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Morphological Processing of Complex Words in Turkish

Türkçedeki Karmaşık Sözcüklerin Biçimbilimsel İşlemlenmesi

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ABSTRACT

The main objective of this study is to examine how native speakers of Turkish process morphologically complex words when they are presented with masked primes. The present paper also seeks to find out whether semantics and/or orthography play a role in the early stages of morphological processing. A masked priming visual word recognition experiment was conducted with 44 Turkish speakers. Based on the accuracy rates and reaction times of the participants, this study aimed to figure out the organization of the mental lexicon. The results showed statistically significant priming effects for transparent items while no significant priming was revealed for the opaque and form items. These results replicate earlier studies and indicate that native speakers of Turkish decompose inflectionally and derivationally complex words in the early stages of visual word recognition. Moreover, the results also suggest that early morphological processing is blind to orthographic properties.

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Introduction

Cross-linguistic studies have shown that human beings have a visual word recognition system which helps them to analyze letter strings in terms of their constituent morphemes (Rastle et al., 2004). Morphologically complex words give us a lot of information about the visual word recognition system. It has been observed that the visual word recognition system relies on morphological information (Diependaele et al., 2011). An essential component of the structure is supplied by morphemes, in other words, arbitrary orthography between word forms and their meanings (Marslen-Wilson et al., 1994). Words and morphemes are stored in our mental lexicon, that is why the study of morphology has an utmost importance in understanding the structure of the mental lexicon. Morphological processing has vital value for psycholinguists as it helps us understand how access to the mental lexicon is affected by form and meaning.

There are three leading ideas about how whole words and constituents are represented in the

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mental lexicon. While the full decomposition hypothesis proposed by Taft and Forster (1975) proposes that complex forms are parsed into their stems and affixes, Butterworth's (1983) full listing hypothesis claims that regardless of their internal structure, all words (simplex and complex) are listed in the mental lexicon as they are. Words and Rules Theory (Pinker, 1999), on the other hand, posits that both of the aforementioned hypotheses are partially correct, suggesting that while some of the words are stored as full forms, others are decomposed.

Another discussion concerns the comprehension of complex words in terms of the number of mechanisms in operation. These are single-mechanism models and hybrid models. Single mechanism rule-based accounts (similar to the full decomposition hypothesis) by Ling and Marinov (1993) suggest that formal rules are in use during the formation of complex words. For instance, a word such as 'players' is stored in the mental lexicon as *'play + -er + -s'*. It means that morphemes of complex words are stripped and their affixes and stems are stored separately. Single mechanism associative accounts of morphological processing (similar to the full listing hypothesis) by Rumelhart and McClelland (1986), on the other hand, postulate that both simplex and complex word forms are listed as full forms in the mental lexicon. So, the word in the previous example is stored as a whole form and other complex and/or simple words related to this word such as *'player'* and *'play'* are also stored in the lexicon separately. Alternatively, hybrid models (similar to words and rules theory) (e.g., Pinker, 1991) propose that processing of complex words can be both associative and rule based. To exemplify, consider two words such as *'played'* and *'went'*. According to hybrid models, while regularly inflected words like *'played'* are stored after affix stripping, irregular words like *'went'* are stored as whole constituents.

Some researchers argue that morpheme, which is defined as the smallest unit to analyse grammar (Lyons, 1968) or the smallest meaningful unit in a language (Bloomfield, 1933), is the unit for language recognition. Since words such as *cups*, *undo*, and *airplane* are composed of more than one morpheme *(cup + -s, un + do, and air + plane)*, they are considered to have complex structures according to the morpheme-based approach. There are three ways of forming morphologically complex words: derivation, inflection, and compounding. If a derivational or inflectional affix is added to a stem *(e.g., un + do → undo, cup + -s → cups)*, these processes are called derivation and inflection respectively. Compounding, however, requires us to combine two stems *(air + plane → airplane)*. Since the aim of this study is to examine the processing of derived and inflected words, compounds are not a part of the current research.

