevant literature that tests the morphological dissociation mechanism with individuals with OCD in any other language, it was believed that the results to be obtained would be of great importance for future research. On the one hand, the results will provide new

inputs to morphological processing models, and will allow for a better understanding of the language processing mechanisms of individuals with OCD.

The present study, thus, aimed to investigate the morphological processing patterns in adults diagnosed with Obsessive-Compulsive Disorder (OCD) and to explain the effect of procedural memory deficits for these word processing patterns. In this context, the possible effects of procedural memory disorders (Rauch et al., 1997) on language processing were examined within the framework of Ullman's declarative/procedural memory theory (2001, 2004) by focusing on Turkish inflected (e.g., “*sat-mı*”ş) and derived (e.g., “*sat-ıcı*”) morphologically complex words.

1.5. Research Questions

Within the scope of this thesis, answers to the following two general research questions will be sought:

- 1- Are there any difference(s) between individuals diagnosed with OCD and healthy individuals in terms of their morphological processing patterns?
- 2- In what ways, if any, is the processing of inflected and derived words different in individuals diagnosed with OCD and healthy controls? Could such differences be due to procedural memory impairments in individuals with OCD?

It was hypothesized that, given that OCD is associated with frontostriatal abnormalities and that procedural memory relies on frontal-basal ganglia structures (Rauch et.al.,1997), OCD patients would show deficits in tasks related to procedural memory processes, especially in the processing of inflected forms. It was predicted that such deficits would manifest themselves in the form of a lack of a priming effect for inflectional, but not for derivational, morphology. The hypotheses and the research questions were pre-registered on OSF (<https://osf.io/52c6q>).

Within the framework of the research questions and hypotheses presented above, in order to examine the possible memory-based differences between the two groups, it is first necessary to examine how morphological processing operates in healthy individuals based on the existing literature. This will be done in the next chapter.

CHAPTER 2

REVIEW OF LITERATURE

2.1. The Distinction Between Inflection and Derivation

Although inflection and derivation are taken as two distinct morphological processes in the present work and previous research, this distinction is still a matter of debate as some linguists do not see the need for such a distinction, pointing to the level of similarity between the two processes. To exemplify, Bochner (1992) points out that the affixation types that are similar -including, the prefixation, suffixation, and infixation- are utilized in inflectional and derivational morphology in several languages. Aronoff (1994) notes that some of the affixes may apply both inflectional and derivational morphemes depending on the language in question like, for example, the affix *-ing* in English. Furthermore, Distributed Morphology approaches do not differentiate between these processes, either, as Harley & Noyer (1999) outlined.

Stump (1998) lists five conditions that could be used to differentiate between inflectional processes and derivational processes. The first condition is that inflection preserves the stem's original lexical meaning and syntactic category; however, derivation often changes both the lexical meaning and the syntactic category of the word (for instance, "*happiness*" is derived from the adjective "*happy*"). Secondly, inflectional affixes are syntactically bound while derivational affixes are not because syntactic context does not require a lexeme to be simple or complex, as in the cases of "*child*" and "*student*". Thirdly, inflection is usually described as more productive than derivation as a given inflectional operation generally applies freely to all (or most) members of a category (as in the case of tense markers, which can be attached to all - or most- verbal roots). This, however, is not necessarily the case for derivational operations. For instance, although it is possible to derive "*childhood*" and "*adulthood*" by attaching "*-hood*" to the nominal roots "*child*" and *adult*, respectively, it is not

possible to apply the same operation to some other nominal roots (e.g., **birdhood* or **doghood*). Fourthly, inflection is semantically consistent. The past tense suffix *-ed*, for example, has only one meaning, and it only indicates the past tense. On the other hand, the semantic effect of derivation is different; for example, “*friendship*” is derived from the word “*friend*”, however it creates a concept that is different from the root form which includes the state of being friends. Lastly, inflection puts a stop to other morphological processes while derivation does not (e.g., “*leaflets*” is acceptable but “*leaveSlet*” is not).

In order to differentiate between derivation and inflection, a number of criteria can be utilized. Haspelmath (2013) offered a number of most widely adapted criteria for distinguishing the processes of derivation and inflection from each other, which are listed in Table 1.

Table 1: A list of properties of inflection and derivation as offered by Haspelmath (2013)

	Inflection	Derivation
(i)	Relevant to syntax	Not relevant to the syntax
(ii)	Obligatory	Optional
(iii)	Not replaceable by simple word	Replaceable by simple word
(iv)	Same concepts as base	New concept
(v)	Relatively abstract meaning	Relatively concrete meaning
(vi)	Semantically regular	Possibly semantically irregular
(vii)	Less relevant to base meaning	Very relevant to base meaning
(viii)	Unlimited applicability	Limited applicability
(ix)	Expression at word periphery	Expression close to the base
(x)	Less base allomorphy	More base allomorphy
(xi)	Cumulative expression possible	No cumulative expression
(xii)	Productive	Not productive

2.2. Models of Adult Morphological Processing

Regarding how morphologically complicated words are processed in a native language, two main opposing theories have arisen. While the first view suggests that a single system performs all morphological operations, the second view argues that two distinct systems are used. These two differing stances will be examined below.

2.2.1. Single Mechanisms Models

Single-mechanism models can be classified into two main types. The first type is single-mechanism associative (connectionist) models, where morphologically complex words are processed as whole-word units. The second type is single-mechanism (or rule-based models), which rely on rule-based representations. The key difference between these models depends on whether morphologically complex forms are accessed as complete units or processed using morphological rules.

2.2.2. Associative Mechanisms

According to associative models of morphological processing, morphological rules lack mental representations. Instead, these models hold that all word forms -regardless of whether they are morphologically complex or simple- are processed through associative connections and stored as complete units in a single connectionist system. Word frequency and phonological similarity have an impact on these associations, with frequent or phonologically similar words being easier to recall (Stemberger & MacWhinney, 1988; Alegre & Gordon, 1999). On the other hand, rule-based approaches place more emphasis on diverging processing for complicated forms.

Many influential models (e.g., MacWhinney & Leinbach, 1991; Plunkett & Marchman, 1993) were based on the architectural features of Rumelhart & McClelland's (1986) Parallel Distributed Processing Model, which was an influential associative model that mimics the acquisition of the English past tense. An encoding network, a decoding network, and a pattern associator make up its three constituent parts. Because all learning takes place through its input and output pools, which each contain 460 units representing "Wickelfeatures" (e.g., fricative, voiced, nasal), the pattern associator is essential. Verb base forms are represented by input units, while their past tense forms are predicted by output units.

Every input unit is connected to every output unit in the pattern associator model. All connection weights are initially set to 0, indicating that inputs and outputs have no influence. Incorrect outputs cause the model to adjust, strengthening the weights between the proper input-output links as it compares its output with the proper past

tense forms. Until the model consistently generates the right forms, this process keeps going. While the decoding network transforms past tense forms back into phonemes, the encoding network translates phonemes into feature representations of verb bases (Rumelhart & McClelland, 1986). The Rumelhart and McClelland (1986) model of English past tense acquisition is actually a two-stage model. In the first stage, the model was trained on 10 high-frequency verbs and the model was able to learn both the regular and irregular past tense forms. In the second stage, using 410 medium frequency verbs, it overgeneralized irregular verbs first but later learned them correctly and followed a U-shaped curve.

However, Pinker and Prince (1988) pointed out that the model is unable to generalize new regular verbs, providing incorrect responses to 24 regular verbs and no responses to 6, which showed that the single-mechanism associative models of the time could not satisfactorily handle the processing of regular verbs. Despite the fact that the model exhibited good performance in dealing with irregular verbs, its failure to generalize rules of regular verbs showed that more work needed to be done in developing associative models. This generalization problem has been a major issue of debate, resulting in other models to enhance these drawbacks, though their details are beyond the scope of this study.

2.2.3. Rule-based Accounts

Rule-based accounts of morphological processing hold that morphologically complex words are processed using a “combinatorial mechanism” (Yang, 2002). Taft and Forster (1975) posited that prefixed words can be processed by decomposing them into their prefixes and stems (for example, “redo” can be decomposed into its parts as “re” + “do”). This model of prefix stripping emphasizes the importance of morphological structure in language processing. Yang (2002) developed the rules-and-competition model by building it upon previous generative phonological theories (Halle & Mohanan, 1985; Halle et al., 1993) and suggested that English's regular and irregular past tense forms are processed according to a rule-based methodology. While irregular verbs adhere to specific phonological rules, such as vowel changes (e.g., “sit” → “sat”), regular verbs usually stick to the default -ed rule to form their past tenses.

Based on Yang's model (2002), speakers of a language acquire these norms instead of rote memorization of the past tense form for every verb. According to this model, each irregular verb is assigned to a particular rule class (a category), and the model also proposes a competitive dynamic between the default rules and non-default (irregular) rules. A verb goes back to the regular rule if it is not assigned to any irregular class. The model posits that the accurate use of past tense forms is influenced by a word's frequency. For example, Don (2014) states that if two verbs belong to the same rule class, the verb with a higher frequency (for example, "*put*," frequency: 2,248) will show a higher percentage of accurate usage (95.2%) than "*hit*," frequency: 66, correct usage rate: 90.8%).

However, the rules-and-competition model has challenges when accounting for irregular verb classes (Silva, 2009). Although Yang (2002) argued that usage accuracy of irregular verbs are improved with higher frequency, this assertion lacks statistical validation. For example, verbs like *hit* and *put* may have different frequencies, but their correct usage rates might not be significantly different. Inconsistent phonological changes are also observed in irregular verbs following the (-Ø + Backing Ablaut) pattern (e.g., "*shake* → *shook*", "*sit* → *sat*"). More importantly, even though the model attributes overregularization to frequency effects, it falls short in accounting for the U-shaped developmental pattern of irregular past tense acquisition. Taken together, all of these challenges involved with the model point to the possibility that processing irregular word forms may not be comprehensively captured by rule-based models.

2.2.4. Dual Mechanism Models

Single-mechanism models mainly suggest that all word forms -including both the regular and irregular forms- are processed through a single system though both accounts (associative and rule-based) have their above-mentioned limitations (Pinker & Prince, 1988; Yang, 2002; Silva, 2009). Although these two models efficiently account for irregular word forms - showcasing the challenges rule-based models encounter with irregulars while handling regulars well-, the associative models fall short in explaining regular forms.

To overcome these issues with models of morphological processing, a dual-mechanism model was introduced by Pinker and colleagues (Pinker, 1991, 1999; Pinker & Ullman, 2002) which describes two separate systems for regular and irregular morphological processes. This model aims to provide a more uniformed explanation of the processes taking place during morphological processing.

According to Pinker and Ullman (2002), the dual-mechanism model encompasses two major interdependent systems: the mental lexicon -which is responsible for storing arbitrary mappings of sound and meaning for morphemes and words-, and the mental grammar -which includes rule-based linguistic operations that generate novel complex words as well as phrases. According to this dual model, irregular forms are stored in the mental lexicon as whole units, while regular forms are processed via grammatical rules in the mental grammar. Through this hybrid model of morphological processing, more comprehensive explanations were provided for both regular and irregular forms.

Even though regular forms are generally thought to be processed via a rule-based computational process, they can also be stored in the mental lexicon as whole words under specific conditions (e.g. availability of irregular forms, or frequency of the regular word forms etc.). For instance, regular forms with high-frequency are more likely to be stored as whole, undecomposed units (e.g. English words with frequencies over 6 per million), as shown by Alegre and Gordon (1999). Moreover, Berent, Pinker, and Shimron (1999) also pointed out that regular forms with available irregular alternatives (e.g., “*dive-dived/dove*”) may also be stored in the lexicon to bypass competition with the irregular counterparts of the words.

In order to overcome overregularization errors (e.g., **hanged*), the dual mechanism model utilizes a blocking mechanism. In this blocking mechanism, whenever an irregular form -or irregular stem- is retrieved from the mental lexicon, the system sends an inhibitory signal to the combinatorial system, halting the attachment of a regular suffix (e.g. the system cancels out errors such as **hanged* or **hunged*). On the condition that no irregular form is available in the lexicon, this blocking mechanism

ceases, and allows the default rule to operate, both with non-existent (e.g., **fluged*) and novel verbs (Pinker & Ullman, 2002).

The dual mechanism model encompasses several variations -which are known as dual route models. According to Clahsen (2004), dual route models involve two prevalent approaches to recognizing and processing morphologically complex words: the first one being pre-lexical morphological parsing -decomposing input into smaller units- and the second one being direct access -or whole-word recognition-. However, dual route models have diverging explanations as to how these two distinct routes differ from each other in terms of functionality. For example, in the Augmented Addressed Morphology (AAM) model whole-word access for already-known words is favored, and morphological parsing is classified as a backup system for new or less-frequent word forms (Caramazza et al., 1988). On the contrary, the Morphological Race Model (MRM) holds that both routes are activated simultaneously, and the routes are chosen on the basis of the factors such as lemma frequency and phonological transparency (Schreuder & Baayen, 1995).

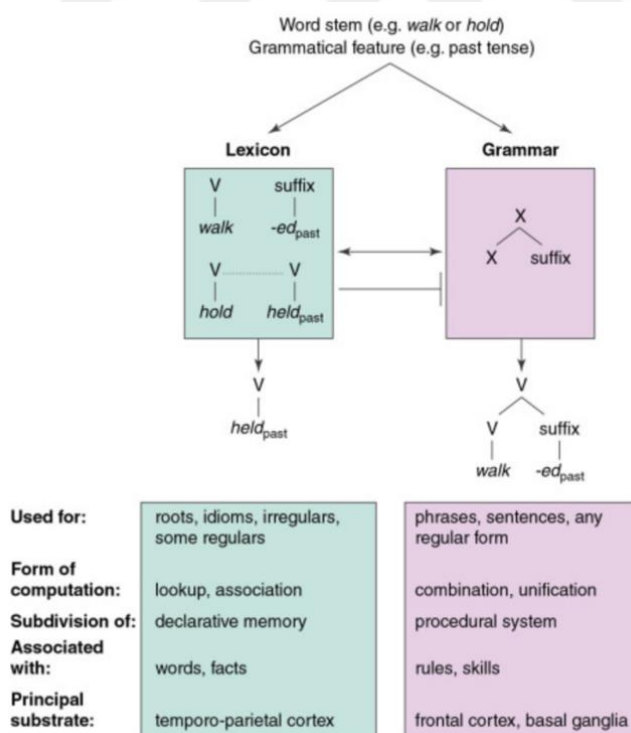


Figure 1: A representation of the Dual-Mechanism Model (Pinker & Ullman, 2002)

2.2.5. Background on the Declarative/Procedural Model: Ullman (2001 & 2004)

Linguistic research has traditionally focused on language itself, yet both the structure of the brain and evolutionary principles suggest that language and non-linguistic cognitive domains share fundamental characteristics. The cerebellum and basal ganglia carry out comparable computations in various areas, suggesting that language utilizes the same computational mechanisms as cognitive functions other than linguistic ones (Shimamura, 1995; Alexander et.al., 1986). Support for this idea also comes from evolutionary theory, as biological structures usually develop from existing ones (Mayr, 1963). Therefore, valuable insights into the neurocognitive systems that underlie language can be gained from non-language domains, which are often better understood. By integrating models from different cognitive fields and broadening research beyond concepts limited to language, researchers can gain a more profound understanding of language and generate more precise models. Research procedures that are invasive and not feasible in human language studies can be conducted using animal models in non-linguistic areas. Investigating common processes in well-researched fields like neuroanatomy and physiology can result in advancements in understanding the neurocognitive aspects of language. According to Ullman and colleagues (2002), our understanding of both language and non-language domains can be improved through neurocognitive connections between the two domains. Emphasis is put on the idea that exploration into non-linguistic areas should complement language research rather than completely replacing it.

2.2.5.1. Grammar and Lexicon Distinction

It has been widely agreed that human linguistic abilities depend on two crucial mental capacities. The first one is the mental lexicon, which is formed through the words that are memorized, and the second is the mental grammar - rules governing the hierarchical and sequential construction of the lexical forms into larger systematized words, phrases, and sentences (Ullman, 2001, p.1; 2002, pp. 233). Language use is possible through this structured relation between form and meaning -although the predictability of this correspondence may vary across linguistic forms. Moreover, there is a clear distinction between the predictability level of lexical forms and

grammar rules. The interrelation of word roots and word forms are idiosyncratic (i.e. arbitrary) in nature (the word form “*flower*” and the meaning “flower” is fully arbitrary- therefore it needs to be memorized and cannot be derived and/or predicted). The entirety of these stored form-meaning pairs has been regarded as the mental lexicon.

According to Ullman (2001; 2004), the mental lexicon also includes non-derivable information, such as the specific accompanying arguments for a verb (e.g. “*throw*” requires a direct object), and any non derivable unexpected word forms that are specific to a word (e.g. English past tense forms such as “*sing / sang / sung*”). Other distinct information stored in the lexicon encompasses elements that can vary in length in comparison to words, such as bound morphemes (e.g. suffixes like “*-ed*” or “*-ness*”, affixes like “*-un*”, “*-ir*”). The representations of intricate linguistic structures whose meanings cannot be transparently derived from their components are also stored separately in the lexicon (e.g. idiomatic phrases like “*raining cats and dogs*”).

As much as these irregular and arbitrary forms are found in the language, there are also regular forms defined by certain grammatical rules. Such forms follow learnable grammatical rules and lexical patterns; moreover, in contrast to the non-derivable linguistic forms, the meaning of these forms can be fully derived. It is these rules and the lexical components from which the regular forms are constructed that make their meaning predictable (i.e. derivable). The knowledge of these rules has been described as mental grammar. In addition to wholly predictable form-meaning pairs, there are also only partially predictable combinations -which could also be defined by rules. The situations in which those rules apply must be committed to memory because their application is not always fully predictable (Ullman, 2001).

The rules that govern and restrict language structure allow the combination of lexical items and abstract features to form complex representations. Grammatical rules allow us to understand unfamiliar forms, such as “*Emmanuel slaced the klug.*” because they contain clues about meaning, order, and relationships between elements. Language functions through rule-governed, hierarchical, and sequential processes (such as syntax and morphology), enabling us to interpret the aspects of the new constructions based on these established linguistic patterns and rules. Through this established rule

system one can assume that the unfamiliar item “*the klug*” is a noun phrase while the verb of the sentence is “*slaced*” and it was realized in the past tense. Within the framework of this rule-based system, one can infer knowledge at the sentence and word level.

Since Chomsky (1995), it has been argued that humans’ ability to produce and understand complex grammatical forms is possible through implicit mental rules and constraints, which are possibly innately specified. Because grammatical processing is independent of other cognitive systems and these rules function without conscious awareness (innately), they are considered to be “informationally encapsulated” (Frazier & Fodor, 1978; Fodor, 1983). Aside from operating without conscious awareness, grammatical processing is also fast and automatic. It has been found to be triggered by linguistic stimuli and Fodor (1983) and Friederici (2002) argued it does not necessitate conscious control.

Importantly, according to Ullman (2001; 2004), these two linguistic capacities, namely the mental lexicon and the mental grammar, “interact” with each other in various ways. In this rule system, the grammar is responsible for combining lexical items into complex structures. Additionally, even though some complex linguistic structures with unique meanings, like idioms, are stored in the mental lexicon, their linguistic form still remains within the restrictions of grammatical rules. Regular (derivable) complex forms like “*waited*” or “*the purse*” could be computed each time they are used, but they may also be stored in the mental lexicon after the first encounter. Lastly, idiosyncratic or exceptional forms were found to be chosen over regular, derivable ones in several languages (Kiparsky, 1982; Pinker, 1984; Halle & Marantz, 1993). Therefore, it is thought to suggest that stored lexical items are often prioritized over those generated by the mental grammar.

2.2.5.2. Inflection and Derivation within the Framework of the Declarative / Procedural (D/P) Model

The distinction between inflection and derivation as two separate linguistic operations along with their interdependency on the declarative and procedural memory circuits is central to our understanding of the brain structures responsible for linguistic

processing. Based on the Ullman's D/P Model (2001), inspired by the Dual Mechanism Theory (Pinker and Prince 1988), these two morphological operations rely on separate memory and neural resources, thereby mirroring their diverging cognitive requirements. The declarative memory system is linked to the mental lexicon, which governs retrieval and storage of lexical items; the procedural memory system, on the other hand, underlies the mental grammar structures and, therefore, serves rule-governed linguistic operations as part of inflectional morphology and syntax.

Inflectional morphology is associated with the implementation of the rules of grammar in order to change the forms of the words (e.g. "*see-saw*"), and is operated within the domain of mental grammar, which is embedded in the procedural system. The neural substrate of the procedural memory system is heavily connected to frontal/basal ganglia structures, and this system is in control of automatizing rule-based behaviors (Ullman, 2004). The reason why inflectional operations are automatized, fast, and uncostly -like many other procedural actions (i.e. riding a bike) - lies within their reliance on the procedural memory circuits. In the linguistic sense, it has been evidenced by several studies that verb inflections (especially regular inflection), which operate on expected and formulaic rule patterns, are processed by the procedural/rule-governed system (Ullman, 2002; Pinker, 2004).