The (Dis)Similarities between Inflection and Derivation

Even though this research considers derivation and inflection as separate processes, it is still a matter if derivation and inflection are two distinct phenomena. From one standpoint, inflection and derivation have similarities, and they should not be regarded as separate processes. Aronoff (1994), for instance, posits that there are some affixes *(e.g., -AcAk in Turkish)* which might act as both derivational and inflectional morphemes. Likewise, Bochner (1992) postulates that processes such as suffixation, infixation, and prefixation are used for both derivation and inflection in numerous languages. Moreover, there is no distinction between derivational and inflectional processes according to Distributed Morphology approaches (Harley & Noyer, 1999).

On the contrary, derivation and inflection are considered to be different mechanisms according to classical descriptions of morphological processes. While inflection is seen as a process that produces disparate word-forms of a specific lexeme, derivation is defined as a "word formation" process that forms novel lexemes (Blevins, 2006). Thus, realization-based theories of morphology assume that there are different morpholexical representations of inflected and derived words in the mental lexicon based on this difference (Matthews, 1991; Anderson, 1992).

Along with the difference in terms of definition between derivational and inflectional processes, five criteria are offered by Stump (1998) with the aim of differentiating inflection and derivation. Firstly, inflectional processes keep syntactic category and lexical meaning of the stems the same *(e.g., chairs is an inflectional form of the noun chair)*, while derivational processes often do not *(e.g., the noun beauty becomes the adjective beautiful with the addition of derivational morpheme -ful)*. The second criterion is that inflectional affixes are syntactically pertinent, which means the usage of a specific inflectional word-form heavily depends on the syntactic context of a lexeme in hand. However, derivational affixes are not syntactically relevant as it is not required for a lexeme to be morphologically simplex or complex in a grammatical context. The case of productivity comes as the third criterion. Inflectional processes are used effectively; however, derivational processes are restricted in terms of variety of application. Semantic regularity is listed as the fourth criterion. The regularity of inflection is higher than derivation by means of semantics. As the fifth and the last criterion, when an inflectional affix is used, that word becomes closed to derivation, whereas after a derivational affix, a word is still open to derivation.

To date, most of the research on morphological processing focused on either inflected words or derived words. There is limited research investigating the interplay of these two morphological processes within a single study. The presence of both inflectionally and derivationally complex words in this research enables a comparison of the mechanisms underlying the processing of morphologically complex words.

The majority of studies to date have focused on Indo-European languages, such as French, German, English, and Portuguese (see Grainger et al., 1991; Sonnenstuhl et al., 1999; Rastle et al., 2000; Veríssimo & Clahsen, 2009). Consequently, there is a lack of research on typologically diverse languages, which limits the generalizability of findings. As a non-Indo-European language with highly productive agglutinating morphology, Turkish provides an important case for such studies. The topic remains underexplored, especially in terms of understanding its mechanisms and generalizability across languages. While a few studies have examined morphological processing in Turkish (e.g., Gürel, 1999; Kırkıcı & Clahsen, 2013; Jacob et al., 2018), it remains an area open for in-depth investigation to understand its underlying mechanisms and generalizability in comparison to other languages.

Gürel (1999) investigated the extent of morphological decomposition in native Turkish speakers using an unprimed lexical decision task. She found that not all multimorphemic Turkish words are accessed in a decomposed form. Words with frequent suffixes appear to be accessed via a whole-word access procedure. The study suggests that the frequency of the suffix influences whether a word is accessed through a direct route or a parsing route. This research challenges the assumption that agglutinative languages like Turkish always involve decomposition during lexical access and highlights the role of affix frequency in processing strategies. It also suggests that the morphological parser in Turkish is highly effective. Kırkıcı and Clahsen (2013) compared the processing of inflectional (aorist) and derivational (-lIk nominalization) morphology in native and non-native Turkish speakers using masked priming. The study revealed similar priming patterns for inflection and derivation in native Turkish speakers. However, non-native speakers showed priming for derivation but not for inflection. The authors proposed that non-native speaker processing may not utilize early automatic morphological decomposition for inflection to the same extent as native speaker processing, and that non-native speaker priming may rely on shared lexical entries. This research suggests a dissociation between inflectional and derivational processing in non-native speakers, unlike in native speakers. It contributes to the understanding of how non-native speakers process complex morphology and suggests that morphological decomposition might not be a primary mechanism for all morphological types in second language acquisition. This study also highlights that non-native data can provide unique insights into theoretical distinctions in morphology. Jacob et al. (2018) examined the processing of derived (-(y)IcI) and inflected (-mIş)

Turkish words in heritage speakers living in Germany and compared them to native speakers in Türkiye using masked priming. The key finding was that both heritage and native speakers showed significant priming effects of similar magnitude for both derivation and inflection. Control conditions confirmed that these priming effects were morphological. The study concluded that heritage speakers possess preserved, native-like decomposition mechanisms for complex words despite potentially limited language input. However, they also found that overall lexical decision times were slower for heritage speakers. This research indicates that fundamental morphological processing mechanisms can be preserved in heritage speakers of Turkish, suggesting that sufficient input for the development of these mechanisms can occur even in a heritage language context. It also distinguishes heritage speakers from non-native language learners in terms of inflectional processing and suggests that differences in language output observed in heritage speakers might not stem from deficits in processing mechanisms.

Lastly, although there are studies considering the effects of orthography and semantics on the morphological processing of Turkish words, there are just a handful number of these studies (e.g., Gacan, 2014; Şafak, 2015). Gacan (2014) primarily investigated the processing of derived words in native speakers of Turkish and non-native speakers of English at different proficiency levels. It focused on the Turkish suffixes -lI (attributive) and -sIz (privative), and their English counterparts -ful and -less, using masked priming experiments. The findings provided evidence for the automatic language decomposition of Turkish derived words formed with transparent, frequent, and productive suffixes -lI and -sIz during visual word recognition. The observed priming effects were morphological in nature and independent of orthographic overlap. This research supports the claim that languages with rich morphology like Turkish utilize combinatorial processing for complex word forms, aligning with suggestions by Frauenfelder and Schreuder (1992) and Hankamer (1989). It extends the findings of Kırkıcı and Clahsen (2013), who also observed priming effects for Turkish derived words with another transparent and frequent suffix (-lIk). The study suggested that native speakers of Turkish rely on the morphological structure of derived words during early visual processing. Şafak (2015) examined the processing of both inflected and derived words in native speakers of Turkish and non-native speakers of English. She used masked priming experiments with native Turkish speakers processing Turkish inflected verbs with -mIş (evidential) and derived nouns with –(y)IcI (agentive), as well as advanced Turkish learners of English processing English inflected verbs with -ed and derived nouns with -er. The study aimed to determine if complex words are decomposed and the role of semantic and orthographic relatedness. The results indicated that native Turkish speakers decompose both inflected and derived words into stems and suffixes during visual word recognition in Turkish. This morphological processing in Turkish was found to be independent of semantic relatedness between the complex words and their stems. The study supports the expectation that native speakers of Turkish process both inflected and derived words in a morphologically structured format due to the productive morphological system of Turkish. This aligns with findings from Kırkıcı and Clahsen (2013). Şafak's findings contribute to the understanding of whether a single combinatorial mechanism underlies the processing of all complex word forms in Turkish.

Aim of the Study

The aforementioned reasons establish the foundation for the present study. This study has three primary objectives. First, it aims the examine how native speakers of Turkish process complex words. Second, it seeks to determine the role of semantics and orthography in early morphological processing in Turkish. Finally, it investigates whether there are differences in the processing patterns of derivationally and inflectionally complex words in Turkish. In light of these objectives, the present study addresses the following research questions:

1. Are Turkish derived and inflected words stored as full-forms or decomposed into morphological

units by native speakers during visual word recognition?
2. Do semantics and/or orthography play a role in L1 Turkish morphological processing?