Unlike inflectional morphology, derivational morphology is associated with the mental lexicon and is responsible for creating new words by adding morphemes (affixes) to existing base structures (e.g. "*joy-joyous*"). Both individual lexical units (i.e., words) and the associative connections among them are stored by the declarative memory system, which is based on medial temporal lobe structures (Pinker & Ullman, 2002). Unlike inflectional morphology, which follows rigid rules, derivational processes include more flexible operations and are heavily reliant on the mental lexicon. This distinction was also made clear in the Separation Hypothesis proposed by Aronoff (1993), which postulates that inflectional and derivational processes differ in the sense that inflection is governed by the syntactic rules whereas derivation involves lexical operations that create new lexical items (i.e. words) with distinct meanings and may not be strictly constrained by syntax. The significance of the declarative system for lexical retrieval and storage was also reported in studies with

amnesic patients, where word learning and word retrieval are impaired due to declarative memory deficits (Gabrieli et al., 1988). Overall, research on typical and atypical populations set the basis for the interdependence between inflectional processes and the procedural memory (rule-based) system on the one hand and derivational processes and the declarative memory (associative) system on the other. Additionally, the D/P Model offers a detailed account of the ways in which these two systems interact in various contexts. For example, because of their high frequency, or their distinction from the irregular forms, regular forms may be stored in the declarative memory system even though they are typically processed by the procedural memory system. According to Alegre and Gordon (1999), words with irregular alternatives (e.g. “*dove, smelt* → *dived, smelled*”), can potentially cause regularly inflected forms in the mental lexicon to enter the domain of the declarative memory system and, therefore, full-form storage. This phenomenon demonstrates the adaptability of the declarative system to both exceptional and frequent forms, where stored full form alternatives may take precedence over the combinatorial rule based system to establish systematized and automatic word retrieval and usage.

The Morphological Race Model, besides other proponent models of the dual route processing, also explains the potential interaction between the declarative and procedural systems (Schreuder & Baayen, 1995). Based on the Morphological Race Model, the decomposition route is responsible for the breaking down of morphologically complex items, whereas the direct access route is associated with the retrieval of whole-word representations stored in the mental lexicon. The model suggests that in the early stages of word recognition processes, both of these routes are activated simultaneously. Word frequency, phonological transparency, and the presence of irregular forms eventually influence the final route decision (parsing vs. direct retrieval). The parallel and simultaneous activation demonstrates that the brain uses declarative and procedural mechanisms for morphological processing, utilizing the advantages of each system according to the particular requirements of the linguistic input.

Overall, the D/P framework provides an extensive examination of the distinct neural and cognitive foundations of morphological processing by integrating inflectional

morphology into the procedural memory system and derivational morphology into the declarative memory system. Moreover, the model offers a solid theoretical foundation for language processing difficulties observed in diverse neuropsychological groups. These fundamental differences between inflectional and derivational processes are crucial for deepening of our understanding of mechanisms underlying language processing within the framework of clinical disorders, which might have a deteriorating effect on comprehension and production, creating the testbed for the current research investigating procedural memory and morphological processing impairments in patients with OCD.

2.2.5.3. The Two Memory Systems: Declarative and Procedural Memory

Both the declarative and the procedural memory systems have been examined to reveal their structure more extensively not only in human models but also in animal models; moreover, it has been repeatedly found that although the two memory systems function independently, they interact in certain aspects (Poldrack & Packard, 2003; Schacter & Tulving, 1994; Eichenbaum & Cohen, 2001; Mishkin et al., 1984; Squire & Knowlton, 2000). These studies explored different dimensions of the two memory systems (e.g. anatomical, developmental, computational etc.) in various species and these studies paved the way for strong predictions pertaining to the language capacities of humans.

2.2.5.4. Declarative Memory

The role the declarative system plays in the acquisition and representation of episodic knowledge (information related to an event) and semantic knowledge (information based on facts) were consecutively described by Mishkin et al. (1984), Schacter and Tulving (1994), Squire and Knowlton (2000) and Eichenbaum and Cohen (2001). According to these studies, the declarative memory system is crucial for rapid learning (learning upon a single representation of a stimulus) and the associative binding of arbitrarily presented knowledge (Cohen et.al.,1997). The items acquired by this system are known to be available for the other cognitive systems, and can be recalled explicitly (at least a certain part of the information can be remembered with conscious awareness). Therefore, it is not informationally encapsulated (Squire & Zola, 1996).

The primary brain regions on which the declarative memory system relies are medial temporal lobe structures (Suzuki & Eichenbaum, 2000). These structures include the hippocampal region (hippocampus, the dentate gyrus, and the subicular complex) on the one hand and perirhinal cortex, and parahippocampal cortex and entorhinal cortex on the other (Squire & Knowlton, 2000, Ullman, 2004). Although investigated less compared to the medial-temporal lobe structures, the hippocampus is connected with the diencephalon, and is involved in declarative memory (Ullman, 2004). In non-human primates, the medial temporal lobe was found to be arranged in a hierarchical order; moreover, according to Suzuki and Amaral (1994), there are certain interconnections between temporal and parietal neocortex and hippocampal region and entorhinal cortex. The entorhinal cortex is connected to the perirhinal and parahippocampal cortices, which are connected with temporal and parietal neocortical regions (Suzuki and Amaral, 1994).

Buckner and Wheeler (2001) argued that the medial temporal lobe is pivotal for certain memory functions especially in the process of consolidation, encoding and retrieval of novel memories. As novel memories become past memories within time, they were found to transition from reliance on medial temporal structures to dependence on neocortical regions, notably the temporal lobes (Hodges & Patterson, 1997; Squire et al., 2001). According to Damasio and colleagues (1996), specialized brain regions within the temporal lobes encode different types of knowledge. Medial temporal structures are thought to function to bind cortical inputs, in order to eventually form an integrated memory representation (Alvarez & Squire, 1994; McClelland et al., 1995).

According to Eichenbaum (2000), “declarative memory system” is used as a term to encompass the entirety of the mental organization pertaining to the acquisition, representation and the use of the given information beyond the structures in control of the novel memory learning. Although it is known that divergent brain structures are responsible for the declarative memory, the unique roles and operations they carry out were only partially investigated and therefore remain partially understood. However, several studies have consistently found that prefrontal areas are the significant contributors of this system (Tulving et al., 1994; Buckner & Wheeler, 2001). Especially, in the encoding of the novel memories, the ventro-lateral prefrontal cortex

(also known as VL-PFC, and is aligned with the inferior frontal gyrus) is in charge. Alongside being aligned with the inferior frontal gyrus, VL-PFC also corresponds to Brodmann's areas 44, 45, and 47 (Damasio, 1995); moreover, it is responsible for the selection or retrieval of declarative knowledge (Buckner & Wheeler, 2001; Thompson-Schill et al., 1997; Wagner et al., 1998).

Additionally, two divergent sub-areas (that are both anatomically and functionally separate) of the inferior frontal cortex have been identified. The first sub-region is chiefly linked with the processing of phonological input and is called "the posterior/dorsal inferior frontal cortex" (also known as Brodmann areas 6 and 44). The other sub-region is associated with the processing of semantic information and is called "the anterior/ventral inferior frontal cortex" -also known as Brodmann areas 45 and 47 (Fiez, 1997; Poldrack et al., 1999). The specific operations for which these two sub-regions are responsible may be in conformity with the functions of the working memory (Moscovitch, 1992; Buckner & Wheeler, 2001). It has been shown through neuroimaging studies that working memory tasks lead to the activation of VL-PFC (Smith & Jonides, 1999). In some neuroimaging studies, it was demonstrated that the same region was activated when the same participants were presented with recalling and working memory tests (Braver et al., 2001). Nonetheless, the anterior frontal-polar cortex (also known as Brodmann area 10) was found to be responsible for retrieval and monitoring of the memories (Buckner & Wheeler, 2001) aside from being associated with working memory functions (McLeod et al., 1998; Braver et al., 2001).

Lastly, there is evidence demonstrating that specific areas of the cerebellum are in control of searching, retrieving and processing of the declarative memories (Desmond & Fiez, 1998; Ivry & Fiez, 2000). The declarative system is strongly associated with the ventral system; moreover, the ventral system is established within the inferior and lateral temporal lobes (Ungerleider & Mishkin, 1982; Goodale & Milner, 1992). Humans were found to be consciously aware of the specific operations of this system (Norman, 2002). According to Goodale (2000), the ventral system enables creating perceptual representations of items as well as their relationships, which are necessary processes for object recognition, identification, and the long-term storage of knowledge about objects (Ullman, 2004).

The declarative system was investigated not only at operational and neuroanatomical but also at molecular and cellular scales (Lynch, 2002; Curran, 2000). An organic compound called “acetylcholine” was found to be of critical importance for both hippocampal functions and declarative memory (Packard, 1998; Freo et.al., 2002). There is also evidence suggesting that the levels of an enzyme-controlling acetylcholine synthesis called “choline acetyltransferase” is correlated with declarative memory performance (Baskin et al., 1999). Acetylcholine's role in declarative memory capacities is further supported by pharmacological studies conducted with healthy adults. Several studies have shown that “acetylcholine esterase (AChE) inhibitors”, improve memory function as they are responsible for increasing acetylcholine activity at the synapse (Ballard, 2002; Hammond et.al.,1987).

Estrogen was also found to have an effect on the declarative memory system- likely because of its modulation by acetylcholine (Sherwin, 1988; Packard, 1998;Phillips & Sherwin, 1992; Shughrue et.al., 2000). Furthermore, this enhancing effect of estrogen on the declarative memory was found both in women and men (Maki & Resnick, 2000; Sherwin, 1998) although testosterone -later converting to estrogen- was also found to have an enhancing effect on memory function (Cherrier et al., 2001). Cellular and molecular mechanisms of long-term hippocampal learning were found to be strengthened by estrogen (McEwen et al., 1998; Woolley & Schwartzkroin, 1998). Both medial temporal lobe and declarative memory functions were associated with estrogen via not only prenatal-organizational but also through postnatal-activation effects. Research on clinical populations also supports this effect of estrogen on the memory. For example, women lacking estrogen due to Turner syndrome showed decreased declarative memory function and smaller hippocampi; however, their memory demonstrated improvement with estrogen therapy (Murphy et al., 1993; Ross et al., 2000). Similarly, when postmenopausal women were asked to perform tasks that require remembering facts and events, hormone replacement therapy was found to boost blood flow to areas of the brain involved in memory, such as the hippocampus (Maki & Resnick, 2000; Resnick et al., 1998).

2.2.5.5. The Procedural Memory

The acquisition and control of sensory-motor and cognitive habits, skills, and procedures—like driving a car or learning to play a game skilfully— are supported by the procedural memory system (Eichenbaum & Cohen, 2001; Mishkin et al., 1984; Schacter & Tulving, 1994; Squire & Knowlton, 2000). It is also frequently called “the implicit memory system” because it encompasses knowledge and learning that remain outside of conscious awareness. In the context of the declarative/procedural model, procedural memory as a term denotes a specific kind of implicit non-declarative memory (Squire & Knowlton, 2000). Moreover, the procedural memory refers to the entirety of the system that is associated with learning, representing, and the use of information as against solely the elements necessary for acquisition of novel memories (Ullman, 2004).

Compared to the declarative memory, the procedural memory is less well-studied and ,therefore, less understood; however, its operational and neurocognitive substructures are becoming more refined. Procedural memory is implicated in processing and acquiring rule and context dependent stimulus response correspondences (Knowlton et.al., 1996; Wise et al., 1996; Packard & Knowlton, 2002; Poldrack et al., 1999; White, 1997). The system plays a significant role for acquiring and controlling episodic sequences that are either serial or abstract, or cognitive or sensory motor in real time (Aldridge & Berridge, 1998; Boecker et al., 2002; Doyon et al., 1997; Graybiel, 1995; Howard & Howard, 1997; Saint-Cyr et al., 1988; Willingham, 1998). Procedural system operates through learning gradually and via consistent exposure to the related stimulus-response relation in contrast to the comparatively fast acquisition in the declarative memory. The information learned in the procedural memory remains outside of the effect of other mental mechanisms, meaning it is comparably less flexible and more rigid (Mishkin et al., 1984; Squire & Zola, 1996). The learned relations or rule patterns are applied in an automated manner, and the responses are brought on by trigger in place of conscious awareness and control. Procedural memory is essential for acquiring novel sequences and for orchestrating instinctive activities, such as the stereotypical "grooming sequences" in mice, which consist of predictable activity chains (Aldridge & Berridge, 1998). According to Conway and Christiansen (2001) apes, monkeys, and humans can all learn probabilistic sequences; however,

only humans have been shown to be able to learn hierarchical patterns, though apes have been shown to be able to do so as well.

Several interrelated brain structures such as frontal and basal ganglia circuits are implicated in the procedural memory system. Moreover, brain regions like cerebellum, superior temporal cortex, and parietal cortex were found to have a significant contribution to the procedural memory system (De Renzi, 1989; Heilman et al., 1997; Hikosaka et al., 2000; Mishkin et al., 1984; Rizzolatti et al., 2000; Schacter & Tulving, 1994; Squire & Zola, 1996). The basal ganglia has a major role in the functioning of procedural memory; moreover, it is a structure comprising of a set of subcortical regions -such as globus pallidus, subthalamic nucleus, and substantia nigra, and the neostriatum (Wise et al., 1996). While the putamen and caudate nuclei constitute the neostriatum in primates, the caudate is involved in cognitive processes in contrast to the putamen, which is mostly involved in motor tasks (Alexander et al., 1986; Middleton & Strick, 2000a). Although the ventral striatum is essential for emotional memory, for the activity of procedural memory, the dorsal striatum is crucial (Packard & Knowlton, 2002). Aside from being involved in several other cognitive activities, procedural memory was found to be responsible for implicit learning (Eichenbaum & Cohen, 2001; Mishkin et al., 1984; Schacter & Tulving, 1994; Squire & Knowlton, 2000). It is also involved in stimulus-response learning, as shown by Packard and Knowlton (2002) and White (1997). Furthermore, the basal ganglia contribute to sequence learning, as supported with research (Aldridge & Berridge 1998; Doyon et al., 1997; Graybiel, 1995) supporting this function. In addition, reinforcement learning, particularly in the dorsal striatum, is another key function of the basal ganglia (Doya, 2000). It is also implicated in precise timing control, motor planning (Penhune et al., 1998), as well as context-dependent rule-based selection in working memory (Menon et al., 2000) motor program management (Haaland et al., 1997); rhythm and interval timing (Meck & Benson, 2002); mental rotation (Podzebenko et al., 2002). Even though they might seem as if they are completely divergent mental capacities, they were found to be strongly linked with one another. However, their specific interactions have not been investigated in detail (Wise et al., 1996; Meck & Benson, 2002).

Like many other brain mechanisms such as the medial temporal lobe, the basal ganglia receives input from distinct cortical regions, though the main source of input is the

frontal cortex (Alexander & Crutcher, 1990; Middleton & Strick, 2000b; Wise et al., 1996). The thalamus is in charge of transmitting these inputs back to the frontal cortex upon processing them in the basal ganglia (Middleton & Strick, 2000b). The neostriatum projects to both the "direct" and "indirect" pathways, which demonstrates the high level of connectivity among the basal ganglia. These distinct circuits have opposite effects on the frontal cortex's basal ganglia outputs ;moreover, while the direct pathway releases inhibitions on excitatory projections from the thalamus to the frontal cortex, the indirect pathway imposes inhibitions on these connections. This created equilibrium between restraint (inhibition) and release (disinhibition) enables the targeted triggering of particular cortical processes or collections (Young & Penney, 1993) while the imbalance between the two processes can cause either too much inhibition or too little inhibition, and such a disparity is linked with motor and behavioral issues in conditions like Parkinson's and Huntington's diseases (Young & Penney, 1993). Additionally, both routes are modulated by dopaminergic neurons extending from the substantia nigra to the neostriatum as evidenced by clinic studies. For example, the regulation of these pathways becomes dysfunctional in conditions like Parkinson's disease or Huntington's disease due to the destruction of these neurons (Young & Penney, 1993). These dopaminergic neurons are essential for both reinforcement learning and memory consolidation in the basal ganglia, in addition to their involvement in real-time modulation (Doya, 2000; Packard & Knowlton, 2002; White, 1997).

The basal ganglia consist of separate and functionally divided pathways -which is essential for computing different kinds of information (Alexander & Crutcher, 1990; Middleton & Strick, 2000). The circuits involved with the basal ganglia are sent inputs through the neostriatum. Some of these circuits are related with the caudate nucleus while the others are more linked with the putamen based on the cortical and/or subcortical systems they are connected to. Furthermore, in order to finally project to the relevant subregion in the frontal cortex through the thalamus, each of these circuits follows either the direct or indirect tracks (Alexander et.al., 1990). Pathways that are similar are followed by certain brain regions such as basal ganglia, which then project to relevant areas within the frontal cortex structure - constructing a closed-loop. These loops are thought to compute similar functions -including grammar- in varying brain

regions (Middleton & Strick, 2000b). Moreover, according to Alexander et.al (1990), circuits that are specific to grammar are likely to project to Broca's area, which is one of the important constituents of the procedural memory system and plays a role in processing hierarchical and abstract structures, motor-sequence learning, mental rotation and non-motor sequences, and phonological components in the working memory system, timing, and rhythm coordination (Conway & Christiansen, 2001; Dominey et al., 2003; Jordan et al., 2001; Goschke et.al., 2001; Smith & Jonides, 1999; Fiez et al., 1995). Furthermore, Brodmann Area 44 is involved with motor skill observation and motion imagery; and mirror neurons imply a potential role in language comprehension (Rizzolatti & Arbib, 1999; Rizzolatti et al., 2001).

2.2.5.6. The Relation Between the Declarative and the Procedural Systems

The declarative and the procedural systems are interrelated in terms of not only their competitive but also cooperative dynamics in order to enhance memory function as well as learning (Poldrack & Packard, 2003). The structures involved with procedural memory also enable the selection and management of the information in the declarative system. Although the two systems are functionally separate, they also complement each other through the rapid learning specifically in sequence learning because the rapid learning in the declarative memory enhances the procedural process, which is known to be slower (Willingham, 1998). Moreover, it has been shown in lesion studies that damage to one of these competitive brain structures has the potential to increase the other system's functionality (Packard & Knowlton, 2002). In animal and human studies, hippocampal damage was found to have an improving effect on procedural learning (McDonald & White, 1993), while neostriatum damage has a facilitative effect on declarative learning (Mitchell & Hall, 1988; Packard & Knowlton, 2002).

Additionally, in rodent studies, the "see-saw" effect within the two memory systems was found to be affected by the projections among the medial temporal lobe and dorsal striatum (Sorensen & Witter, 1983). When the hippocampus and entorhinal cortex are stimulated, the striatal responses are found to be suppressed (Finch, 1996). On the contrary, when the caudate is stimulated hippocampal spikes are suppressed (La Grutta & Sabatino, 1988). Moreover, lesions in the hippocampal area are likely to improve

the transmission of dopamine to the striatum (Jaskiw et al., 1990). Similarly acetylcholine has a facilitative effect on this transmission via the inhibition of the striatal function (Packard & Knowlton, 2002). Furthermore, estrogen causes the modulation of this facilitative effect by improving the activity of acetylcholine in the hippocampal area (Calabresi et al., 2000).

Neuroimaging studies conducted with healthy adults also showed the competitive nature of the two memory capacities. For example, it was shown that learning that takes place within the procedural system triggers the caudate nucleus, whose activity is correlated with reduced medial temporal functioning (Poldrack et al., 2001). Even though the declarative memory is active in the early phases of learning, as the process advances, the learning is taken over by the procedural memory, which constitutes the key finding in learning a language. This shifting reliance between the systems exemplifies the dynamic interaction between declarative and procedural memory systems during learning.

2.2.5.7. D/P Model

On the basis of the abovementioned parallelisms between the two memory systems, the D/P model as proposed by Ullman (2004) suggests that in linguistic and non-linguistic tasks, the brain structures that are associated with declarative and procedural memory operate similarly. The relevant systems enable both lexical processing and grammatical processing similar to how they handle non-language tasks; moreover, they share physiological, computational, biochemical, anatomical and processing related properties. One of the main predictions of the model is that the language processing in the brain is connected to these two and parallel mechanisms, and their broader cognitive and motor capacities are utilized in the model.