Based on the findings of previous experimental research conducted on native speakers of various languages along with Turkish (Silva & Clahsen, 2008; Kırkıcı & Clahsen, 2013; Jacob et al., 2017), it is predicted that L1 speakers of Turkish will decompose inflectionally and derivationally complex word forms into their constituents (i.e., roots and suffixes). One of the reasons behind this prediction depends on the economy of storage claim. In Turkish, to form morphologically complex words, affixation (almost always suffixation) is used. While the number of inflectional forms an English verb can have, is thought to be four (Carlisle et al., 1997), the number is over 2000 for a Turkish verb (Hankamer, 1989). Moreover, the number of derivational morphemes is over 100 in Turkish (Aksan, 1987) and these morphemes generally have more than one function and meaning.

According to the economy of storage claim, the listing of all the words would take up an excessive amount of place in the mental lexicon, thus the mind would be put under a substantial load for the storage and retrieval of words (Frauenfelder & Schreuder, 1992). Additionally, Hankamer (1989) asserts that millions of words are generated by agglutinative languages such as Turkish, hence making the human mind insufficient to store words (simple, complex, and compound) separately.

Moreover, there are studies showing that early morphological processing is semantically blind (Longtin, Segui & Halle, 2003; Rastle et al., 2004); therefore, they support an early morpho-orthographic stage during morphological processing. However, there is also research showing the opposite: a morpho-semantic stage during early morphological processing. These studies assert that semantically dissimilar (opaque) word forms do not prime their stems (e.g., Feldman et al., 2009; Feldman et al., 2012). Since Turkish is a morphologically highly productive language, it is expected that opaque primes in Turkish will not facilitate target words. Finally, it is anticipated that early morphological processing will be independent of orthographic relatedness as most of the previous research findings (e.g., Rastle et al., 2000; Marslen-Wilson et al., 2008) show that morphological properties drive the early decomposition process, not the form of words.

Despite the increasing number of studies on the processing of inflected and derived words together, their number is still comparatively low and the languages examined are predominantly Indo-European languages such as English and German. Therefore, with the purpose of generalizing the findings coming from these languages, it is necessary to analyse typologically different languages such as Turkish. As Frauenfelder and Schreuder (1992) suggest, Turkish is a great ground to be studied. Since there is only a handful of research (e.g. Gürel, 1999; Kırkıcı & Clahsen, 2013; Jacob et al., 2018) examining morphological processing in Turkish by using experimental psycholinguistic methods, more research needs to be conducted.

Methodology

In morphological processing research, priming is one of the most widely employed methods, with the lexical decision task being a common experimental paradigm used in priming studies. The lexical decision task, which operates within the visual word recognition system responsible for reading, requires participants to rapidly determine whether a presented stimulus is a real word in the target language. This method assumes that participants access their mental lexicon during the task. The priming paradigm follows the same general procedure as the lexical decision task but introduces a critical modification, making it an extension of the latter. Specifically, in the priming method, a stimulus (prime) is presented immediately before the target word, upon which participants make a lexical decision. When a word is encountered, its mental representation is activated along with related lexical items. Primes interact with the mental representation of target words in memory, allowing researchers to infer the structure of lexical representation by analyzing reaction time patterns for target words relative to control words (Gernsbacher, 1994).

In most of the morphological processing studies, masked priming, which is a type of priming, is used. With the help of this method, examining the relationships between the words and having an insight about how monomorphemic and polymorphemic forms are represented in the mental lexicon becomes easier.

The Present Study

In the experiment conducted for this study, the focus is on the processing of inflectionally and derivationally complex words. In addition to the similarities/differences between inflection and derivation, the effects of semantics and orthography are also analyzed in this experiment. Contrary to the previous studies carried out on Turkish, the types of inflectional and derivational morphemes are not limited in this research, which gives the opportunity to generalize the findings to more inflectional and derivational suffixes. Thus, a variety of morphemes and target words are used. Since the processing of complex words is asserted to be influenced by phonological transparency, all suffixes are chosen carefully so as not to cause any changes in the word root.

Considering the statements made above, the purpose of the experiment is to examine the processing of inflectionally and derivationally complex words in native Turkish. Thus, the way in which Turkish native speakers process morphologically complex words and whether these words are stored in their mental lexicon as full forms or decomposed into their building constituents will be analyzed in the following sections.

The Experiment Design

The experimental methodology employed in this study is the masked priming paradigm. In this method, participants are first presented with a string of symbols, typically hash marks (e.g., #####). This is followed by the prime word (e.g., *yürüdü*), which is subsequently replaced by the target word (e.g., *YÜRÜ*). Since the prime appears between the forward mask (hash marks) and the target word, this technique is also referred to as the *sandwich technique*. Participants are required to make a lexical decision—determining whether the target stimulus is a real word or a nonword.

In masked priming experiments, the interval between the onset of the prime and the onset of the target, known as stimulus onset asynchrony (SOA), is kept extremely brief (typically 30-80 ms), rendering the prime nearly imperceptible to conscious awareness.

The masked priming technique was developed by Forster and Davis (1984) to prevent participants from adopting predictive strategies, as they are unable to consciously perceive the primes during the initial stages of visual word recognition. This paradigm is well-suited to the present study, as Boudelaa and Marslen-Wilson (2005) suggest that during the early stages of visual word recognition, complex words are automatically decomposed into their constituent morphemes. Moreover, as Forster and Davis (1984) argue, masked priming minimizes the influence of episodic memory effects.

Furthermore, masked priming experiments allow precise control over the relationship between prime and target words, facilitating the systematic investigation of the role of orthography, semantics, and morphology.

Materials

In the present experiment, there are 150 Turkish words serving as critical targets all of which are paired with a prime. In addition to these critical items, there are 300 fillers and 10 practice items. The experimental stimuli comprised of five prime-target conditions in total. These are inflectional transparent, inflectional opaque, derivational transparent, derivational opaque, and form. All the sets had two conditions: related and unrelated. Unrelated primes were morphologically, semantically, and orthographically unrelated (-M, -S, -O) with the target words, and they did not share any letters in the same position. The first set was composed of 30 inflectional transparent items (see Appendix 1). The related primes were morphologically (inflectionally), semantically, and orthographically related (+M, +S, +O). The second set was composed of 30 inflectional opaque items (see Appendix 2). The related primes were morphologically (inflectionally) and orthographically related but semantically unrelated (+M, -S, +O). The third set was composed of 30 derivational transparent items (see Appendix 3). The related primes were morphologically (derivationally), semantically, and orthographically related (+M, +S, +O). The fourth set was composed of 30 derivational opaque items (see Appendix 4). The related primes were morphologically (derivationally) and orthographically related but semantically unrelated (+M, -S, +O). The fifth set was composed of 30 form items (see Appendix 5). The related primes were orthographically related but morphologically and semantically unrelated (-M, -S, +O). All the targets were embedded in the primes. Form primes were made of the target words and non-Turkish suffixes. A sample set of stimuli is presented in Table 1.

Table 1. An example for the stimuli set

	Primes		Target
	Related	Unrelated	
Inflectional Transparent	geçti (passed)	önüne (in front of)	GEÇ (PASS)
Inflectional Opaque	hızlı (speedy)	annem (my mother)	HIZ (SPEED)
Derivational Transparent	azim (ambition)	uyur (sleeps)	AZ (LITTLE)
Derivational Opaque	kaygı (anxiety)	yorum (comment)	KAY (SLIDE)
Form	zarif (elegant)	aylar (months)	ZAR (DICE)

The length and frequency of the targets for each item type were kept as similar as possible. The same measure was taken also for related and unrelated prime sets for each item type (see Table 2). The reason behind this measure was to prevent any unwanted participant bias with regards to the experimental items. The frequency of all the experimental items was taken from the Middle East Technical University (METU) Turkish Corpus (Say et al., 2002).