For lexical and grammatical processing, Ullman (2001) presents a dual-system model that proposes separate systems with specific computational, psychological, and neuroanatomical foundations. The initial system is an associative memory network that encodes and computes dispersed representations of phonological and conceptual-semantic mappings. The second system functions through cognitive principles that construct intricate linguistic structures using sequential and hierarchical processes, particularly in morphology.

The model posits that the memory system (declarative) controls morpho-phonological transformations that do not involve productive sequencing operations, such as irregular forms like "go-went". On the other hand, the rule-based (procedural) system manages fully productive transformations that involve regular affixation or compounding, such as "listen + -ed" becoming "listened". The two systems concurrently calculate possible outputs for a specific morphosyntactic configuration. If there is an existing item in memory, it prevents rule-based computation.

According to Ullman (2001) these systems are not domain-specific to language. The rule-based system facilitates implicit learning and the performance of procedural tasks, such motor skills, whereas the memory system supports more general declarative knowledge, including lexical information and non-linguistic facts and occurrences. The associative memory system is specifically located in temporal lobe areas from a neurological perspective, while the rule-based system is linked to left frontal and basal ganglia regions (Ullman, 2001; Ullman 2004).

In his 2001 and 2004 publications, Ullman suggests that morphological processing is modular, with discrete neural circuits regulating different sorts of transformations - asserting that there is an interplay between language and other cognitive processes that is not specific to any particular area.

In his proposed mental model of morphology, Ullman distinguishes between a memory system and a rule-based system, each serving unique cognitive and computational functions. Morphological transformations are realized through either a memory system or rule based system (Ullman et. al., 1997). The memory system functions as an associative network that retains and processes phonological and mental associations, managing irregular morphological formations such as sting-stung and occasionally generalizing patterns like "*spling-splung*". According to Plaut et al. (1996), the memory system can be perceived as operating similarly to an artificial neural network, in which connections between units eventually solidify into repeatable patterns. However, in contrast to conventional models, these phonological representations are organized, in that they represent the components of the stored words -such as affixes, phonemes, and syllables (Pinker, 1999; Pinker & Prince, 1992).

In essence, the system stores words as assemblies of their constituent parts, and linguistic "rules" are not independent processes; rather, they reflect recurrent patterns.

The rule-based system, on the other hand, reflects mental operations and information that govern the construction of complex forms, representing more than just patterns. It uses symbol manipulation to compute morphological transformations in real-time, such as "*talk* + *-ed* → *talked*" or "*shirt* + *sleeve* → *shirt-sleeve*" (Newell & Simon, 2007). In contrast to the memory system, which deals with irregular forms (e.g. "*go-went*"), the rule system computes transformations that are productive, such as suffixation ("*-ed*"), or affixation. It controls concatenation and sequencing, but it leaves out non-affixal modifications such stem alterations, which are memory-stored (Pinker & Prince, 1992). The model suggested by Ullman holds that structured associative memory is where morphological transformations involve overt affixation; however, it lacks full productivity (as in the cases of German plural "*-er*" suffixation or the Japanese adjectival "*-katta*" suffixation).

Ullman's proposed morphological processing model integrated two systems that are modular to a great extent: a rule-based system as well as an associative memory system. According to Fodor (1983 as cited in Ullman, 2001) the two systems are considered to be "informationally encapsulated"- meaning they can function independently of each other and without requiring information from one another. The mental lexicon is stored through the associative memory system- which is also in control of the learning, storage and retrieval of morphological forms that could be both simple and complex. On the other hand, the rule-based system is not only responsible for the computation of the grammatical rules but also it manages cognitive and physical abilities extending beyond the language. Both the associative memory and rule-based system are domain-general and they operate in tasks beyond the linguistic ones such as episodic and semantic knowledge, or acquisition of skills.

The second system, namely the procedural system (also referred to as skill or habit system), is crucial for learning and using physical and cognitive abilities or habits—often without conscious awareness (Alexander et al., 1990; Gabrieli et al., 1993; Mishkin et al., 1984). Procedural memory has been linked to the learning of new motor and cognitive "skills" or "habits," as well as the control of "long-established" ones

(Ullman, 2001). This system is also known as "implicit memory" because the conscious memory does not seem to be used for either learning or recalling these activities (Alexander et al., 1990; De Renzi, 1989; Gabrieli et al., 1993; Graybiel, 1995; Mishkin et al., 1984; Schacter & Tulving, 1994; Squire et al., 1993; Winocur & Moscovitch, 1990). This "implicit memory" mechanism is informationally encapsulated to a large extent (Squire & Zola, 1996) and is essential for sequence learning and skill performance (Graybiel, 1995; Willingham, 1998).

Structures in the frontal and basal ganglia constitute the foundation of the procedural system (Mishkin et al., 1984; De Renzi, 1989; Winocur & Moscovitch, 1990; Gabrieli et al., 1993; Squire et al., 1993; Schacter & Tulving, 1994; Graybiel, 1995; Squire & Zola, 1996). The frontal cortex and basal ganglia circuits are connected largely through the thalamus. The thalamus projects to a specific cortical region, primarily in the frontal cortex, and these circuits appear to be parallel and functionally separated. Each of these parallel, independently operating circuits receives inputs from certain cortical and subcortical areas and projects its outputs, mostly via the thalamus, to a different area of the frontal cortex. According to Alexander et al. (1986; 1990),

basal ganglia circuits -as well as motor circuits that project to frontal motor regions- are arranged in parallel, featuring analogous synaptic architectures that facilitate similar neuronal functions among them. The frontal lobes are posited to have a similar structural organization, and distinct regions execute comparable computational functions across diverse domains (Shimamura, 1995; Roberts et al., 1998).

Developmental "non-language" disorders such as dyslexia, ADHD, and autism spectrum disorder are characterized by procedural memory deficits and abnormalities in brain structures supporting this system. These disorders are associated with grammatical and lexical impairments, although the nature of the impairments varies by disorder. Both dyslexia and ADHD are linked to motor function impairments, difficulties in motor timing, and working memory deficits (Denckla et al., 1985; Diamond, 2000). For instance, children with dyslexia and ADHD struggle with time interval reproduction and motor control (Barkley et al., 1997; Goswami et al., 2002). The cerebellum is implicated in dyslexia (Nicolson et al., 2002) and ADHD (Berquin et al., 1998), while the basal ganglia, specifically the caudate nucleus, also shows

abnormalities in ADHD (Castellanos, 2001) and possibly dyslexia (Georgiewa et al., 2002).

A high rate of comorbidity is observed between dyslexia, ADHD, and Specific Language Impairment (SLI). According to Cohen et al. (2000), approximately 55% of children with a reading disorder exhibit oral language impairments, and 51% of children with SLI have a reading disability (McArthur et al., 2000). This interrelationship is also seen in ADHD, where as many as 45% of children show language impairments (Tirosh & Cohen, 1998). ADHD, in particular, is the most common psychiatric diagnosis among children with language impairments (Cohen et al., 2000), highlighting the significant overlap between these disorders.

The DP model suggests that these shared impairments arise from dysfunctions in procedural memory, further explaining why these developmental disorders are interconnected with both motor and linguistic challenges.

2.2.5.8. The Lexical / Declarative Memory System

One of the main suggestions of the D/P model holds that the brain mechanism underlying the declarative memory also supports mental lexicon and is responsible for storing linguistic information that is arbitrary and idiosyncratic (e.g. meanings of the words, irregular forms, such as the english past tense, as well as several regular forms) (Ullman, 2001a; 2001b; 2004; Pinker & Ullman, 2002). Relevant brain regions such as the medial temporal and neocortical areas are employed in the process of retrieval and encoding of this idiosyncratic information (Damasio et al., 1996). As was mentioned earlier, hormones like estrogen and organic compounds like acetylcholine were also found to have a pivotal role in the lexical memory, especially for the learning of the novel lexical entries (Packard & Knowlton, 2002).

The declarative memory is in charge of acquiring, storing, and applying factual (semantic) and event-related (episodic) knowledge (Eichenbaum & Cohen, 2001; Mishkin et al., 1984). This mechanism promotes quick learning by associating information (Cohen et al., 1997). The hippocampus and associated cortical regions are medial temporal lobe structures that mediate it and are involved in the encoding and retrieval of new memories (Squire & Knowlton, 2000; Suzuki & Eichenbaum, 2000).

Memories eventually shift to neocortical regions, becoming less reliant on these areas (Hodges & Patterson, 1997; Squire et al., 2001). Several parts of the brain are responsible for supporting declarative memory. These regions include the ventrolateral prefrontal cortex (Buckner & Wheeler, 2001; Tulving et al., 1994), which is responsible for encoding and retrieving knowledge, and the anterior frontal-polar cortex (BA 10) that is involved in monitoring retrieval (Braver et al., 2001). In addition to these structures, the cerebellum also plays a role in the processing of declarative memories. Furthermore, there is close interaction between this system and the ventral stream system, which manages long-term storage and object identification (Goodale & Milner, 1992; Ungerleider & Mishkin, 1982).

2.2.5.9. The Grammatical Memory/Procedural System

The other system outlined in the D/P model is the grammatical system, also known as the procedural memory system, which is in charge of supporting the mechanisms underlying the mental grammar and the processing and learning of linguistic components that are based on rules. The system relies on a separate set of brain structures like the basal ganglia and the frontal cortex, which also underlie learning and computing grammatical structures and rule-based linguistic patterns. This system is also responsible for controlling complex structures formed through hierarchical sequencing including syntax, morphology, and phonology (Pinker, 1999; Ullman, 2001). Even though the regions involved with procedural memory -mainly basal ganglia and frontal cortex- play diverging roles in working memory, real-time selection, rule-based learning, these areas were also found to support brain functions that are specific to grammar (Ullman, 2004).

Demonstrating domain-general computation (Fodor, 1983), the basal ganglia actively interacts with the frontal cortex and the thalamus in order to constitute parallel pathways to process grammar and other rule-based domains. For the processing of hierarchical patterns and the selection of items in the working memory, the BA 44 component in Broca's area is pivotal; it is also essential for the functioning of the grammatical memory (Ullman, 2004). Furthermore, by complementing grammar-specific and domain general functions, supramarginal gyrus and cerebellum

potentially contributes to the attention-based selection and error-based learning employed in linguistic functions.

In the described model, the interaction among the lexicon / declarative system and grammar / procedural system is crucial for the language processing capacity in the human brain. The grammar/procedural system formulates complex patterns through the selection and organization of the lexical items that are readily stored in the lexical/declarative memory. Information in the declarative system can potentially support explicit rule learning in the grammatical system, and the stored structures in declarative memory can enhance abstracting grammatical patterns in procedural memory (Ullman, 2001). Additionally, there is stipulated to be a competition between the two memory systems. Rule-based processing may be disrupted when a stored form is accessed. Moreover, compensatory dependence on one of these systems may result in impairment to the other (Pinker, 1999; Ullman & Pierpont, 2005).

Importantly, although the D/P model is built upon the parallelisms between the linguistic functions and the two memory systems, it does not propose a precise one-to-one relationship between the mental grammar and procedural memory, or the lexicon and the declarative memory (Ullman, 2001; 2004). Additionally, several other domain specific regions (like Broca's area) may perform both language related and non-language functions based on the structure of the brain region. According to this model, not all the regions in the brain play a part in language tasks but, rather, some of these areas are involved with linguistic functions besides the non-linguistic ones, and are activated only on certain occasions. Furthermore, depending on the intricacy of morphological structures, including inflectional and derivational processes, as well as the requirements of lexical retrieval and syntactic integration, language processing may require the use of additional brain regions and domain-specific mechanisms. The main prediction of the model is that language and non-language processes that share the same brain systems are supposed to exhibit similar features both in normal functioning and in circumstances of dysfunction and recovery.

2.2.5.10. D/P Model In Relation to Other Models

The model shares certain commonalities with the other language models that link procedural memory and hierarchical sequencing to grammatical processing (Dominey et al., 2003; Friederici, 1990). According to Ullman (2004), the D/P model is in line with Dominey's model as Dominey's model also deals with the non-language sequencing -yet it is neuroanatomically not well-grounded. Dual models also support the D/P model in terms of their separation of lexicon and grammar. However, the D/P model specifically describes the neurobiological basis of language processing (Chomsky, 1995; Pinker, 1994). Despite that, the D/P model is different from dual system models in that it claims that Broca's area is only responsible for processing linguistic information (Grodzinsky, 2000). The proposed model also diverges from connectionist models because it opposes the idea of grammatical composition (Bates & MacWhinney, 1989). The model moves the linguistic theories forward by integrating the neurobiological functioning of the brain; however, it also disagrees with connectionist approaches as they fall short in terms of predicting the connections between the grammatical and procedural memory (Joanisse & Seidenberg, 1999). This cognitive and neuroanatomical framework provided in the model reinforces a wider understanding of the interplay between the procedural/grammatical memory and lexical/declarative systems; moreover it offers a broader picture of language processing.

2.2.5.11. Evidence from Experimental Studies

The DP model is supported by a number of experimental studies, and neuroimaging studies have identified the main brain structures implicated in language processing. For example, PET scan (Positron Emission Tomography) and fMRI (functional magnetic resonance imaging) studies demonstrated that disorders such as developmental aphasia and language impairments -especially adult-onset conditions- are due to the impairments in brain regions that are associated with language processing. Proving their implication in procedural memory, several brain regions such as VL-PFC (ventral-lateral prefrontal cortex) and Broca's area along with adjacent areas have repeatedly been shown to be related to syntactic tasks (Caplan et al., 1998; Embick et.al., 2000; Friederici, 2002). Several other studies exhibited that

language disorders that have not normally been linked with one of the two memory systems (declarative/procedural) could still influence language processing through an indirect impact on one of these systems (Ullman, 2001)

It was also found that neural activation patterns related to grammatical processing like the ones in the basal ganglia and supplementary motor area (SMA), and especially caudate nucleus enhances the association between the grammar processing and procedural memory (Caplan et al., 1998; Moro et al., 2001). Both electrophysiological and hemodynamics data constitute evidential support for the claims the DP model makes. The empirical evidence is in line with the proposition that lexically stored grammatical knowledge -like verb argument structures- is processed through the involvement of diverging temporal lobes; therefore the the capacities of the procedural and declarative memory in linguistic tasks is further separated (Kuperberg et al., 2000).

In addition to hemodynamic and electrophysiological data, ERP (event related potential) studies also broaden our understanding of how the brain responds (electrophysiologically) to the real-time cognitive processing of target stimuli. In specific tasks -in the linguistic domain-, the impairments in the processing of lexical (and also non-language semantic) information are linked with the bilateral negativities that increase about 400 ms post-stimulus (the "N400s") (Kutas & Hillyard, 1980). It was suggested that the N400 is particularly associated with the temporal lobe regions (such as medial temporal lobe) and, therefore, with the declarative memory system (Ullman, 2001; Olivares et.al., 1994; Kiehl et.al., 2002; Simos et.al., 1997). In contrast, grammatical/syntactic deficiencies were found to activate the negativities in the left anterior regions (LANs) ranging from 150 ms to 500 ms- which are linked to rule-based/morpho-syntactic processing, left frontal brain regions, and therefore with procedural memory systems (Friederici et al., 1993; Neville et al., 1991; Penke et al., 1997; Weyerts et al., 1997; Ullman, 2001; Friederici et al., 1998). In addition to being related with these brain areas, on a broader scale, left anterior negativities were also identified in sequencing errors that are not linguistic- proving their relation to processes in procedural memory (Hoen & Dominey, 2000; Ullman, 2001a,b). However, Friederici and Frisch also found a possible impact of the declarative, rather than the procedural, memory because N400s were identified in place of LANs when

participants were given a task in which they had to process syntactic information (Friederici & Frisch, 2000).

Studies conducted on SLI (Specific Language Impairment) also constitute evidence supporting the DP model's fundamental propositions. SLI is a developmental language disorder that does not have any peculiar neurobiological, psychological or social causes (Leonard, 1998; Ullman, 2005; Ullman et.al., 2011). In earlier studies, the disorder's most prominent symptoms were linked with working memory related processing impairments or grammar related deficiencies (Moraleda-Sepúlveda, 2022; Clahsen, 1989; Rice & Oetting, 1993; Gathercole & Baddeley, 1993). However, later studies suggested that SLI is mainly caused by deficiencies in the procedural memory system and abnormalities in the brain mechanism underlying this memory system (Ullman & Gopnik, 1999; Ullman & Pierpont, 2005). The disorder is especially associated with grammatical disruptions not only in syntax but also in morpho-phonology and morpho-syntax (Clahsen et al., 1997; van der Lely & Ullman, 2001). According to earlier studies, although lexical information was known to stay undeformed, SLI generally disrupts certain processes like word retrieval- supporting the relationship between the procedural memory impairments and these functions (Leonard, 1982; Weismer & Hesketh, 1996; Rapin & Wilson, 1978).

In the later studies, SLI was increasingly defined not only in terms of linguistic deficiencies, but rather as an impairment in procedural memory (Ullman & Pierpont, 2005; Ullman, 2024). SLI is characterized by motor impairments, especially in tasks necessitating complex motor procedures such as bead stringing (Bishop, 2002; Hill, 2001). In addition to these, further supporting the connection between procedural memory deficits and SLI was the discovery that brain abnormalities, specifically in the basal ganglia and Broca's area, were linked to the disorder (Jernigan et al., 1991; Vargha-Khadem et al., 1998; Spinelli, 2016). However, individuals with SLI were found to show compensatory inclinations, especially by relying more on the declarative system in place of the procedural memory. The findings of several studies support this compensatory effect as was seen in frequency effects for inflected items (Oetting & Horohov, 1997). In contrast to typically developing children, children with SLI exhibited unchanging retrieval and storage patterns in regular and irregular past tense forms as well as for plurals. The fact that these children rely more heavily on the

declarative memory highlights how adaptive children with SLI are when it comes to overcoming linguistic hindrances (van der Lely & Christian, 2000).

In addition to SLI, aphasia is also a language disorder caused by brain lesions in certain areas. The disorder may present itself with diverse symptoms and is therefore categorized under two types: fluent, and non-fluent aphasia. Non-fluent aphasia shows itself through impaired performance in tasks related to syntax and morphology. The disorder is also associated with agrammatism as a result of deficits in Broca's area, basal ganglia and neighboring areas (Goodglass, 1993; Alexander, 2003). In an earlier study conducted by Ullman, it was shown that individuals suffering from non-fluent aphasia had more problems with tasks requiring regular morphology patterns (Pinker & Ullman, 2002; Ullman et al., 1997). Along with frequently seen phonological deficits and speech disruptions, non-fluent aphasia also results in agrammatisms in speech due to localized lesions in the right cerebellum or left basal ganglia (Fabbro et.al., 1996; Silveri et.al., 1994). Even though such impairments are observed, people with non-fluent aphasia are generally able to identify and understand certain non-compositional content words (such nouns and adjectives) (Goodglass, 1993). The challenges in the retrieval of lexical items, especially the retrieval of content words, are likely because of the damage in brain regions like the basal ganglia and Broca's area (Alexander, 1997; Dronkers et al., 2000). In contrast, fluent aphasia is associated with lesions in the brain regions related to declarative memory, potentially overlapping with areas related to procedural memory (such as posterior regions), resulting in impairments in both declarative and procedural systems.

Non-fluent aphasia is also strongly linked to impairments in the brain structures linked with procedural memory and motor functions. Individuals with the condition exhibit deficiencies in motor skills such as speech and stored complex structures (i.e. ideomotor apraxia) (Alexander, 1997; Goodglass, 1993; Dronkers et.al., 2000). Patients with aphasia have problems with the acquisition of novel motor sequences, and they show impairments in terms of the timing of their speech as well as working memory deficiencies (Conway & Christiansen, 2001; Szelag et al., 1997). However, fluent aphasia is linked to lesions in the temporo-parietal and left temporal regions. Therefore, both the identification and the production of content words along with the knowledge relating to the concepts are damaged (Alexander, 1997). Fluent aphasia

leads to the production of sentences that are grammatically and syntactically correct as morphological markers are generally spared. Nevertheless, compared to non-fluent aphasics, who have more problems with regular morphology, fluent aphasics show reduced performance in tasks requiring the employment of irregular morphology (Ullman et al., 1997).

In addition to language disorders like SLI and Aphasia, developmental non-language disorders such as dyslexia, ADHD, and autism spectrum disorder are associated with procedural memory dysfunctions and deficiencies in the brain regions involved with the procedural memory system. The assumption of the DP model holds that such non-language conditions also display grammatical dysfunctions in addition to impairments in the lexical retrieval processes (Denckla et al., 1985; Diamond, 2000). ADHD and dyslexia were frequently linked with impairments in working memory and motor functioning in addition to deficits in motor timing and reproduction of time intervals (Barkley et al., 1997; Goswami et al., 2002). Importantly, brain parts like the cerebellum, the basal ganglia and caudate nucleus were found to be associated with both dyslexia and ADHD (Berquin et al., 1998; Nicolson et al., 2002). Both disorders generally accompany each other along with SLI; moreover, they lead to common impairments (Cohen et al., 2000). As an example, a large number of children who have challenges with reading were also found to have oral deficits, similar to the fact that a considerable proportion of children with SLI also have impairments in reading (McArthur et al., 2000). Additionally, children with ADHD have a considerably high rate of language impairment (Tirosh & Cohen, 1998), which makes ADHD the most prevalent psychiatric condition for children with language impairments (Cohen et al., 2000).