Table 2. Mean word-form frequencies and length (in letters) of all the experimental items

Item type	Condition	Mean word-form frequencies	Mean number of letters
Inflectional Transparent	Target	95.77	3.50
	Related Prime	93.27	5.03
	Unrelated Prime	98.17	4.93
Inflectional Opaque	Target	97.63	2.97
	Related Prime	97.13	4.53
	Unrelated Prime	98.07	4.6
Derivational	Target	96.00	3.30

Transparent	Related Prime	95.07	5.23
	Unrelated Prime	96.97	5.13
Derivational Opaque	Target	98.20	3.13
	Related Prime	98.23	4.87
	Unrelated Prime	97.97	4.90
Form	Target	87.37	3.10
	Related Prime	88.73	4.80
	Unrelated Prime	97.73	4.73

To preclude participants from guessing the purpose of the experiment and coming up with strategies about the order of the words, 113 nonword-nonword, 112 word-nonword, and 75 nonword-word filler pairs were also added to the experimental word pairs. The Turkish module of the software Wuggy (Keuleers & Brysbaert, 2010) was used to generate nonwords, thus making sure that all the nonwords were in line with the orthographic and phonological properties of Turkish. The filler primes and targets were also matched in terms of length with the experimental primes and targets.

Moreover, a Latin Square design was used to create two lists by distributing all prime-target pairs. The order of filler and experimental items were pseudo-randomized to make sure that the same prime-target pair types did not occur successively. Furthermore, the lists were reversed with the aim of eliminating the fatigue effect, which means that there were four lists in total at the end. In each list, half of the targets were preceded by a related prime, and the other half was preceded by an unrelated prime.

According to Clahsen et al. (2001), target words should not bring any new material which is not available from the prime to check the priming effects of the stem since there is a possibility that the unprimed material can decrease potential priming effects (as cited in Kırkıcı & Clahsen, 2013). All the targets were simple words, and they were presented in upper case letters while the primes were presented in lower case with the aim of minimizing visual overlap between them.

Participants

A total of 44 native speakers of Turkish (mean age = 22.16 years, SD = 3.72, age range = 18-31, 22 females) participated in this study. All participants reported having acquired Turkish as their first language from birth. They were randomly selected from **** University and participated voluntarily. No financial compensation or course credit was provided. All participants were either undergraduate or graduate students and were unaware of the study's purpose until the experiment concluded. Additionally, all participants reported having normal or corrected-to-normal vision, and none disclosed a history of neurological or psychological disorder.

Procedure

A laptop with a 15.6-inch monitor was used to run the experiment. The computer ran on a Windows 8.1 system. The experiment was controlled by the software DMDX (Forster & Forster, 2003), and responses to the target words were collected via a Logitech gamepad. The masked visual priming method (Forster & Davis, 1984) was used with the help of the software.

A pilot study was conducted with six participants to refine the experimental design and implement necessary adjustments. During this process, participants' responses, reaction times, and feedback were carefully evaluated to refine the experimental design.

The experiments took place at Hacettepe University. Before the beginning of the experiment, each participant was given an informed consent form, which made clear that they could withdraw from the experiment any time they wished. The participants were instructed to decide whether the presented string of letters were real Turkish words or not as accurately and fast as possible and press the appropriate button on the gamepad. The participants were provided with both oral and written instructions before the experiment started. All the participants were instructed to use their dominant hand to press the 'yes' button whether it was right or left.

Each experiment started with 10 trials as an orientation process, and at the end of this process, the participants could ask any questions they had. Just after the short practice session, a manipulation checklist (see Appendix 6) was given to the participants in order to make sure that the primes could not be recognized. In the checklist, there were some of the primes and targets, as well as some other words which did not appear during the practice session. The participants were requested to mark the words that they had seen. None of the participants marked the primes presented during the practice session. Then, they could start the actual experiment.

Each trial started with a forward mask of hash signs (#) for 500 milliseconds (ms). The number of hash marks was the same as the number of letters in the primes they were matched with. The forward mask served as a fixation point. After the hashes, the prime was shown for 50 ms and then the target word was displayed for 500 ms. When the time for the target word passed, the participants had 5000 ms to decide whether the word shown was an existing word or not (see Figure 1). The background colour was black while the words were displayed in white colour, primes with Bookman Old Style and targets with the Courier New font in size 28.

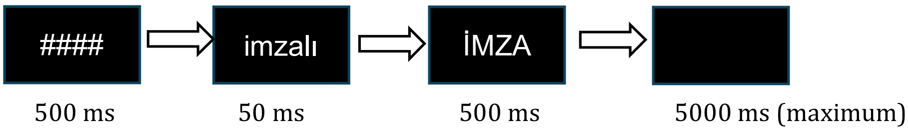

Figure 1. Representation of the sequences for each trial in masked priming procedure

There was one break during each experiment after half of the test trials were completed. After half of the test trials were completed, the software paused, and the participants saw instructions telling them that they could continue the experiment whenever they were ready to do so. The experiments were carried out in a quiet place. Each experiment lasted approximately 30 minutes. Upon completion of the experiment, each participant was asked to describe their experience, report their observations, and speculate on the study's objective. No subject stated seeing any prime stimulus.

Data Analysis

Prior to the analyses, data was cleaned by applying the steps used in previous morphological processing studies. In order to do so, first, all response times to fillers and practice items were deleted. Second, two inflectional transparent and one derivational opaque item were removed as they were responded to incorrectly by more than 30 percent of the participants. Additionally, responses of two participants were also removed since they reacted to more than 20 percent of the items incorrectly. Then, inaccurate responses (i.e., nonword responses to real words) and outliers (extreme RTs) were excluded from the analysis. Reaction times below or above 2.5 standard deviations were treated as outliers and they were not included in any further analyses.

As in Diependeale et al. (2011), in order to reduce the positive skewness of the data distribution, all reaction times were inverse transformed by dividing -1000 by the reaction times (i.e., -1000/RT). Then, inverse transformed data were submitted to repeated measures analysis of variance (ANOVA) with the factors item type (inflectional transparent, inflectional opaque, derivational transparent, derivational opaque, and form) and relatedness (related and unrelated). After this, planned comparisons (post-hoc tests) were performed to examine the significant main effects. Lastly, in order to find out the significant main effects, paired-samples t-tests were performed.

Results

In this section, firstly, descriptive results of the experiment are presented. After that, inferential results are given. In the inferential results part, statistics obtained from the analyses are given.

Descriptive Results

Table 3 shows the mean reaction times, standard deviations (SDs), and priming effects for inflectional transparent, inflectional opaque, derivational transparent, derivational opaque, and form conditions. Participants responded to transparent (both inflectional and derivational) words faster than opaque (both inflectional and derivational) and form words. Participants responded to target words with related primes faster than target words with unrelated primes (except for inflectional opaque), but the priming effects were significant only in inflectional transparent and derivational transparent conditions. These effects suggest that morphological complex words with transparent relationships between the prime and the target are processed via decomposition, facilitating faster lexical access. Conversely, the lack of significant priming effects in the other conditions demonstrates that morphological decomposition does not occur when semantic transparency is absent or when words share only orthographic similarities. These findings suggest that early decomposition is not purely form-driven.

Table 3: Mean RTs (in ms), SDs (in parenthesis), and priming effects in the experiment

Item Type	RTs	Priming Effect
Inflectional Transparent	646.26 (131.22)	39.89
Inflectional Opaque	683.18 (140.09)	-3.68
Derivational Transparent	640.72 (140.34)	38.80
Derivational Opaque	681.00 (144.38)	6.75
Form	675.09 (128.68)	12.98

Table 4 shows the mean number of errors and percentage of errors for each item and prime type. The highest number of errors were seen in inflectional transparent targets preceded by unrelated primes while the lowest number of errors were seen in inflectional opaque targets primed by unrelated words.

Table 4: Mean number of errors and percentage of errors in the experiment

Item Type	Mean number of errors	Percentage of errors
Inflectional Transparent Related	1.07	7.14
Inflectional Transparent Unrelated	1.26	8.41
Inflectional Opaque Related	0.67	4.44
Inflectional Opaque Unrelated	0.45	3.02
Derivational Transparent Related	0.52	3.49
Derivational Transparent Unrelated	0.52	3.49
Derivational Opaque Related	0.79	5.24
Derivational Opaque Unrelated	1.12	7.46
Form Related	0.86	5.71
Form Unrelated	1.07	7.14