In addition to ADHD and dyslexia, cerebellar anomalies (Courchesne et al., 1988; Lyon & Rumsey, 1996) as well as deficiencies in motor function (Bauman, 1992; Ohta, 1987), working memory (Bennetto et al., 1996), and procedural learning - particularly in sequences- are the main characteristics of autism spectrum disorder (Mostofsky et al., 2000; Sigman & Ungerer, 1984). Impairments in the language are the most common symptoms of autism; moreover, in several studies it was shown that expressive language is immensely reduced in individuals with autism (Bailey et al., 1996). Although conceptual information and lexical knowledge generally remain

undamaged -with evident deficits in retrieval, other linguistic impairments are found in both morphology and syntax (Bartolucci et al., 1980; Ramondo & Milech, 1984; Tager-Flusberg, 1985).

In addition to developmental language disorders, certain adult-onset non-linguistic conditions -such as Alzheimer's/ Parkinson's/ Huntington's diseases, amnesia, semantic dementia etc.- were also linked to procedural memory deficits along with the impairments underlying this system. Alzheimer's disease (AD) mainly influences brain structures such as medial and neocortical temporal lobes; however, areas like frontal cortex and Broca's area remain unchanged by the condition (Arnold et al., 1991). The dysfunction within the temporal lobe structure is the main underlying factor debilitating their learning of novel conceptual and lexical knowledge (Grossman et al., 1998). Patients with AD exhibit reduced motor skills and limited syntactic processing; however, they have more problems with irregular verbs (as evidenced in a study on formation of the English past tense) (Ullman et al., 1997; Cappa & Ullman, 1998). In another study conducted with Italian AD patients, it was found that they face more problems in terms of the production of the regular verbs especially in present and past participle forms (Walenski et.al., 2009). Overall these findings about AD show its selective effects on grammatical and lexical processing that are linked to procedural and declarative memory.

Similar to AD, semantic dementia is also a non-language disorder defined by the continuous degeneration of the brain regions such as inferior and lateral temporal lobe structures; moreover, although certain abilities stay unchanged (motor,phonological, syntactic) damage to these areas result in severe disruption of conceptual and lexical information (Bozeat et al., 2000). Comparable with AD, semantic dementia also causes challenges when it comes to irregular verb form in comparison to regularly suffixed (-ed) past tense form and regular forms. According to Patterson et al. (2001), there is a correlation between the degree of impairment on irregular verbs and the performance of the individuals with semantic dementia on lexical memory tasks, suggesting that language problems are related to the loss in semantic memory.

In earlier studies (Dubois et al., 1991; Young & Penney, 1993), it was found that the degeneration of dopaminergic neurons in the basal ganglia structure is the primary

cause of Parkinson's disease (PD), which results in motor suppression (hypokinesia) and difficulties expressing motor sequences. This dysfunction in the related brain regions lead to deficits not only in grammatical processing (Grossman et al., 1993; Lieberman et al., 1992), but also in cognitive and motor abilities of the patients (Saint-Cyr et al., 1988). Even though structures like temporal lobe -and therefore, word recognition -stay undamaged in this condition, individuals with PD struggle more with recalling and they produce more errors with regular form and past tense *-ed* form in comparison to irregular forms (Sagar et al., 1988; Dubois et al., 1991; Ullman et al., 1997). The amount of right-side hypokinesia shows left basal ganglia injury; moreover, it correlates with the usage of grammatical rules and errors in regular verb forms but not irregular ones (Ullman, 2004). In addition, a common underlying mechanism in motor functions and *-ed* suffixes within the framework of DP model because there is an overlap between the error rates of naming target objects and regular past tense forms (Ullman; 1999). Overall, these results shed light on the varying roles of brain structures like basal ganglia and left frontal lobe in grammatical processing in individuals with Parkinson's disease.

Very much like the other language and non-language conditions listed above, Huntington's disease damages the basal ganglia system; however, additional structures have also been found to be damaged by this condition -such as the indirect path- resulting in hyperkinesia (or uncontrolled motor moves) (Young & Penney, 1993). Dissimilar to the errors seen in irregular form in patients with PD, patients with Huntington's disease tend to add extra suffixes to the end of verbs (such as the *-ed* suffix). Such an error pattern further displays the critical role of basal ganglia circuits in controlling motor movements, suffixation processes and grammar processing; moreover, their contribution to the declarative/procedural model becomes more solidified (Ullman et al., 1997; 1999; 2001a; 2004).

2.3. Obsessive-Compulsive Disorder (OCD)

Obsessive-compulsive disorder (OCD) is a disorder that is frequently encountered (3% of the general population) and is characterized by loss of control over behavior (compulsions) and cognition (obsessions) (Stein et.al., 2019). While obsessions are described as anxiety-causing recurrent and intrusive impulses, images, and thoughts,

compulsions are repetitive behaviors and mental states that are produced in response to obsessions (Goodman et.al.,2021; Stein et.al., 2019).

Obsessions are the ones that come to mind stubbornly, repeatedly, even though the person knows and accepts that they are actually irrational -and cause trouble-, they cannot prevent themselves from thinking despite all their efforts. They are thoughts, doubts, impulses that disturb and worry or even frighten, and imaginary events, images or scenes that come to life that he thinks may come true. Compulsions are time-consuming repetitive behaviors that help reduce anxiety related to obsessions. Many compulsions are quantitatively exaggerated forms of activities of daily living, such as washing hands, locking doors, etc.

As OCD is a heterogeneous disorder, there are several types of OCD with varying kinds of compulsions and/or obsessions. Although there are studies suggesting that hoarding could be a separate psychiatric disorder (Grisham & Norberg, 2010), types of OCD are categorized under five major dimensions: symmetry, contamination, repugnant obsessions, hoarding, being responsible for causing or failing to prevent harm (Abramowitz et al., 2009). The diagnosis of the disorder is realized through clinical interviews as well as DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, fourth edition) criteria which requires obsessions and compulsions to cause annoyance and anxiety, drain a considerable amount of time, and/or impede normal functioning.

OCD has been linked to a deficiency in the brain's serotonin system. Although serotonin dysregulation has been associated with several other psychological disorders, OCD has been linked to hypersensitivity of postsynaptic serotonin receptors (Gross et.al, 1998; Abramowitz et.al., 2009). Preliminary evidence has shown white matter anomalies in frontal regions in people with OCD, which is consistent with the hypothesis of dysregulation in this and other brain regions. The two characteristic features of OCD, intense doubting and repetitive actions (compulsions), indicate that certain regions of the brain are affiliated with the condition. The frontal orbito-striatal area and the dorsolateral prefrontal cortex have been associated with the impairment of responses as well as planning, organisation and verification of the previous actions (Rauch & Jenike, 1993). A brain imaging meta-analysis conducted with adults

displayed that the obsessive and compulsive symptoms may be implicated in the caudate nucleus and the orbital cortex (Whiteside et.al., 2004). There have been similar results for children with OCD (MacMaster et.al., 2008).

2.3.1. OCD and Language Processing

Although some common findings have been reached across languages regarding morphological processing in healthy individuals, there is a lack of studies on how language processing processes occur in neurodevelopmental disorders and, if any, what kind of differences they show compared to healthy individuals. Although this deficiency constitutes the main starting point of this study, several clear findings reached in studies on brain and memory in individuals with OCD also constitute the basis of this thesis study.

As indicated earlier, the declarative/procedural (DP) model proposes that the mental lexicon, which contains word-specific information, is based on the declarative memory and associated with the temporal lobe (Ullman, 2004; 2001a). The declarative memory stores and retrieves factual and event-based information. On the other hand, the mental grammar responsible for combining words into complex structures is based on a separate nervous system. This system is made up of specific frontal, basal-ganglia, parietal and cerebellar structures and is associated with procedural memory. Procedural memory favors the learning and execution of motor and cognitive skills, especially those involving sequences. These two brain systems, with their anatomical, physiological, and biochemical bases, allow for certain claims and predictions about their role in language processing. The basic premise of the DP model (Ullman, 2001a,b) is that important aspects of the distinction between the mental lexicon and the mental grammar depend on the distinction between declarative and procedural memory, two memory systems involved in non-linguistic functions in humans and other animals (Eichenbaum & Cohen, 2001; Mishkin et al., 1984; Schacter & Tulving, 1994; Squire & Knowlton, 2000). That is, lexical memory depends -to a large extent- on the declarative memory system; in contrast, grammar depends on the procedural memory system.

Considering that OCD is associated with frontostriatal circuit abnormality, it follows that patients with OCD may exhibit performance deficits in procedural memory tasks. Procedural memory can be conceptualized as unaware learning and can be observed in the development of speed and accuracy in tasks such as implicit sequence learning, mirror reading, probabilistic classification, star mirror tracking, or the Pursuit Rotor Task (Squire, 1986). It should be noted that procedural memory probably involves several processes, as evidenced by disparities in performance on different procedural memory tasks in the same group of patients (Gabrieli et al., 1997).

It was suggested that individuals with OCD experience increased arousal and maldistribution of attention due to a deficit in procedural memory, which leads to information being processed with full awareness rather than without it (Rauch & Savage, 2000; Rauch et al., 1997). To compensate for this anomaly, the declarative memory circuit is used, but it may be less efficient. Functional neuroimaging studies investigating procedural memory tasks have found abnormal activation of the frontostriatal circuit and increased hippocampal activation in individuals with OCD compared to healthy controls, providing support for this hypothesis (Rauch et al., 1997; Roth et al., 2003).

The dual mechanism model and the Declarative/Procedural model propose certain assumptions about the different nature of regular and irregular forms (Marcus et al., 1992, Ullman & Pinker, 2002). If these assumptions can be empirically tested and confirmed, they strongly support the general theory. However, there are no such studies that examine the predictions of the declarative/procedural model within the framework of derivation and attraction morphology.

2.4. Research Gap

Although several psychiatric conditions causing procedural memory dysfunction have been investigated in terms of its impact on linguistic abilities of the individuals leading to a clear effect of procedural memory deficits on several linguistic domains, obsessive compulsive disorder has never been studied in this respect- even though it is a condition strongly linked with impairments in the procedural memory systems and underlying frontal/basal-ganglia structures (Rauch et.al., 1997). The current study

aims to fill this gap by examining the effect of procedural memory deficits on language processing in patients with OCD.



CHAPTER 3

METHODOLOGY

3.1. The Main Experiment: Lexical Decision Task Using Masked Priming Paradigm

In the Masked Priming paradigm, the prime is presented on the screen for a short period of time that is imperceptible to the participants (e.g., 40 ms-80 ms). The main goal of the experimental design is to make the participants think that they will be responding to the targets only while the effect of prime on the reaction will only be visible at the early visual word recognition level. The time that passes between the start of the prime and the start of the target is called “Stimulus Onset Asynchrony (SOA)”. The aim in keeping the SOA as short as possible is to prevent the participant from realizing that the prime and the target have certain features in common. An important feature of masked preparation experiments is the necessity of masking the prime, so that the prime is preceded by a mask consisting of a series of symbols (e.g., #####). This paradigm is often referred to as the sandwich technique as the prime is sandwiched between the preceding mask and the following target (#####-prime-target)(Forster & Davies, 1984).

In morphological masked priming experiments, participants are typically presented with three types of prime-target word pairs (see Table 2). In the identical condition, the prime and the target words are identical, while in the test condition, there is a morphological, orthographic and/or semantic relationship between the two. In the unrelated condition, which constitutes the control condition, there is no connection between the prime and target word.

Table 2: Sample experimental conditions for Lexical Decision Task Using Masked Priming Paradigm

Identical Condition	Test Condition	Unrelated Condition
talk-talk	talked-talk	window-talk

Participants are tested for the presence and the extent of potential priming effects by comparing the response times obtained in the test condition and the other two conditions. If there is no difference in response time between the test and the identical conditions, but the response times obtained in both conditions are shorter than the average response times obtained in the unrelated condition, full priming is the case. In the case of full priming, it is inferred that the complex word presented to the participant as a preparer in the test condition is parsed by the participant.

In the present study, a 50 ms SOA was used, as in most masked priming experiments in the literature (e.g., Kırkıcı & Clahsen, 2013; Şafak, 2015). In most earlier studies conducted using the masked priming paradigm, the SOA was kept at around 50 ms and no problems were reported (Rastle et.al., 2004 (42 ms.); Longtin et.al., 2003 (46 ms.); Kırkıcı & Clahsen, 2013 (50 ms.)).

The paradigm was presented using PsychoPy (Peirce et al., 2019). Participants first saw a fixation symbol (+) on the screen for 500 ms (so that they know where to look on the screen exactly) and a blank screen for 500 ms. The blank screen was followed by the mask screen (#####) for 500 ms. Immediately after the mask, the prime word was displayed for 50 ms. This was immediately followed by the target word. The target word remained on the screen until the participant made a decision (if no decisions were made, the target skipped to the next item after 4500 ms.). The participants made a lexical decision about the target word. If the participant did not provide their answer within 4500 ms, the software automatically moved on to the next experiment item and marked the answer as 'blank'. The experimental events are shown in Figure 2. Ethical approval was obtained from the Middle East Technical University (METU) Human Subjects Ethics Committee in January 2024 (Appendix A).

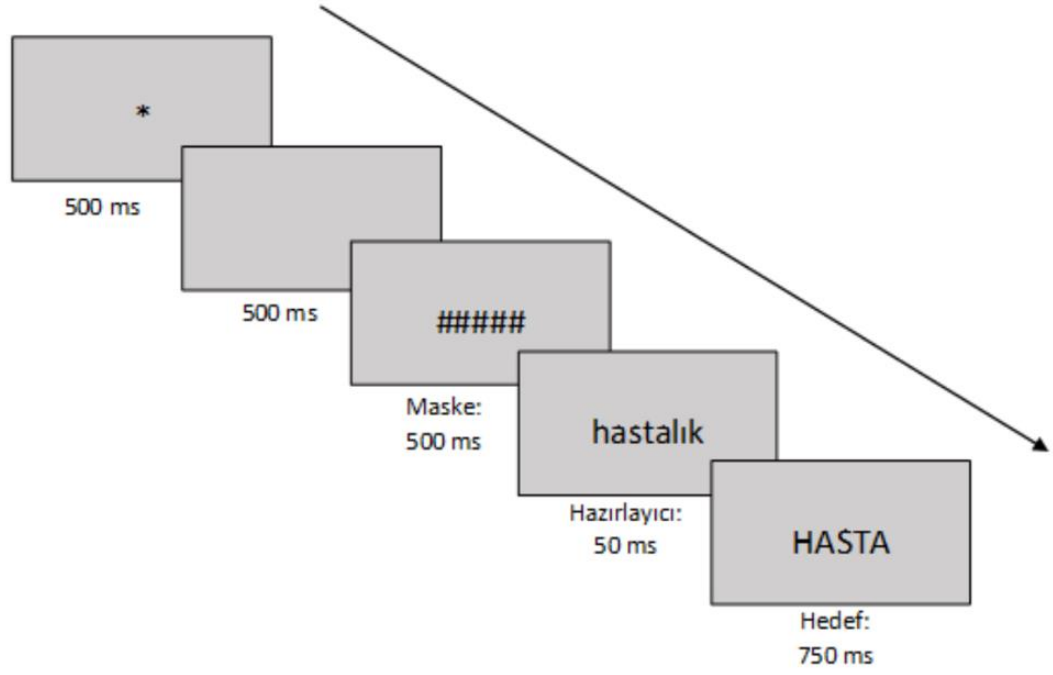


Figure 2: Experimental Events in Lexical Decision Task Using Masked Priming Paradigm

3.2. Materials

The lexical decision task included 100 experimental stimuli, 300 fillers, and 10 practice items - all of which -except for the practice items and the morpho-orthographic prime-target pairs- were adopted from Şafak (2015). The first (morphological) item set included 28 morphological items in four conditions: Identity, Inflected (Related), Derived (Related) and Unrelated. While in the inflected (related) condition, primes were inflected using the -mIş suffix, derived (related) primes were affixed with the -(y)IcI derivational marker (Appendix B). The second (orthographic) list consists of 24 orthographic (form) items in three conditions: identity, related, unrelated (Appendix C). The third list included 24 semantic items in three conditions: identity, related, unrelated (Appendix D). The fourth (morpho-orthographic) list included 24 morpho-orthographic items in three conditions: identity, related, unrelated (Appendix E). For all identity conditions in each list the primes were identical to target (which were in the form of infinitive verb stems). Moreover, all unrelated conditions in each item list, primes were morphologically, orthographically, and semantically unrelated to the targets (-M-O-S).

1. Identity - where the prime and target were the same infinitive verb stem.
2. Inflected (Related) - where primes had the -mİş inflectional suffix.
3. Derived (Related) - where primes had the -(y)İcİ derivational suffix.
4. Unrelated - containing unrelated primes that were either nouns or adjectives, with no morphological, orthographic, or semantic connection to the targets.

In all related conditions, the targets were infinitive verb stems that could potentially take both the inflectional -mİş and the derivational -(y)İcİ suffixes. The inflected and derived primes shared morphological, orthographic, and semantic traits with their targets, while unrelated primes had no such relationships, nor did they share any letters in the same position as the targets. All prime target pairs were also matched in terms of frequency and letter length in a listwise manner.

3.3. Additional Tests

3.3.1. Rey Auditory Verbal Learning Test (RAVLT)

Individuals with OCD may experience heightened arousal and misallocation of attention due to deficiencies in the procedural memory system, leading to compensatory mechanisms where certain cognitive and linguistic functions are assumed by the declarative memory system (Ullman & Pullman, 2015; Rauch & Savage, 2000; Rauch et al., 1997). This compensatory process, while aiming to address the deficiencies, may result in less efficient functioning of the declarative memory circuitry. In order to account for a possible take-over, the Rey Auditory Verbal Learning Test (RAVLT) was employed (Öktem, 1992). The test was adapted into Turkish by Öktem (1992). The RAVLT was used to assess participants' long-term declarative memory capacities. This test involved participants being presented with words verbally and required them to repeat and recall the words. Here, a list of 15 words was sequentially read to participants five times, and after each reading, individuals were asked to recall the words from the list. Thus, it assessed both verbal immediate memory (Trial 1) and verbal learning capacity (increase in the number of words learned between Trials 1-5). Following these 5 trials, proactive interference was assessed with the reading of a second list (Trial 6), retroactive interference was assessed with the re-reading and recall evaluation of the initial list (Trial 7), and recognition was measured by asking participants to identify the words from the initial

list within a longer list containing all the words (Trial 8), providing a comprehensive assessment of declarative memory.

3.3.2. Procedural Memory Measurements

Procedural learning was measured using “Serial Reaction Time Paradigm” (Figure 3). In this paradigm, participants were presented with a small white circle on the screen in one of four different locations, and they were instructed to click it with the mouse cursor as soon as it appeared. Participants were expected to do this as quickly as possible. In this test, the measurement parameters were the net number of touches and the acceleration in reaction time between touches. The net number of touches were determined by subtracting the total number of incorrect touches (touches where the participant failed to catch the white circle) from the total number of touches. The acceleration in reaction time is the shortening of reaction times between the initial reaction to the appearance of the white circle and subsequent reaction times, which is considered a variable directly associated with procedural learning.

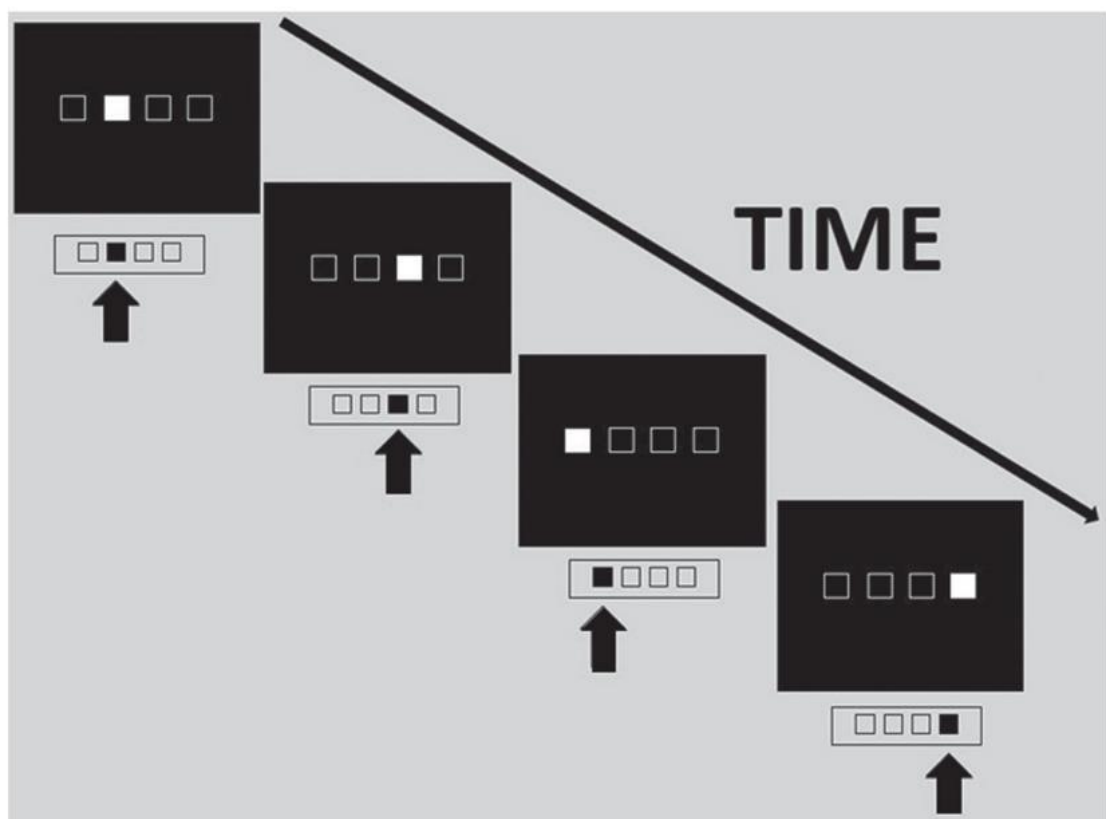


Figure 3: Serial Reaction Time Paradigm on Screen

3.3.3. Lexicon (Vocabulary Size) Test

In order to assess morphological processing comprehensively, participants were presented with a Turkish vocabulary test. This test aims to measure participants' grammatical knowledge and their level of understanding of word meanings. In line with the aims of the current study, participants completed the X-Lex Turkish Vocabulary Size Test using pen and paper. The test was adapted from English by Ongun (2018) (Meara & Milton, 2003, as qtd. in Ongun, 2018, see Appendix G).

3.3.4. Measurement of Obsessive-Compulsive Symptom Severity

Yale-Brown Obsessive-Compulsive Scale (Y-BOCS): The Y-BOCS was used to assess the severity of OCD symptoms in the OCD group participants. Participants were directed questions regarding obsessive thoughts and compulsive behaviors. The Turkish validity and reliability study of the scale was conducted by Tek et al. (1995), which found the scale's internal consistency coefficient to be .98 for the entire scale, .97 for the obsession subscale, and .96 for the compulsion subscale.

3.3.5. Measurement of Depression Symptoms

Hamilton Depression Scale (HAM-D): The HAM-D was used to measure the severity of depressive symptoms. It was administered separately for participants in both groups. This is a clinician-rated scale. The test was originally developed by Hamilton (1959). The Turkish validity and reliability study of the scale was conducted by Akdemir et al. (1996).

3.3.6. Measurement of Anxiety Symptoms

Hamilton Anxiety Scale (HAM-A): The HAM-A, a clinician-administered scale, was used to measure the severity of anxiety symptoms. It was administered separately for participants in both groups. The test was originally devised by Hamilton (1959). The Turkish validity and reliability study of the scale was conducted by Yazıcı et al. (1998).

3.4. Participants

3.4.1. Patients with OCD/Experimental Group

A total of 36 OCD participants were recruited from Başkent University Psychiatry Clinic and Etlik City Hospital on a voluntary basis. All OCD participants were between the ages of 18 and 45 (mean age: 32.4), and they were all either currently studying at a university or had a bachelor's degree. Consent was requested from all participants.

Along with the Hamilton Anxiety Scale (HAM-A) and the Hamilton Depression Rating Scale (HAM-D), the Yale-Brown Obsessive Compulsive Scale (YBOCS) was used to run a clinical evaluation of patients with OCD. These evaluations provided a thorough picture of the patients' levels of anxiety, depression, and OCD symptoms. In addition to the Hamilton Anxiety Scale (HAM-A) and the Hamilton Depression Rating Scale (HAM-D), the Yale-Brown Obsessive Compulsive Scale (YBOCS) was used to do clinical evaluations of patients with OCD. These measures provide a thorough picture of the patients' levels of anxiety, depression, and OCD symptoms. All clinical evaluations were conducted by Psychiatry experts in the relevant clinics.

The YBOCS scores were used to assess the severity of obsessive-compulsive symptoms. These demonstrated a range of severity among the patients. The total YBOCS scores for the OCD patients ranged from 2 to 29 (mean score:16.5). Scores of 2 indicate subclinical OCD, while scores of 12 reflect mild symptoms; scores of 28 and 29 demonstrate severe OCD symptoms, suggesting a significant impact on their daily functioning.

Anxiety levels were assessed using the HAM-A, which categorizes scores as follows: 0-5 indicates no anxiety, 6-14 indicates mild anxiety, and scores of 15 and above indicate severe anxiety. In this scale, the HAM-A scores of the OCD patients ranged from 0 to 13 (mean score: 6.7), with several patients reporting no anxiety (scores of 0) and others exhibiting mild anxiety (scores between 6 and 14).

Symptoms of depression were evaluated using the HAM-D (Hamilton Depression Scale), which has the following score categories: 0-7 indicates no depression, 8-15 indicates mild depression, 16-28 indicates moderate depression, and scores higher than 29 indicate severe depression. The HAM-D scores of OCD patients ranged from 0 to 11 (mean score: 5.8)). This shows that most of the OCD participants experienced either no depression or mild depressive symptoms at the time of testing.

3.4.2. Healthy Participants/Control Group

A total of 36 non-OCD individuals were selected from the student population of Middle East Technical University. They were matched by age, gender, and education level to the OCD-participants. The non-OCD participants reported to have never been diagnosed with a psychiatric illness before (especially depression and/or anxiety) and agreed to participate on a voluntary basis. All non-OCD participants were evaluated by a psychiatrist at one of the participating clinics for symptoms of anxiety and depression in order to have an experimental group that is purely consisting of healthy participants with no undiagnosed conditions (such as OCD, anxiety or depression) that could potentially obscure the results. Volunteers with high anxiety and/or depression levels based on the Hamilton Anxiety/Depression scale were excluded from the experiments. The non-OCD participants were also evaluated for any undiagnosed symptoms of OCD through Yale-Brown Obsessive-Compulsive Scale, and volunteers with obsessive/compulsive symptoms were not admitted to the main experiments. All the remaining non-OCD participants had no symptoms of anxiety, depression or OCD. All the participants' scores were assessed by psychiatrists from the participating clinics. Consent was requested from all participants.

3.5. Data Analysis

3.5.1. Descriptives

The initial analysis included reaction time data from participants in two groups: Healthy and OCD. The following table summarizes the counts of responses before and after data cleaning:

Table 3: Data Cleaning Procedures

Criteria	Healthy	OCD
Total Responses	14520	14460
Removed due to RT > 3000 ms	0.00%	0.00%
Removed due to Incorrect Responses	5.48%	4.63%
Removed due to 2 SD Limit	3.12%	2.84%
Remaining Responses	91.40%	92.53%
Mean RT (ms, raw)	754	738
SD RT (ms, raw)	391	392
Mean RT (ms, cleaned)	707	693
SD RT (ms, cleaned)	0.201	0.197

The Healthy group recorded a total of 14,520 responses, while the OCD group had 14,460 responses. No responses were excluded from either group due to reaction times exceeding 3000 ms.

In terms of RT exclusion due to incorrect responses, 5.48% of responses from the Healthy group and 4.63% of the responses from the OCD group were excluded. Additionally, 3.12% of responses from the Healthy group and 2.84% from the OCD group were excluded from the dataset as they were identified as outliers (exceeding 2 SD from the mean). The removed percentages were compatible in both groups, and the exclusion was balanced.

After the data cleaning procedure, in the Healthy group 91.40% of responses remained, while in the OCD group 92.53% of the responses remained. The mean group RT for the Healthy group was 754 ms, which was slightly longer than the OCD group's RT mean of 739 ms. The standard deviations for raw reaction times were also similar in both groups, with 392 ms for the Healthy group and 393 ms for the OCD group. After the outlier removal process, the mean RT decreased to 707 ms for the Healthy participants and 693 ms for the OCD participants. Mean SD went down to 202 ms in the healthy group and 197 ms in the OCD group.

After the first round of data-cleaning, a condition based standard deviation cleaning was conducted and this accounts for the %0.8 of the remaining responses for the OCD group and %0.5 of the Healthy group's responses. After conducting a by-item analysis, one morphological prime-target pair (*eğlenceli-KURTARMAK*) was removed from the data due to a high error rate of 37% as it was increasing the reaction time of the baseline level for the morphological condition. Similarly, one semantic pair (*ayıl- BORSA*) and one morpho-orthographic pair (*hindi-HİN*) were removed due to high error rates (%41 and %29 respectively) after the by-item analysis.

To examine the effects of group and various prime conditions on reaction times, a series of Mixed Linear Models (MixedLM) were conducted in a stepwise manner in Python. All the analyses were conducted using the mixed-effects model (*MixedLM* function) in Python with the *statsmodels* library.

The first model was fitted to examine the interaction between group and condition, with reaction time as the dependent variable and group and condition as fixed effects. The model accounted for random effects associated with individual participants. In the model, condition and group were included as fixed effects, and the participants were included as a random effect (N = 72, number of observations= 26,368).

To further explore the effect of declarative memory metrics (auditory-verbal learning), a second model was fitted by incorporating RAVLT scores and their interactions with group and condition. This model included additional fixed effects for Learning Error Score, Perseveration, Inconsistency Score, False Recall Score, and False Recognition, along with their interactions with both group and condition. Additionally, to assess the

effect of overall lexical (declarative) memory on various morphological processing metrics, another model was fitted incorporating Lexicon test scores.

Finally, a more comprehensive model was fitted to include procedural memory measures in order to examine the interaction of procedural learning with group and condition alongside the previously mentioned auditory-verbal learning performance metrics (RAVLT). The models were fitted using the Restricted Maximum Likelihood (REML) method, and the significance of fixed effects and interactions was assessed through z-tests and p-values.

3.6. Results

3.6.1. Morphological Condition

Table 4: Reaction Times (ms) and Priming effects for morphological conditions (healthy controls)

Condition	Mean RT	SD	Priming Effect
identity morphological	662	110	42
derived morphological	691	119	13
inflected morphological	616	136	70
unrelated morphological	704	296	

Table 5: Linear mixed-effects model results for morphological conditions (healthy controls)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.659	0.016	40.27	0.000	0.627	0.691
identity_morphological	-0.035	0.014	-2.500	0.012	-0.025	0.030
derived_morphological	-0.020	0.014	-1.900	0.047	-0.028	0.027
inflected_morphological	-0.060	0.014	-4.286	<0.001	-0.069	-0.016
Group Var	6	0.011				

Reaction time (RT) analyses were conducted across four types of items in the morphological priming condition in the healthy group. With a mean RT of 616 ms, the inflected morphological condition yielded the most facilitative priming effect (70 ms). The identity morphological condition followed the inflected morphological condition with a mean RT of 662 ms, yielding 42 ms priming effect. The derived morphological condition had a mean RT of 691 ms and a 13 ms priming effect. The unrelated

morphological condition served as the baseline and was the slowest condition (RT: 704 ms), as expected.

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the healthy group across three morphological priming conditions (identity, derived, and inflected). The unrelated condition served as the baseline. The model included a random intercept for subjects to account for individual variability.

The model was in support of the initial priming effects by showing that RTs in the inflected morphological condition were significantly faster ($\beta = -0.060$, $z = -4.286$, $p < 0.001$) than the unrelated baseline. The identity morphological condition also produced a significant repetition priming effect ($\beta = -0.035$, $z = -2.500$, $p = 0.012$). Moreover, the derived morphological condition yielded significant priming ($\beta = -0.020$, $z = -1.900$, $p = 0.047$).

Table 6: Reaction Times (ms) and Priming effects for morphological conditions (OCD patients)

Condition	Mean RT	SD	Priming Effect
identity morphological	612	2	16
derived morphological	614	183	14
inflected morphological	737	49	-109
unrelated morphological	628	173	

Table 7: Linear mixed-effects model results for morphological conditions (OCD patients)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.632	0.015	41.324	<0.0001	0.602	0.662
identity_morphological	-0.045	0.015	-3.000	0.0027	-0.075	-0.015
derived_morphological	-0.038	0.014	-2.714	0.0066	-0.066	-0.010
inflected_morphological	0.103	0.014	7.504	<0.0001	0.076	0.130
Group Var	0.005	0.010				

In the OCD group, with a mean RT of 737 ms, the inflected morphological condition yielded a robust inhibitory effect of -109 ms. The identity morphological condition had a mean RT of 612 (priming effect: 16 ms); and the derived condition had a mean RT of 614 ms (priming effect: 14 ms). Finally, the unrelated morphological condition served as the baseline with a mean RT of 628 ms.

The mixed-effects model showed that the priming effect in the inflected morphological condition was significantly inhibitory ($\beta=0.103$, $SE=0.014$, $z=7.504$, $p<0.0001$). On the other hand, the identity morphological priming condition exhibited significant repetition priming effect ($\beta=-0.045$, $SE=0.015$, $z=-3.000$, $p=0.0027$). Derived morphological condition also showed a significant priming effect ($\beta=-0.038$, $SE=0.014$, $z=-2.714$, $p=0.0066$).

Figure 4 shows the comparative results of the morphological condition RTs of Healthy and OCD group.

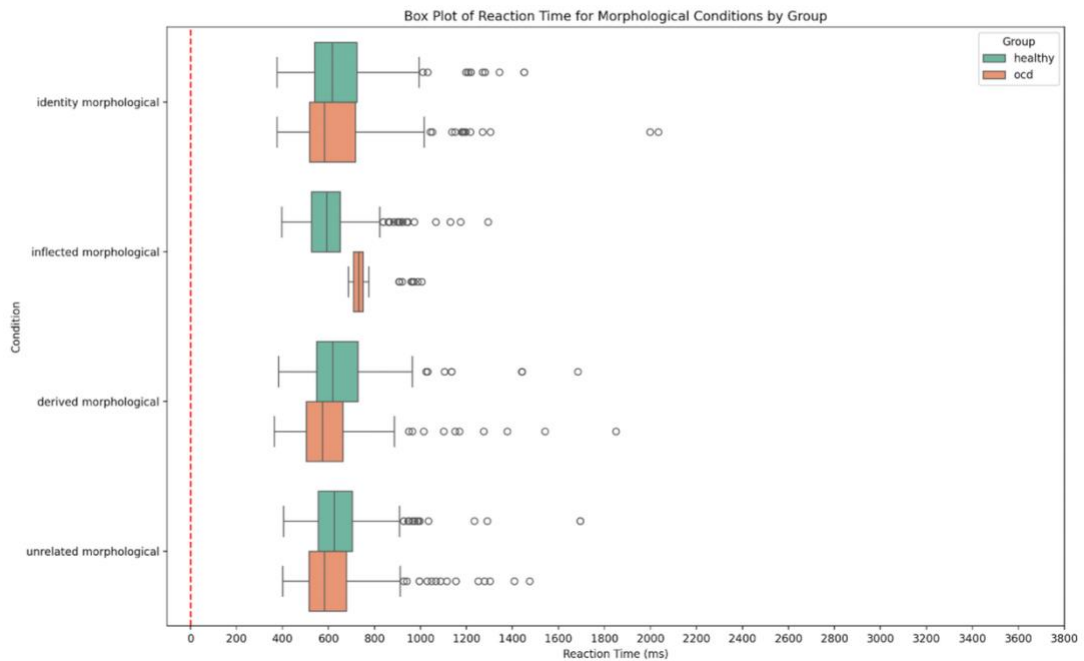


Figure 4: Boxplot of RTs for Morphological Condition by Group

The most striking difference in morphological processing patterns of the control group and the OCD group was observed in the inflected condition RTs. While the non-OCD population showed a robust facilitation effect in the inflected morphological condition ($\beta=-0.060$, $SE=0.014$, $z=-4.286$, $p<0.001$), the OCD group exhibited a very strong inhibitory effect in the inflected condition ($\beta=0.103$, $SE=0.014$, $z=7.504$, $p<0.0001$). There is a clear asymmetrical effect of inflected morphological condition on the word processing patterns of the two groups.

3.6.2. Semantic Condition

Table 8: Priming effects for semantic conditions (healthy controls)

Condition	Mean RT	SD	Priming Effect
identity semantic	663	239	23
related semantic	684	185	2
unrelated semantic	686	257	

Table 9: Linear mixed-effects model results for semantic conditions (healthy controls)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.687	0.019	35.794	0	0.650	0.725
identity_semantic	-0.017	0.019	-0.873	0.043	-0.054	0.021
related_semantic	-0.001	0.019	-0.280	0.354	-0.037	0.036
Group Var	0.007	0.011				

RT analyses across three semantic conditions were conducted to see the priming effects (identity, related, unrelated).

The identity semantic condition had a mean RT of 663 ms, followed by the related semantic condition with 684 ms, and the unrelated condition (baseline), 686 ms. The observed priming effects were 2 ms for the related semantic condition and 23 ms for the identity condition.

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the healthy group across the semantic conditions.

The intercept was found to be significant ($\beta = 0.687$, $z = 35.794$, $p < .0001$), meaning that there was a strong baseline effect. The identity semantic condition showed a significant repetition priming effect with a negative coefficient ($\beta = -0.017$, $z = -0.873$, $p = 0.043$). The related semantic condition, on the other hand, did not significantly differ from the unrelated condition ($\beta = -0.001$, $z = -0.280$, $p = 0.354$).

Table 10: Reaction Times (ms) and Priming effects for semantic conditions (OCD patients)

Condition	Mean RT	SD	Priming Effect
identity semantic	637	221	24
related semantic	655	189	6
unrelated semantic	661	200	

Table 11: Linear mixed-effects model results for semantic conditions (OCD patients)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.648	0.019	34.091	0	0.611	0.686
identity_semantic	-0.008	0.017	1.203	0.034	-0.025	0.041
related_semantic	-0.015	0.017	0.901	0.096	-0.018	0.049
Group Var	0.008	0.012				

RT analyses across the semantic conditions were conducted to check for priming effects (identity, related, unrelated) in the OCD group.

The identity semantic condition had a mean RT of 637 ms, the related semantic condition 655 ms and the unrelated semantic condition (baseline) had the slowest RT with 661 ms. There was repetition priming effect in the identity condition (24 ms), followed by the facilitation in related semantic condition (6 ms).

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the OCD group across three semantic conditions.

The intercept was found to be significant, meaning a robust baseline effect ($\beta = 0.648$, $z = 34.091$, $p < .0001$). The identity semantic condition exhibited a significant priming effect with a negative coefficient ($\beta = -0.008$, $z = 1.203$, $p = 0.034$). The related semantic condition was not found to have a significant priming effect ($\beta = -0.015$, $z = 0.901$, $p = 0.096$).

Figure 5 shows the comparative results of the semantic condition RTs of the Healthy and OCD group.

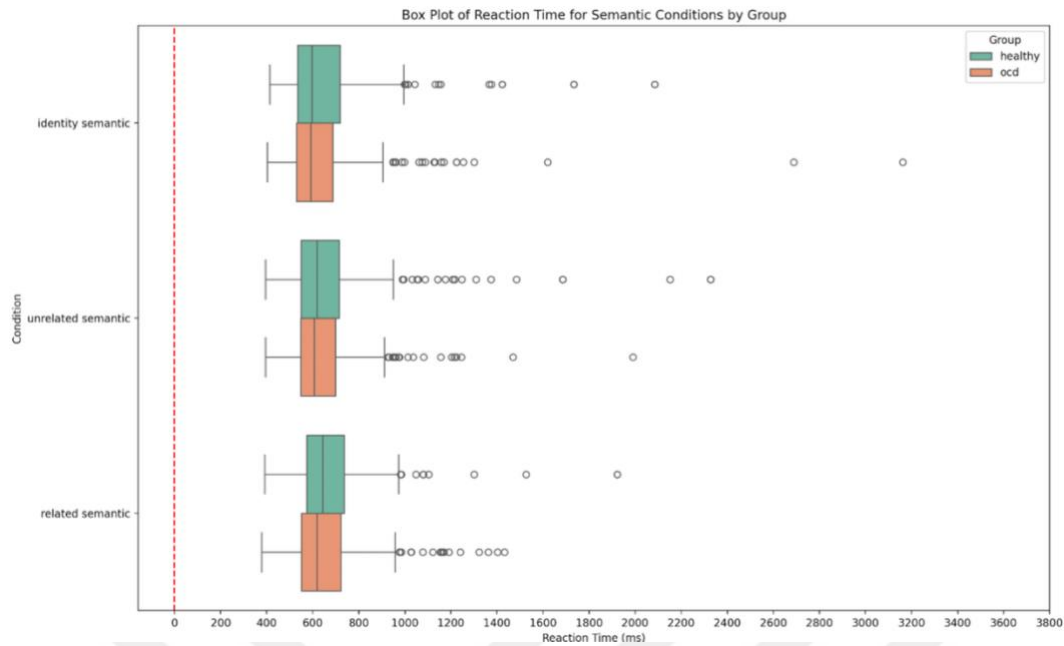


Figure 5: Boxplot of RTs for Semantic Condition by Group

Both groups demonstrated significant priming effects in the identity condition, however, the related semantic condition did not show a significant difference from the baseline. Overall, the OCD group was numerically faster across three semantic conditions in comparison to the non-OCD controls.

3.6.3. Orthographic Condition

Table 12: Reaction Times (ms) and Priming effects for orthographic conditions (healthy controls)

Condition	Mean RT	SD	Priming Effect
identity orthographic	628	192	51
related orthographic	665	187	14
unrelated orthographic	679	175	

Table 13: Linear mixed-effects model results for orthographic conditions (healthy controls)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.677	0.017	39.372	0.000	0.643	0.711
identity_orthographic	-0.044	0.014	-3.080	0.002	-0.073	-0.016
related_orthographic	-0.013	0.015	-0.917	0.056	-0.042	0.015
Group Var	0.007	0.012				

RT analyses across three orthographic conditions were conducted to check for priming effects (identity, related, unrelated) in the healthy group. The identity orthographic condition had the fastest mean RT with 628 ms, followed by related orthographic condition with 665 ms and unrelated (baseline) condition with 679 ms. The identity condition produced the strongest priming effect (51 ms), followed by the priming effect of the related orthographic condition with 14 ms.

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the healthy group across three orthographic conditions. There was found to be a repetition priming effect for the identity orthographic condition ($\beta = -0.044$, $z = -3.080$, $p = 0.002$). The related orthographic condition did not significantly differ from the baseline unrelated condition ($\beta = -0.013$, $z = -0.917$, $p = 0.056$).

Table 14: Reaction Times (ms) and Priming effects for orthographic conditions (OCD patients)

Condition	Mean RT	SD	Priming Effect
identity orthographic	655	226	20
related orthographic	660	202	5
unrelated orthographic	675	190	

Table 15: Linear mixed-effects model results for orthographic conditions (OCD patients)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.676	0.019	35.468	00.000	0.639	0.713
identity_orthographic	-0.020	0.016	-1.252	0.021	-0.033	0.012
related_orthographic	-0.002	0.017	-0.132	0.294	-0.035	0.030
Group Var	0.008	0.013				

RT analyses across the orthographic conditions were conducted to check for priming effects in the OCD group. The fastest condition was the identity orthographic condition with a mean RT of 655 ms, followed by the related orthographic condition with 660 ms. Finally, the unrelated condition (baseline) had the slowest mean RT with 675 ms. As for the priming effects, the identity condition yielded a repetition priming (20 ms) followed by the related condition with a priming effect of 5 ms.

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the OCD group across three orthographic conditions. There was found to be a strong baseline effect with a significant intercept ($\beta = 0.676$, $z = 35.468$, $p < .0001$). The identity morphological condition showed a significant priming effect with a negative coefficient ($\beta = -0.020$, $z = -1.252$, $p = 0.021$). However, the related orthographic condition did not produce a significant priming effect ($\beta = -0.002$, $z = -0.132$, $p = 0.294$).

Figure 6 shows the comparative results of the orthographic condition RTs of Healthy and OCD groups.

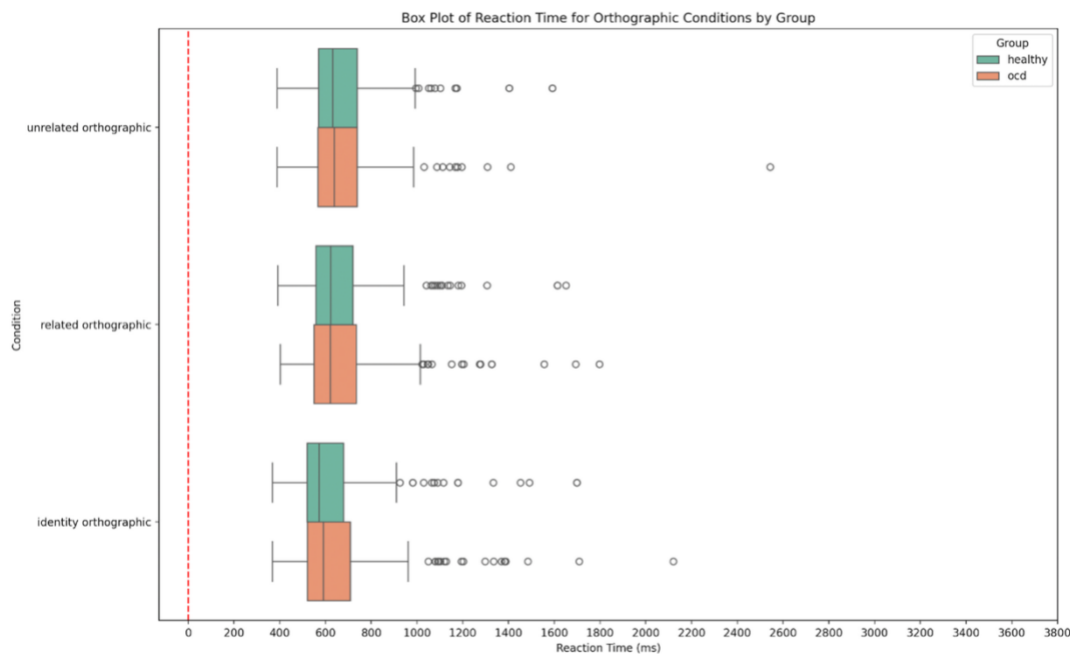


Figure 6: Boxplot of RTs for Orthographic Condition by Group

Overall, the mixed effects models showed that both healthy and OCD groups demonstrated significant repetition priming effects in identity orthographic condition; however, there were no significant priming effects observed in the related orthographic condition. The OCD group was slightly faster in their RTs in the orthographic condition.

3.6.4. Morpho-Orthographic Condition

Table 16: Reaction Times (ms) and Priming effects for morpho-orthographic conditions (healthy controls)

Condition	Mean RT	SD	Priming Effect
identity morpho-orthographic	697	261	32
related morpho-orthographic	706	259	23
unrelated morpho-orthographic	729	213	

Table 17: Linear mixed-effects model results for morpho-orthographic conditions (healthy controls)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.696	0.22	31.077	00.00	0.652	0.740
identity_morpho-orthographic	-0.016	0.21	0.254	0.027	-0.043	0.045
related_morpho-orthographic	-0.014	0.22	1.477	0.051	-0.011	0.077
Group Var	0.009	0.13				

RT analyses across the morpho-orthographic conditions were conducted to check for priming effects (identity, related, unrelated) in the healthy group.

The identity morpho-orthographic condition was the fastest condition with a mean RT of 697 ms, followed by the related morpho-orthographic condition (706 ms) and the unrelated (baseline) condition (729 ms). The identity condition produced a repetition priming effect (32 ms) , and the related condition showed a facilitation effect of 23 ms.

A linear mixed-effects model was fitted to further analyze the reaction times (RTs) in the healthy group across three morpho-orthographic conditions.

There was found to be a significant intercept demonstrating a strong baseline effect ($\beta = 0.696$, $z = 31.077$, $p < .0001$). The identity condition showed a significant repetition priming effect ($\beta = -0.016$, $z = 0.254$, $p = 0.027$), together with a non-significant (but marginal) priming effect observed in the related morpho-orthographic condition ($\beta = -0.014$, $z = 1.477$, $p = 0.051$).

Table 18: Reaction Times (ms) and Priming effects for morpho-orthographic conditions (OCD patients)

Condition	Mean RT	SD	Priming Effect
identity morpho-orthographic	678	259	38
related morpho-orthographic	700	266	16
unrelated morpho-orthographic	716	247	

Table 19: Linear mixed-effects model results for morpho-orthographic conditions (OCD patients)

Condition	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	0.716	0.25	28.207	0	0.666	0.766
identity_morpho-orthographic	-0.038	0.24	-1.548	0.012	-0.085	0.010
related_morpho-orthographic	-0.010	0.22	-1.440	0.102	-0.064	0.014
Group Var	0.013	0.17				

RT analyses across the morpho-orthographic conditions were conducted to check for priming effects (identity, related, unrelated) in the OCD group.

The identity morpho-orthographic condition produced the fastest mean RT (678 ms), followed by the related morpho-orthographic condition with 716 ms and lastly, the unrelated morpho-orthographic condition (baseline) with 716 ms. The identity morpho-orthographic condition produced the strongest priming effect of 38 ms followed by the priming effect in the related morpho-orthographic condition (16 ms).

A mixed-effects model was conducted to further examine the effect of Prime Type (Identity, Related, Unrelated) on reaction times for the OCD group.

The identity morpho-orthographic condition exhibited a significant priming effect ($\beta = -0.038$, $z = -1.548$, $p = 0.012$). On the other hand, the related morpho-orthographic condition was not found to be significantly different from the baseline condition ($\beta = -0.010$, $z = -1.440$, $p = 0.102$).

Figure 7 shows the comparative results across all conditions tested of the morpho-orthographic for condition RTs of for the Healthy and the OCD group:

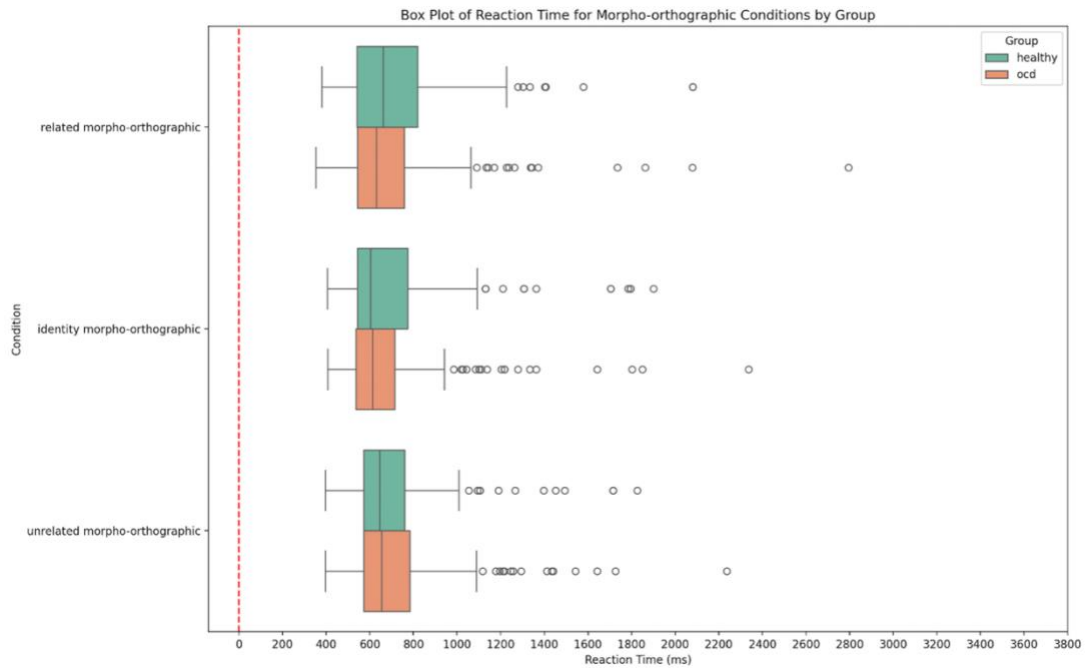


Figure 7: Boxplot of RTs for Morpho-Orthographic Condition by Group

Overall, the mixed effects models showed that both healthy and OCD groups demonstrated significant repetition priming effects in identity orthographic conditions. The related condition did not significantly differ from the unrelated baseline condition in both groups.. The OCD group was numerically faster in the related morpho-orthographic and identity morpho-orthographic conditions in comparison to the non-OCD controls.

3.6.5. Interactions and Further Analyses

3.6.6. Prime Type × Group Results

In order to further examine the interaction between Prime Type (condition) and Group (OCD vs. Healthy) on reaction time, a mixed-effects linear model was run. The model formula followed a stepwise manner in which the model complexity increased progressively. The initial model included Prime Type and Group as fixed effects, with participants as a random intercept (model formula : $RT \sim \text{Condition} * \text{Group} + (1 | \text{Participant})$).

The results of the mixed effects linear model revealed that there was no significant main effect of the group ($\beta = -0.043$, $z = -1.211$, $p = .226$). This means that, the overall mean RTs of OCD group and the healthy group did not statistically differ from each other although there was a slight numerical difference. On the other hand, there was a statistically significant difference between the inflected morphological condition and the OCD group ($\beta = 0.155$, $SE = 0.029$, $z = 5.391$, $p < .001$). Taken together, these results show that the OCD group was, overall, not slower than the healthy group in terms of their mean RTs across conditions; however, in the inflected morphological condition they showed extremely slower RTs compared to the healthy group. Overall, this was the only significant interaction effect observed in the model summary, all the remaining interactions and main effects were found to be non-significant (all $p > 0.05$).

3.6.7. Prime Type $\times$ Group $\times$ RAVLT Results

The model results demonstrated that there is a significant interaction between Learning Error Score and group ($\beta = -0.067$, $SE = 0.025$, $z = -2.627$, $p = 0.009$). The results mean that higher Learning Error Scores are linked to decreased reaction times in the OCD group relative to the healthy controls, indicating a negative correlation with learning error scores and the RTs in the OCD group. On the contrary, there were no significant interactions between learning error score and condition (prime type), indicating the error scores were not modulated by prime type in any condition (all $p > 0.05$).

There was also a significant interaction between perseveration and related morpho-orthographic condition ($\beta = -0.050$, $SE = 0.023$, $z = -2.221$, $p = 0.026$). This result indicates that as the perseveration increases, the RTs for related morpho-orthographic condition decrease in all participants regardless of their group.

3.6.8. Prime Type $\times$ Group $\times$ Lexicon Test Results

The model found no significant effect of group on Lexicon Test Scores ($\beta = 0.12$, $SE = 0.10$, $z = 1.20$, $p = 0.23$), indicating that OCD and healthy participants performed similarly. The Prime Type $\times$ Group interaction was not significant ($\beta = -0.05$, $SE = 0.08$, $z = -0.63$, $p = 0.53$), indicating that prime type had no effect on lexicon test performance across groups. The Lexicon Test Score did not significantly predict

performance ($\beta = 0.08$, $SE = 0.06$, $z = 1.33$, $p = 0.19$), and its interaction with Prime Type was also insignificant ($p > 0.05$).

Finally, the three-way interaction (Prime Type $\times$ Group $\times$ Lexicon Test Score) was non-significant ($\beta = -0.03$, $SE = 0.07$, $z = -0.43$, $p = 0.67$), indicating no significant combined effect of these variables on lexicon performance. These findings show that neither Prime Type nor Lexicon Test Scores systematically influenced performance in the OCD or healthy groups.

3.6.9. Prime Type $\times$ Group $\times$ Procedural Learning Scores Results

As the last step, the potential interaction between procedural learning task scores, group and condition was investigated. For each participant, individual regression slopes were computed resulting in the beta coefficients. In the model, the coefficients were included to see the effects or interactions of procedural learning (model formula: $RT \sim \text{Condition} * \text{Group} * \text{Procedural Learning Scores} + (1 | \text{Participant})$).

The model results revealed that there was no statistically significant interaction between the group and the procedural learning scores ($\beta = 0.010$, $z = 0.945$, $p = 0.345$). For prime type, condition and procedural learning score interaction, the only marginal significant interaction was observed between inflected morphological condition and procedural learning score in the OCD group ($\beta = 0.078$, $z = 0.518$, $p = 0.051$). The results further suggest that the procedural learning deficits are correlated with higher RTs in the inflected morphological condition in the OCD group relative to healthy controls. All the remaining interactions were non-significant ($p > 0.05$).

CHAPTER 4

DISCUSSION & CONCLUSION

4.1. Discussion of the Results

The present study aimed to investigate morphological processing patterns in patients with OCD in comparison to healthy controls within the framework of Ullman's D/P Model (2004). Specifically, two main research questions were examined: (1) Are there differences between individuals with OCD and healthy individuals in terms of their morphological processing patterns? (2) In what ways, if any, is the processing of inflected and derived words different in individuals diagnosed with OCD and healthy controls? It was explored if potential language processing differences could be attributed to the procedural memory impairments in patients with OCD.

Within this context, given the strong association between OCD and frontostriatal abnormalities (Rauch et al., 1997; Menzies et al., 2008; Saxena & Rauch, 2000), as well as the role of frontal-basal ganglia structures in procedural memory, it was hypothesized that OCD patients would demonstrate deficiency in tasks involving procedural memory processes, particularly the processing of inflected forms. Specifically, these deficiencies were predicted to appear as an anti-priming (inhibitory) effect for inflectional morphology while maintaining priming for derivational morphology as the latter is related to declarative memory and is linked to medial temporal lobe structures.

The most notable finding of the main experiment was that the OCD group indeed showed a significant anti-priming effect in the inflected morphological condition. In the OCD group, the prior presentation of inflected morphological primes (e.g. "*korumuş, s/he protected it*") significantly slowed-down the recognition of the target stems (e.g. "*KORUMAK, to protect*") relative to unrelated morphological primes (e.g.

“mandalina, tangerine”). The healthy participants, on the other hand, exhibited the typical morphological processing pattern reported in the literature: significant priming for inflected word forms. . In other words, the prior presentation of inflected morphological primes (e.g. *“korumuş”, “s/he protected it”*) significantly facilitated the recognition of the target stems (e.g. *“KORUMAK”, “to protect”*) relative to the unrelated morphological primes (e.g. *“mandalina”, “tangerine”*) in the healthy group.

As for the effect of derived words on stem target recognition, healthy participants also showed strong priming effects for the target words (*“KORUMAK”, “to protect”*) preceded by derived morphological primes (e.g. *“koruyucu”, “the protector”*) relative to the unrelated morphological primes (e.g. *“mandalina”, “tangerine”*). However, the facilitation effect observed in the identity morphological condition was stronger than the priming observed in relation to the unrelated morphological condition. Taken together, the processing pattern in the morphological condition for healthy participants across four prime types (unrelated, inflected, derived, identity) are well aligned with the previous research conducted with native speakers (Morris & Stockall, 2012; Clahsen & Neubauer, 2010; Clahsen et al., 2010; Silva & Clahsen 2008). Moreover, these results support the idea that lexical representations in morphologically rich languages such as Turkish are organized in such a way that they facilitate the effective breakdown and processing of intricate word forms (Frauenfelder & Schreuder, 1991).

The OCD group also exhibited priming upon the presentation of a prior derived morphological prime, though a smaller facilitation was observed compared to the healthy group. Similarly, there was found to be a significant facilitatory effect of the identical primes in the OCD group. While the word recognition patterns of the OCD group and the healthy control group were similar across the unrelated, derived and identity morphological conditions, the presentation of the inflectional stimuli led to a significant inhibition relative to the unrelated condition and to the healthy group. This result was further supported by the significant interaction observed between the inflected morphological condition and the OCD group.

The reduced priming effects recorded for morphologically related pairs in OCD participants suggest that individuals with OCD may be more dependent on whole-word

storage than decomposition-based morphological processing. This result is consistent with theories suggesting that OCD is linked to impaired rule-based processing and deficiencies in procedural memory (Ullman et al., 2005). Since morphological decomposition is argued to strongly depend on procedural mechanisms (Marslen-Wilson & Tyler, 1997; Ullman; 2004), the OCD group's observed decrease in priming effects may be the result of underlying issues with recruiting and effectively using the underpinning morphological rules. The idea that OCD-related cognitive deficits impact domain-specific linguistic computations in addition to general executive dysfunction is supported by the decreased morphological facilitation observed in the OCD group. On the other hand, the greater dependence on derivational priming, which is governed by brain structures responsible for the declarative memory, may be the reason behind the reduced morphological priming effect in the OCD group, which makes up for procedural processing inefficiencies (Ullman, 2004). The observed anomalous priming patterns in the inflected morphological condition may be explained by this transition from rule-based morphological parsing to rote memorization.

Another possible explanation for the relatively reduced priming effects in the OCD group is “hyperactive mistake monitoring”, a defining feature of the condition (Gehring et al., 2000). It becomes extremely difficult to make connections between morphologically related words if one is overly sensitive to little changes in expected linguistic structures. Priming effects may be diminished as a result of a decreased capacity to quickly access morphological components. By investigating the electrical correlates of morphological processing in OCD, future studies could investigate this theory in further detail.

Two sets of control items were used in the study to examine any potential effects of semantic and orthographic relatedness on morphological priming effects. Priming effects for purely semantically related prime-target pairs were not observed in the semantic item set. This was due to the fact that when target words (like “*GEZI*”, “*trip*”) were recognized, semantically related words (like “*seyahat*”, “*travel*”) elicited as long reaction times as unrelated prime words (like “*ayran*”, “*ayran*”). This result implies that participants are unable to activate the semantic properties of prime words at an SOA of 50 ms, and that semantic overlap between primes and targets does not aid in the process of visual word recognition. This is consistent with earlier research showing

that the early visual word recognition system is not influenced by semantic effects (e.g., Lavric et.al., 2012; Longtin et al., 2003; Rastle et al., 2004).

Similar to the semantic condition, no priming effects were found in the orthographic item set for prime-target pairs that were solely orthographically related (for example, “*papağan*”- “*parrot*” – “*PAPATYA*”- “*daisy*”). There was only found to be a significant repetition priming effect in the identical prime target pairs (e.g. “*papatya*”, “*daisy*”- “*PAPATYA*” “*daisy*”) in the orthographic condition. The current results for the orthographic item set is in accordance with the earlier studies (e.g., Rastle et al., 2004; Marslen-Wilson et al., 2008), which demonstrated that the early phases of visual word recognition are unaffected by the orthographic relatedness between primes and targets. The lack of priming effects under these circumstances emphasizes that morphological relatedness, not semantic or orthographic similarity, was the main factor driving the facilitation seen for inflected and derived word forms.

Additionally, priming effects were also absent in the morpho-orthographic control condition for the related prime-target pairs (e.g. “*boğa*- *BOĞ*”, “*bull*- *TO STRANGLE*”). Only the identical prime-target pairs in the morpho-orthographic set (e.g. “*boğ*-*BOĞ*”, “*to strangle*- *TO STRANGLE*”) revealed priming effects simply due to the repetition priming as observed in the previous control conditions. The claim that morphological priming effects seen in the inflected and derived conditions were caused by actual morphological structure rather than as a result of semantic or orthographic overlap is further supported by this result. These results are in line with earlier research that demonstrated that in early visual word recognition, morpho-orthographic processing functions independently of meaning and surface-level form overlap (Rastle et al., 2004; Diependaele et al., 2009).

Thus, the present study allows for the drawing of three broad conclusions. The first finding supports the notion that inflectional and derivational morphology in Turkish are processed through similar mechanisms: healthy participants demonstrated morphological priming effects for both inflected and derived word forms. Second, these priming effects were seen when semantic, orthographic, and morpho-orthographic effects were absent. This suggests that morphological relationships, not other lexical associations, are what drive priming in visual word recognition. Lastly,

morphological priming effects were overall reduced in OCD patients relative to the healthy group, most likely as a result of deficits in procedural memory and application of the rule-driven morphological computations.

The study's hypothesis, which was based on the fundamental notion of the Declarative/Procedural (D/P) Model, that people with OCD would have difficulty with tasks requiring procedural memory structures (Ullman et al., 2005; Ullman, 2004), was thus supported by the OCD group's increased difficulty in processing words preceded by an inflected morphological prime. Since OCD is linked to frontostriatal abnormalities and mental grammar is controlled by brain regions associated with the basal ganglia (Menzies et al., 2008; Saxena & Rauch, 2000), procedural memory processes, which are essential for processing inflected forms in language, would be especially impaired in OCD. This is consistent with the hypothesis that OCD patients, who rely on disrupted frontal-basal ganglia circuits, have deficits in rule-based morphological processing, reinforcing the role of procedural memory dysfunction in the disorder.

The interaction analyses also shed light on the nature of morphological processing differences in individuals diagnosed with OCD. The mixed-effects linear model revealed no significant effect of group (OCD vs healthy) on overall reaction times, implying that the OCD and healthy control groups had similar mean RTs. However, a significant interaction was found between the OCD group and the inflected morphological condition, with OCD participants exhibiting significantly slower reaction times than healthy controls. This suggests that the OCD participants' procedural processing deficits have a disproportionate impact on the decomposition and recognition of inflected word forms, which require grammatical rules rather than simple lexical retrieval. The fact that there was a significant processing difficulty in the OCD group for the inflected morphological condition, further supported by the OCD*inflected condition interaction, strengthens the idea that procedural memory related basal-ganglia abnormalities are reflected in the language processing patterns of the OCD participants.

In addition to these findings, procedural learning scores were found to interact with the inflected morphological condition in OCD participants, with higher procedural

learning deficits being correlated with slower RTs in the inflected morphological condition. This significant interaction directly aligns with theories - the D/P Model theory being the most relevant for the current study - that procedural learning deficits in OCD contribute to inefficiencies in decomposition of the inflected words, reinforcing the notion that individuals diagnosed with OCD tend to use declarative, whole-word storage strategies rather than relying heavily on the rule-based mental grammar supported by the procedural memory structures.

Finally, the mixed effects models revealed interactions involving several RAVLT measures in both groups. A significant interaction between learning error scores and group revealed that higher learning error scores were associated with faster RTs in the OCD group, implying that participants with higher cognitive rigidity may rely more on whole-word retrieval strategies. Furthermore, the interaction between perseveration and the related morpho-orthographic condition revealed that increased perseveration was associated with faster RTs, regardless of group. This finding suggests that people with high perseverance tendencies may be more sensitive to form-based patterns in visual word recognition. Lastly, the lexicon test did not show a meaningful difference across conditions in both groups, meaning the results were not modulated by the lexicon size of the participants.

In conclusion, the results of the study support the hypothesis that people with OCD have deficits in procedural memory-dependent morphological processing and are consistent with the predictions of the Declarative/Procedural (D/P) Model (Ullman, 2004; Ullman et al., 2005). When compared to the significant priming effects in the healthy group, the observed anti-priming effect in the inflected morphological condition for the OCD group emphasizes the disproportionate impairment in rule-based morphological decomposition, which is evidenced to be controlled by frontostriatal circuits (Menzies et al., 2008; Saxena & Rauch, 2000). Crucially, the lack of priming effects in the orthographic, morpho-orthographic, and semantic control conditions supports the idea that real morphological structure, not form- or semantic-based relationships, was the driving force behind the observed morphological priming effects (Rastle et al., 2004; Diependaele et al., 2009). Further evidence that procedural learning deficits lead to inefficiencies in the decomposition of morphologically complex words, as predicted by the D/P Model, comes from the significant interaction

between procedural learning scores and the inflected morphological condition in OCD participants (Ullman et al., 2005). When combined, these results offer fresh proof of the part procedural memory dysfunction plays in OCD linguistic computations, showing that deficits in rule-based processing go beyond deficiencies in general executive function to include domain-specific morphological processing.

4.2. Implications for Morphological Processing Models & Future Research

The results of the study show that automatic morphological parsing is not always maintained in all populations. While healthy adults primarily engaged in on-the-fly, rule-based morphological decomposition, OCD patients showed processing patterns that suggested a reliance on compensatory declarative memory systems, as posited by the D/P Model. These findings offer further evidence that language processing mechanisms can be significantly altered by procedural memory impairments - especially in clinical populations with basal-ganglia related procedural memory deficits.

These results challenge the notion that morphological processing functions uniformly in individuals with intact lexical competence. The observed anti-priming impact in the inflected morphological condition implies that procedural memory deficiencies in OCD cause inhibition effects rather than the anticipated facilitation of morphologically complex words. This finding demonstrates the crucial role of the procedural memory in automatic language processing, and implies that morphological models should include alternative mechanisms for compensatory declarative memory reliance in cases where procedural pathways are compromised.

To further deepen our understanding regarding the connection between procedural memory and language processing, future studies should examine if these findings apply to broader neuropsychiatric/clinic populations with frontostriatal abnormality related procedural memory impairment. The degree to which frontostriatal dysfunction affects morphological parsing in both language and non-linguistic domains may also be clarified through neuroimaging techniques, which could constitute direct evidence for the neurological underpinnings of these language processing variations. As another important line of inquiry for future studies, examining whether training or intervention techniques can increase morphological processing efficiency in OCD patients could

inform the development of targeted remediation programs aimed at strengthening procedural memory functions and optimizing language processing strategies in this population.

4.3. Conclusion

The present thesis study provided strong empirical evidence for the D/P Model-driven hypothesis which postulated that people with OCD would demonstrate deficiencies in tasks requiring procedural memory structures. The OCD group's strong anti-priming effect in the inflected morphological condition in the absence of semantic, morpho-orthographic and orthographic effects was the most noticeable finding in the study, suggesting an observed disruption in rule-based morphological decomposition pathways -which are the procedural memory related basal ganglia structures that are deformed in this group. Previously well-evidenced procedural memory impairment in OCD patients is further supported as OCD participants showed significant inhibition when presented with inflected morphological primes, in contrast to the healthy participants who showed robust priming effects for both inflected and derived word forms.

Remarkably, the OCD group has never been examined in a linguistic context before, much less within the framework of the D/P Model, although the model itself instigated the postulation of procedural memory related deficiencies in language. The idea that deficiencies in procedural memory extend beyond motor functions to linguistic domains is supported by the present study, which is the first to empirically demonstrate that procedural memory abnormalities in OCD are in fact reflected in language processing. The results provide supporting evidence for the broader theoretical framework that links OCD to frontostriatal dysfunction and procedural memory impairments by confirming that people with OCD have procedural memory deficiencies that affect rule-based morphological processing. Present thesis study not only further validates the D/P Model, but also paves the way for further investigation into the broader cognitive effects of frontostriatal dysfunction related procedural memory impairments in various neuropsychiatric populations with the similar conditions.

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APPENDICES

A. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE

B. MORPHOLOGICAL ITEM SET

Prime Conditions			
Identical	Related		Unrelated
	Inflected	Derived	
dinlemek	dinlemiş	dinleyici	kumral
okumak	okumuş	okuyucu	çirkin
kullanmak	kullanmış	kullanıcı	heyecanlı
satmak	satmış	satıcı	mevsim
kurtarmak	kurtarmış	kurtarıcı	eğlenceli
koşmak	koşmuş	koşucu	pahalı
sürmek	sürmüş	sürücü	çamaşır
konuşmak	konuşmuş	konuşucu	başvuru
izlemek	izlemiş	izleyici	perşembe
tüketmek	tüketmiş	tüketici	yağmurlu
yönetmek	yönetmiş	yönetici	kahvaltı
yazmak	yazmış	yazıcı	elbise
yüzmek	yüzmüş	yüzücü	berbat
binmek	binmiş	binici	numara
bakmak	bakmış	bakıcı	ilginç
vermek	vermiş	verici	dikkatli
üretmek	üretmiş	üretici	huzurlu
korumak	korumuş	koruyucu	mandalina
taşımak	taşımış	taşıyıcı	pencere
sunmak	sunmuş	sunucu	ağabey
pişirmek	pişirmiş	pişirici	sağlıklı
bulmak	bulmuş	bulucu	sakin
aramak	aramış	arayıcı	nefret
yüklemek	yüklemiş	yükleyici	şişman
çekmek	çekmiş	çekici	pastane
almak	almış	alıcı	serin
göndermek	göndermiş	gönderici	satranç
kesmek	kesmiş	kesici	orman

C. ORTHOGRAPHIC ITEM SET

Prime Conditions		
Identical	Related	Unrelated
bahane	baharat	turuncu
seviye	sevinç	yorgan
taraf	tarak	zümrüt
takvim	takviye	anahtar
hasret	hastane	fermuar
karpuz	karınca	cesaret
kumsal	kumbara	fasulye
mantık	mantar	adliye
papatya	papağan	dilekçe
sandalye	sandalet	mühendis
karanlık	karanfil	gözleme
makam	makale	şöhret
bayrak	bayram	şelale
fırtına	fırsat	cenaze
kelime	kelebek	sanayi
yumuşak	yumurta	cinsiyet
mastar	masraf	tedavi
hazine	haziran	zeytin
teneffüs	teneke	kahraman
mangal	manzara	yelken
minnet	minder	hayran
temmuz	tembel	salata
mercimek	merdiven	kaplıca
patron	patates	bereket

D. SEMANTIC ITEM SET

Prime Conditions		
Identical	Related	Unrelated
lokanta	restoran	tereyağı
doğa	tabiat	muayene
güz	sonbahar	fuar
kent	şehir	nakit
ihtimal	olasılık	kardeş
imkan	olanak	gümüş
gezi	seyahat	ayran
harika	muhteşem	hemşire
öneri	teklif	domates
baş	kafa	sebze
fayda	yarar	şenlik
sis	salam	peynir
ayıl	bayıl	borsa
afiş	broşür	şayet
taze	bayat	şehit
mektup	postane	yoğurt
simit	poğaç	mükemmel
fare	klavye	bulut
aidat	depozito	hayvan
sev	beğen	kira
kazan	kaybet	biber
kürek	kazma	lisans
fış	fatura	dergi
palet	dalgıç	esnaf

E. MORPHO-ORTHOGRAPHIC ITEM SET

Prime Conditions		
Identical	Related	Unrelated
öz	özür	ihmal
sağ	sağır	ceylan
dam	damar	bira
fal	falan	örnek
kay	kayık	tıraş
yak	yaka	akıl
üz	üzüm	kaçak
düş	düşman	kurum
kek	kekik	beşik
kon	konuk	boya
kul	kulak	marka
gem	gemi	saki
alt	altmış	kumaş
kem	kemer	rekor
boğ	boğa	topal
em	emsal	makas
in	incil	haki
hin	hindi	yastık
saz	sazan	kaşif
naz	nazar	imge
bel	belde	haylaz
kül	külçe	yassı
çak	çakır	keriz

F. RAVLT (Rey Auditory Verbal Learning Test)

B LİSTESİ ARKA YÜZÜ

Kibrit
Kitap
Defter
Çiçek
Çilek
Bahçe
Tünel
Gemi
Tren
Kilim
Halı
Hala
Çayır
Çimen
Çamur
Keman
Kemer
Gitar
Turp
Tuz
Biber
Tırnak
Parmak
Para
Elma
Armut
Elmas
Bacak
Duman
Baca
Ceket
Dümen
Düğme
Kapı
Anahtar
Kilit
Köpek
Küpe
Kedi
Tabak
Bardak
Barınak
Çıngırak
Oyuncak
Zil

SBST Puanları	
Anlık Bellek	
Öğrenme Puanı	
Kritere Ulaşma	
En Yüksek Öğrenme	
Öğrenme Yanlış Puanı	
Perseverasyon	
Tutarsızlık Puanı	
Kendiliğinden Hatırlama	
Tanıma	
TOPLAM HATIRLAMA	
Yanlış Hatırlama Puanı	
Yanlış Tanıma	

SÖZEL BELLEK SÜREÇLERİ TESTİ

A LİSTESİ

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Da vul	Pe rd e	Z il	Ka hv e	O ku l	A nn e	Ba hç e	Şa pk a	A y	Çi ftç i	Bu ru n	Hi nd i	Re nk	E v	Ne hir	SK OR
1																
2																
3																
4																
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G. TURKISH X-LEX 15000 VOCABULARY TEST

Lütfen aşağıdaki kelimere bakınız. Bazı kelimeler gerçek Türkçe kelimelerdir ve bazıları gerçek olmayan kelimelerdir. Lütfen bildiğiniz yada kullandığınız kelimere tik koyunuz. Örneğe bakınız.

...sevgi.... ü

Yardıminiz için

Teşekkürler.

bu	kendi	yukarı	şikayet	muhtaç
insan	konuşma	sanatçı	sorkın *	nihayet
dünya	tehdit	menilmek *	imkan	üslime *
şeyler	belinli *	inanç	yaratıcı	anlaşılır
sayı	gelişme	önemli	gelişim	uygulama
saneli *	hastalık	ültelemek *	alakalı	farklılık
görmek	bölüm	doğru	foluk *	fızlamak *
değişik	harika	şiddetli	yolculuk	rahatsızlık
şehir	kuveli *	eğlence	cesaret	izleme
yıllar	tartışma	dönüş	çatışma	kalkınma
aile	temiz	heyecan	galiba	zorluk
bilik *	hemen	baştan	haftalık	kural

ansen *	malesef	kılmak	mana	telafi
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dayanışma	tedbir	tesadüf	tasarruf	bellime *
ilham	tahrip	vaat	imalat	istisna
belirlemek	fital *	küne *	taahhüt	nebze
maalesef	muazzam	gayret	valı *	tulalı *
alaka	araka *	vahim	selmek *	merhamet
tillemek *	bilhassa	öncülük	muamele	memnuniyet
gerekçe	tüzel	serün *	ender	te lif
muhatap	madem	tahammül	ergin	ivme
yatırım	kamusal	muhtelif	meçhul	mümkün
bazında	itaat	ilkel	vaziyet	mahsus
makale	idrak	mesafe	eleştirel	irade

egemen	tasdik	sıfatıyla	bayındırlık	nafile
hayret	ılımlı	tasvir	belenek *	mazlum
bersinli *	kileme *	bennemek *	veraset	telkin
faili	tefek	tatbik	mutabakat	ersemli *
nesnel	itibari	tahakkuk	veyahut	muamma
senikli *	iktisat	asır	ukrelim *	mumak *
seferber	kıdem	sürüm	erkan	misal
algılama	übinelik *	imtihan	itham	tahvil
irtibat	yegane	kürel *	velevki	kelam

tabii	terim	müteakip	irfan	burjuvazi
tahmini	mizah	temin	maksat	aheste
cerayan	parke	zerre	kele	gaza



H. TURKISH SUMMARY / TRKE ZET

Saęlıklı yetiřkinlerle gerekleřtirilen ok sayıda diller arası alıřma, saęlıklı bireylerin ekimlenmiř ve tretilmiř karmařık szckleri okuma sırasında otomatik olarak biimbirimlerine ayırarak iřledięini gstermiřtir (Kırkıcı & Clahsen, 2013). Benzer řekilde, biimsel olarak karmařık gibi grnen ancak gerekte biimbilimsel olarak analiz edilebilir olmayan szckler de saęlıklı bireyler tarafından morfolojik aıdan karmařıkmıř gibi iřlenmekte ve otomatik olarak bileřenlerine ayrılmaktadır. Bu ‘kr’ biimbilimsel zmlleme deseni, Trke de dahil olmak zere birok tipolojik aıdan farklı dil iin rapor edilmiř olup, gnmzde saęlıklı yetiřkinlerin szck tanıma srelerinin temel bir unsuru olarak kabul edilmektedir.

Bu otomatik zmlleme mekanizmasının ocukluk dneminde nasıl geliřtięi, ikinci dil ęrenenlerde nasıl ve ne řekilde ortaya ıktıęı ve atipik poplasyonların anadil iřleme srelerine dahil olup olmadıęı zellikle son yıllarda giderek daha fazla ilgi ekmektedir. ocuklar ve ikinci dil ęrenenlerle yapılan alıřmalar literatrde yer almakla birlikte, hasta gruplarıyla gerekleřtirilen arařtırmalar olduka sınırlıdır ve Trke iin bilinen bir alıřma bulunmamaktadır. Bu nedenle, mevcut alıřma, obsesif-kompulsif bozukluk (OKB) tanısı almıř Trke konuřan bireylerin biimbilimsel iřleme rntlerine odaklanmaktadır.

Bu alıřma, prosedrel bellek (zihinsel dilbilgisi) ile deklaratif belleęin (zihinsel szlk) altında yatan beyin yapıları arasındaki ayrımı temel alan Ullman’ın Deklaratif/Prosedrel Bellek Modeli’ne (Ullman, 2001; 2004) dayalı olarak tasarlanmıřtır. Ullman, deklaratif belleęin dilin anlamlarını ve ierięini iřlerken, prosedrel belleęin dil yapılarını ve kurallarını iřlemekten sorumlu olduęunu ne srmřtr. Bu teorik ereveden yola ıkılarak, literatrde rapor edilen OKB hastalarına ynelik prosedrel bellek bozukluklarının, bu iki bellek sistemi arasındaki etkileřim sonucunda biimbilimsel iřleme srelerinde farklılıklara yol aabileceęi hipotezi geliřtirilmiřtir. Bu doęrultuda, OKB tanısı almıř yetiřkin ana dili Trke

konusucularının türetilmiş (örn. *hasta-lık*) ve çekimlenmiş (örn. *git-miş*) karmaşık sözcükleri maskelenmiş eşleşme deneyi yöntemiyle nasıl işlediği incelenmiştir.

Bu çalışmanın bulguları öncelikli olarak, sağlıklı yetişkinlerde tutarlı ve diller arası geçerliliği olan bir şekilde rapor edilen otomatik sözcük çözümleme mekanizmalarının OKB hastalarında da bulunup bulunmadığını ve bu bireylerin sağlıklı kontrol grubuna benzer bir işleme örüntüsü sergileyip sergilemeyeceğini gösterecektir. Bu bağlamda, çalışma, OKB tanısı almış bireylerin dil işleme süreçlerindeki olası eksikliklere yönelik literatürdeki boşluğu doldurmayı amaçlamaktadır. Çalışmanın bulguları, OKB tanısı almış bireylerin dil işleme süreçleri ve bu süreçlerin altında yatan nörolojik mekanizmaların daha iyi anlaşılmasına katkıda bulunabileceği gibi, gelecekteki tanı ve müdahale yaklaşımlarının geliştirilmesine de olanak sağlayabilir. Ayrıca, bu çalışma, olası prosedürel bellek bozukluklarının OKB tanısı almış bireylerin dil işleme ve okuma süreçleri üzerindeki etkilerine dair önemli bilgiler sunabilir.

Daha önce de belirtildiği gibi, ana dildeki biçimbilimsel işlemeye ilişkin temel örüntüler artık sağlıklı yetişkinler için nispeten iyi anlaşılmış durumdadır. Diller arası çalışmalar, ana dilde biçimbilimsel işlemenin genellikle "otomatik biçimbilimsel çözümleme" olarak tanımlanabilecek bir süreç olduğunu kabul etmektedir. Ancak, hem prosedürel süreçlerde hem de karar verme, set değiştirme gibi farklı bilişsel alanlarda zorluk yaşadığı bilinen bir popülasyon üzerinde bugüne kadar neredeyse hiç çalışma gerçekleştirilmemiştir. Oysa geliştirilen dil işleme modellerinin güvenilirliğini ve geçerliliğini test etmek için hem gelişimsel süreçlerin hem de klinik ve atipik popülasyonlardaki yansımaların dikkate alınması büyük önem taşımaktadır.

Bu doğrultuda, mevcut çalışmada OKB tanısı almış bireylerde biçimbilimsel işleme süreçleri ilk kez test edilmiştir. Bu sayede, Türkçede biçimbilimsel işleme süreçlerinin bellek farklılıklarından ya da eksikliklerinden nasıl etkilendiğini incelemek için benzersiz bir fırsat doğmuştur. Literatürde, herhangi bir dilde OKB tanısı almış bireylerle biçimbilimsel ayrışma mekanizmasını test eden bir araştırmaya rastlanmadığından, elde edilecek sonuçların gelecek araştırmalar için büyük önem taşıyacağı düşünülmektedir. Bir yandan, çalışma bulguları biçimbilimsel işleme modellerine yeni girdiler sağlayacak; diğer yandan OKB tanısı almış bireylerin dil işleme mekanizmalarının daha iyi anlaşılmasına olanak tanıyacaktır.

Bu doğrultuda, mevcut çalışma obsesif-kompulsif bozukluk (OKB) tanısı almış yetişkin bireylerde biçimbilimsel işleme örüntülerini incelemeyi ve bu sözcük işleme örüntülerinde prosedürel bellek eksikliklerinin etkisini açıklamayı amaçlamaktadır. Bu bağlamda, prosedürel bellek bozukluklarının (Rauch ve ark., 1997) dil işleme üzerindeki olası etkileri, Ullman'ın Deklaratif/Prosedürel Bellek Teorisi (2001, 2004) çerçevesinde ele alınarak, Türkçedeki çekimlenmiş (*sat-mış*) ve türetilmiş (*sat-ıcı*) biçimbilimsel açıdan karmaşık sözcüklere odaklanılarak incelenmiştir.

Bu tez kapsamında aşağıdaki iki genel araştırma sorusuna yanıt aranmıştır:

- 1- OKB tanısı almış bireyler ile sağlıklı bireyler arasında biçimbilimsel işleme örüntüleri açısından herhangi bir fark var mıdır?
- 2- OKB tanısı almış bireyler ile sağlıklı bireyler arasında çekimlenmiş ve türetilmiş sözcüklerin işlenmesi açısından herhangi bir fark var mıdır? Eğer varsa, bu farklar OKB tanısı almış bireylerdeki prosedürel bellek bozukluklarından kaynaklanıyor olabilir mi?

OKB'nin frontostriatal anormalliklerle ilişkilendirildiği ve prosedürel belleğin frontal-bazal gangliyon yapılarından destek aldığı göz önünde bulundurulduğunda (Rauch ve ark., 1997), OKB hastalarının özellikle çekimlenmiş biçimlerin işlenmesinde, prosedürel bellek süreçleriyle ilişkili görevlerde eksiklikler göstereceği hipotez olarak öne sürülmüştür. Bu tür eksikliklerin, çekimsel biçimbilimde eşleşme etkisinin gözlemlenmemesi, ancak türetimsel biçimbilimde bu etkinin korunması şeklinde ortaya çıkacağı öngörülmüştür.

Ana deneyin en dikkat çekici bulgusu, OKB grubunun gerçekten de çekimli morfolojik koşulda önemli bir anti-priming etkisi göstermesiydi. OKB grubunda, çekimli morfolojik prime'ların (ör. “korumuş, s/he protected it”) önceden sunulması, hedef köklerin (ör. “KORUMAK, to protect”) tanınmasını, ilgisiz morfolojik prime'lara (ör. “mandalina, tangerine”) kıyasla önemli ölçüde yavaşlattı. Öte yandan, sağlıklı katılımcılar literatürde bildirilen tipik morfolojik işleme modelini sergiledi: çekimli kelime biçimleri için anlamlı bir priming etkisi. Başka bir deyişle, sağlıklı grupta, çekimli morfolojik prime'ların (ör. “korumuş”, “s/he protected it”) önceden sunulması, hedef köklerin (ör. “KORUMAK”, “to protect”) tanınmasını, ilgisiz

morfolojik prime'lara (ör. "mandalina", "tangerine") kıyasla önemli ölçüde kolaylaştırdı.

Türetilmiş kelimelerin hedef kök tanıma üzerindeki etkisine gelince, sağlıklı katılımcılar aynı zamanda türetilmiş morfolojik prime'larla (ör. "koruyucu", "the protector") sunulan hedef kelimeler ("KORUMAK", "to protect") için de ilgisiz morfolojik prime'lara (ör. "mandalina", "tangerine") kıyasla güçlü bir priming etkisi gösterdi. Bununla birlikte, özdeş morfolojik koşulda gözlemlenen kolaylaştırma etkisi, ilgisiz morfolojik koşula kıyasla daha güçlüydü. Genel olarak, sağlıklı katılımcıların dört prime türü (ilgisiz, çekimli, türetilmiş, özdeş) arasındaki morfolojik koşuldaki işleme modeli, anadili konuşucularıyla yapılan önceki araştırmalarla iyi bir şekilde örtüşmektedir (Morris & Stockall, 2012; Clahsen & Neubauer, 2010; Clahsen et al., 2010; Silva & Clahsen, 2008). Dahası, bu sonuçlar, Türkçe gibi morfolojik olarak zengin dillerde sözcüksel temsillerin, karmaşık kelime biçimlerinin etkili bir şekilde ayrıştırılması ve işlenmesini kolaylaştıracak şekilde organize edildiği fikrini desteklemektedir (Frauenfelder & Schreuder, 1991).

OKB grubu, türetilmiş morfolojik prime'ların önceden sunulmasıyla da priming etkisi gösterdi, ancak sağlıklı gruba kıyasla daha düşük bir kolaylaştırma gözlemlendi. Benzer şekilde, OKB grubunda özdeş prime'ların da anlamlı bir kolaylaştırıcı etkisi bulundu. OKB grubu ile sağlıklı kontrol grubunun kelime tanıma örüntüleri ilgisiz, türetilmiş ve özdeş morfolojik koşullarda benzerdi, ancak çekimsel uyarıların sunulması, ilgisiz koşula ve sağlıklı gruba kıyasla anlamlı bir inhibisyona yol açtı. Bu sonuç, çekimli morfolojik koşul ile OKB grubu arasında gözlemlenen anlamlı etkileşim ile daha da desteklenmiştir.

OKB katılımcılarında morfolojik olarak ilişkili çiftler için kaydedilen azalmış priming etkileri, OKB'li bireylerin parçalama temelli morfolojik işlem yerine tüm sözcüğün depolanmasına daha fazla bağımlı olabileceğini düşündürmektedir. Bu sonuç, OKB'nin kural tabanlı işlemenin bozulması ve prosedürel bellek yetersizlikleriyle ilişkili olduğunu öne süren teorilerle tutarlıdır (Ullman et al., 2005). Morfolojik parçalamanın büyük ölçüde prosedürel mekanizmalara dayandığı öne sürüldüğünden (Marslen-Wilson & Tyler, 1997; Ullman, 2004), OKB grubunda gözlemlenen priming etkilerindeki azalma, altta yatan morfolojik kuralları işe koşma ve etkili bir şekilde

kullanma konusundaki zorluklardan kaynaklanıyor olabilir. OKB ile ilişkili bilişsel eksikliklerin, genel yürütücü işlev bozukluğuna ek olarak, alan-spesifik dilsel hesaplamaları da etkilediği fikri, OKB grubunda gözlemlenen azalmış morfolojik kolaylaştırma ile desteklenmektedir. Öte yandan, deklaratif bellekten sorumlu beyin yapıları tarafından yönetilen türetme primingine olan daha büyük bağımlılık, prosedürel işleme yetersizliklerini telafi eden bir mekanizma olabilir (Ullman, 2004). Çekimli morfolojik koşuldaki anormal priming örüntüleri, kural tabanlı morfolojik ayırtırmadan ezbere öğrenmeye geçişle açıklanabilir.

OKB grubunda gözlemlenen nispeten düşük priming etkilerinin bir diğer olası açıklaması, bu durumun belirleyici bir özelliği olan “aşırı aktif hata izleme” olabilir (Gehring et al., 2000). Eğer bir kişi beklenen dilsel yapılardaki küçük değişikliklere karşı aşırı derecede hassas hale gelirse, morfolojik olarak ilişkili kelimeler arasında bağlantılar kurmak son derece zorlaşır. Azalmış morfolojik bileşen erişim kapasitesi nedeniyle priming etkileri zayıflayabilir. Gelecekteki çalışmalar, OKB’de morfolojik işlemenin elektriksel korelasyonlarını inceleyerek bu teoriyi daha ayrıntılı bir şekilde araştırabilir.

Çalışmada, morfolojik priming etkileri üzerinde olası anlamsal ve ortografik ilişkilerin etkilerini incelemek için iki kontrol ögesi seti kullanılmıştır. Anlamsal öge setinde, yalnızca anlamsal olarak ilişkili prime-hedef çiftleri için priming etkileri gözlemlenmemiştir. Bunun nedeni, hedef kelimeler (ör. “GEZI”, “trip”) tanındığında, anlamsal olarak ilişkili kelimelerin (ör. “seyahat”, “travel”) tepkime sürelerinin, ilgisiz prime kelimelerinki (ör. “ayran”, “ayran”) kadar uzun olmasıdır. Bu sonuç, katılımcıların 50 ms SOA’da prime kelimelerin anlamsal özelliklerini etkinleştiremediğini ve prime-hedefler arasındaki anlamsal örtüşmenin görsel kelime tanıma sürecine yardımcı olmadığını göstermektedir. Bu, erken görsel kelime tanıma sisteminin anlamsal etkilerden etkilenmediğini gösteren önceki araştırmalarla tutarlıdır (ör., Lavric et al., 2012; Longtin et al., 2003; Rastle et al., 2004).

Orthografik koşulda, anlamsal koşula benzer şekilde, yalnızca ortografik olarak ilişkili olan başlatıcı-hedef çiftleri için başlatma etkileri bulunmamıştır (örneğin, “papağan”- “parrot” – “PAPATYA”- “daisy”). Ortografik koşulda, yalnızca birebir aynı başlatıcı-hedef çiftlerinde anlamlı bir tekrar başlatma etkisi gözlemlenmiştir (örneğin,

“papatya”, “daisy”- “PAPATYA” "daisy"). Ortografik madde seti için elde edilen mevcut sonuçlar, kelime tanımada erken aşamaların başlatıcılar ile hedefler arasındaki ortografik benzerlikten etkilenmediğini gösteren önceki çalışmalarla uyumludur (örneğin, Rastle ve ark., 2004; Marslen-Wilson ve ark., 2008). Bu bağlamda başlatma etkilerinin yokluğu, eklenmiş ve türetilmiş kelime formları için gözlemlenen kolaylaştırmanın temel belirleyicisinin anlamsal ya da ortografik benzerlik değil, morfolojik ilişkiler olduğunu vurgulamaktadır.

Ayrıca, ilgili başlatıcı-hedef çiftleri için morfo-ortografik kontrol koşulunda da başlatma etkileri gözlemlenmemiştir (örneğin, “boğa- BOĞ”, “bull- TO STRANGLE”). Morfo-ortografik sette yalnızca birebir aynı başlatıcı-hedef çiftlerinde (örneğin, “boğ-BOĞ”, “to strangle- TO STRANGLE”) önceki kontrol koşullarında gözlemlenen tekrar başlatma etkileri ortaya çıkmıştır. Bu sonuç, eklenmiş ve türetilmiş koşullarda gözlemlenen morfolojik başlatma etkilerinin anlamsal ya da ortografik benzerlikten değil, gerçek morfolojik yapıdan kaynaklandığını bir kez daha desteklemektedir. Bulgular, erken görsel kelime tanımada morfo-ortografik işlemenin anlamdan ve yüzeysel form benzerliğinden bağımsız olarak çalıştığını gösteren önceki araştırmalarla da uyumludur (Rastle ve ark., 2004; Diependaele ve ark., 2009).

Bu nedenle, mevcut çalışma üç genel çıkarım yapılmasını sağlamaktadır. İlk olarak, bulgular, Türkçede eklemeli ve türetme morfolojisinin benzer mekanizmalar aracılığıyla işlendiği fikrini desteklemektedir: sağlıklı katılımcılar, hem eklenmiş hem de türetilmiş kelime formları için morfolojik başlatma etkileri göstermiştir. İkinci olarak, bu başlatma etkileri, anlamsal, ortografik ve morfo-ortografik etkilerin bulunmadığı durumlarda ortaya çıkmıştır. Bu durum, görsel kelime tanımada başlatmanın diğer sözcüksel ilişkilerden değil, morfolojik ilişkilerden kaynaklandığını göstermektedir. Son olarak, OCD hastalarında morfolojik başlatma etkileri sağlıklı gruba kıyasla genel olarak azalmış olup, bu durum büyük olasılıkla prosedürel bellekteki eksiklikler ve kurala dayalı morfolojik hesaplamaların uygulanmasındaki zorluklardan kaynaklanmaktadır.

Çalışmanın temel hipotezi, Bildirimsel/Prosedürel (D/P) Modeli'nin temel ilkesine dayanarak, OCD'li bireylerin prosedürel bellek yapıları gerektiren görevlerde zorlanacağını öngörmekteydi (Ullman ve ark., 2005; Ullman, 2004). Nitekim, OCD

grubunun eklenmiş morfolojik başlatıcılar tarafından öncüllenen kelimeleri işlerken daha fazla zorlanması, bu hipotezi desteklemektedir. OCD'nin frontostriatal anormalliklerle bağlantılı olduğu ve zihinsel gramerin bazal gangliyonlarla ilişkili beyin bölgeleri tarafından kontrol edildiği göz önüne alındığında (Menziés ve ark., 2008; Saxena & Rauch, 2000), prosedürel bellek süreçlerinin, dilde eklenmiş formların işlenmesi için kritik olduğu ve OCD'de özellikle bozulabileceği öne sürülmektedir. Bu durum, bozulmuş frontal-bazal gangliyon devrelerine dayanan OCD hastalarının kurala dayalı morfolojik işlemede eksiklikler gösterdiği hipoteziyle de tutarlıdır ve prosedürel bellek işlev bozukluğunun bu bozuklukta rolünü pekiştirmektedir.

Etkileşim analizleri ayrıca, OCD tanısı almış bireylerde morfolojik işlemenin doğasına dair önemli bulgular sunmaktadır. Karma etkili doğrusal model, grup değişkeninin (OCD vs sağlıklı) genel tepki süreleri üzerinde anlamlı bir etkisinin olmadığını ortaya koymuştur; bu da OCD ve sağlıklı kontrol gruplarının benzer ortalama tepki sürelerine sahip olduğunu göstermektedir. Ancak, OCD grubu ile eklenmiş morfolojik koşul arasında anlamlı bir etkileşim bulunmuş, OCD katılımcıları sağlıklı kontrollere kıyasla önemli ölçüde daha yavaş tepki süreleri sergilemiştir. Bu durum, OCD katılımcılarının prosedürel işleme eksikliklerinin, yalnızca sözcüksel geri çağırma gerektiren kelimeler yerine, gramer kurallarına dayalı eklenmiş kelime formlarının ayrıştırılması ve tanınması üzerinde orantısız bir etkiye sahip olduğunu göstermektedir. Ayrıca, OCD grubunda eklenmiş morfolojik koşul için önemli bir işleme zorluğunun bulunması ve OCD*eklenmiş koşul etkileşimi tarafından daha da desteklenmesi, prosedürel belleğe bağlı bazal gangliyon anormalliklerinin, OCD katılımcılarının dil işleme kalıplarına yansıdığını göstermektedir.

Bu bulgulara ek olarak, OCD katılımcılarında prosedürel öğrenme puanlarının eklenmiş morfolojik koşulla etkileşime girdiği bulunmuştur; prosedürel öğrenme eksikliklerinin artması, eklenmiş morfolojik koşulda daha yavaş tepki süreleri ile ilişkilendirilmiştir. Bu önemli etkileşim, özellikle mevcut çalışma için en ilgili olan D/P Modeli kuramı ile doğrudan örtüşmekte olup, OCD'deki prosedürel öğrenme eksikliklerinin eklenmiş kelimelerin ayrıştırılmasındaki verimsizliklere katkıda bulunduğunu göstermektedir. Bu da, OCD tanısı almış bireylerin, prosedürel bellek

yapıları tarafından desteklenen kural tabanlı zihinsel gramerden ziyade, bildirimsel, tüm kelimeyi depolama stratejilerini kullanma eğiliminde olduğunu pekiştirmektedir.

Son olarak, karma etkili modeller, her iki grupta da çeşitli RAVLT ölçümleri ile etkileşimler ortaya çıkarmıştır. Öğrenme hata puanları ve grup arasında anlamlı bir etkileşim bulunmuş, daha yüksek öğrenme hata puanlarının OCD grubunda daha hızlı tepki süreleri ile ilişkili olduğu gözlemlenmiştir; bu durum, bilişsel katılığı daha yüksek olan katılımcıların tüm kelimeyi geri çağırma stratejilerine daha fazla güvenebileceğini düşündürmektedir. Ayrıca, perseverasyon ile ilgili morfo-ortografik koşul arasındaki etkileşim, artan perseverasyonun, grup farkı gözetmeksizin daha hızlı tepki süreleriyle ilişkili olduğunu ortaya koymuştur. Bu bulgu, yüksek perseverasyon eğilimlerine sahip bireylerin görsel kelime tanımada biçime dayalı kalıplara daha duyarlı olabileceğini düşündürmektedir. Son olarak, leksikon testi her iki grupta da koşullar arasında anlamlı bir fark göstermemiş olup, sonuçların katılımcıların sözcük hazinesi büyüklüğünden etkilenmediğini ortaya koymaktadır.

Sonuç olarak, çalışmanın bulguları, OCD'li bireylerin prosedürel belleğe bağlı morfolojik işlemede eksiklikler yaşadığı hipotezini desteklemekte ve Bildirimsel/Prosedürel (D/P) Modeli'nin öngörülerıyla tutarlı olmaktadır (Ullman, 2004; Ullman ve ark., 2005). Sağlıklı grupta gözlemlenen anlamlı başlatma etkilerine kıyasla, OCD grubunda eklenmiş morfolojik koşulda gözlemlenen anti-başlatma etkisi, kurala dayalı morfolojik ayrıştırmadaki orantısız bozulmayı vurgulamaktadır; bu süreçlerin frontostriatal devreler tarafından kontrol edildiği kanıtlanmıştır (Menzies ve ark., 2008; Saxena & Rauch, 2000). Önemli olarak, ortografik, morfo-ortografik ve anlamsal kontrol koşullarında başlatma etkilerinin yokluğu, gözlemlenen morfolojik başlatma etkilerinin temel itici gücünün, biçimsel ya da anlamsal ilişkiler değil, gerçek morfolojik yapı olduğunu desteklemektedir (Rastle ve ark., 2004; Diependaele ve ark., 2009).

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