Inferential Results

The repeated measures ANOVA conducted on the error data revealed significant main effects of item type (inflectional transparent, inflectional opaque, derivational transparent, derivational opaque, and form) in participant analysis ($F(4, 164) = 8.43$, $p < .001$). However, prime type (related and unrelated) did not demonstrate any significant main effects in item analysis ($F(1, 41) = 1.36$, $p < .250$). This suggests that the error rate differed statistically significantly among the five item types but not between the prime types. Subsequent planned comparisons demonstrated the following significant differences in terms of error rates:

inflectional transparent-inflectional opaque ($p < .003$)
inflectional transparent-derivational transparent ($p < .001$)
inflectional opaque-derivational opaque ($p < .033$)
derivational transparent-derivational opaque ($p < .012$)
derivational transparent-form ($p < .001$)

The repeated measures ANOVA analysis on the inverse transformed reaction time data demonstrated that there was a statistically significant main effect of prime type ($F(1, 41) = 23.47$, $p < .001$) in participant analysis. A paired samples t-test was run to see which item types had a significant difference between related and unrelated conditions. Table 5 demonstrates that inflectional transparent related items received significantly faster reaction times compared to inflectional transparent unrelated items ($t(41) = -5.22$, $p < .001$), and derivational transparent related items were responded to significantly faster than derivational transparent unrelated items ($t(41) = -7.39$, $p < .001$) across participants. On the other hand, no significant difference was found between the related and unrelated conditions of inflectional opaque, derivational opaque, and form items. These results suggest that only transparent (+M +S +O) items (both inflectional and derivational) yielded significant priming effects, indicating that morphological decomposition is driven by semantic transparency. These results highlight the role of semantics even at early stages. On the other hand, opaque (+M -S +O) items (both inflectional and derivational) and form (-M -S +O) items did not facilitate priming effects. These findings suggest that semantic relatedness plays a crucial role in early word recognition, contradicting purely morpho-orthographic accounts. These results also reinforce that morphological processing in Turkish is morphology-specific, not confounded by orthographic similarity.

Table 5: Pairwise comparisons of the RTs in the experiment

Pair 1	Inflectional Transparent Related Inflectional Transparent Unrelated	$t(41)=-5.22$, $p< .001$
Pair 2	Inflectional Opaque Related Inflectional Opaque Unrelated	$t(41)=-0.41$, $p< .683$
Pair 3	Derivational Transparent Related Derivational Transparent Unrelated	$t(41)=-7.39$, $p< .001$
Pair 4	Derivational Opaque Related Derivational Opaque Unrelated	$t(41)=-1.28$, $p< .207$
Pair 5	Form Related Form Unrelated	$t(41)=-1.88$, $p< .067$

Moreover, the repeated measures ANOVA analysis on the inverse transformed reaction time data also showed a significant main effect of item type ($F(4, 164) = 8.13$, $p < .001$) in participant analysis, but not in item analysis ($F(4, 142) = 1.55$, $p < .19$). Planned pairwise comparisons revealed that the differences between the items reported below were statistically significant:

inflectional transparent-inflectional opaque ($p < .019$)
inflectional transparent-derivational opaque ($p < .006$)

inflectional transparent-form ($p < .002$)
derivational transparent-inflectional opaque ($p < .001$)
derivational transparent-derivational opaque ($p < .001$)
derivational transparent-form ($p < .001$)

These results indicate that transparent items (both inflectional and derivational) were significantly faster than opaque (both inflectional and derivational) and form items, whereas there was no significant difference between inflectional opaque and derivational opaque items ($p < .578$), inflectional opaque and form items ($p < .478$), and derivational opaque and form items ($p < .882$).

Discussion and Conclusion

The present study aimed to examine the morphological processing of inflectionally and derivationally complex words in Turkish among native speakers. Specifically, it investigated the early stages of visual word recognition to determine whether complex words are stored in the mental lexicon as whole forms or decomposed into their constituent morphemes. The analysis of derivationally and inflectionally complex words was conducted to assess whether these two types of morphological complexity are processed similarly or differently. Additionally, the study explored the influence of semantic transparency and orthography on early morphological processing by incorporating opaque, form, and transparent word pairs. To address these research questions, a lexical decision experiment employing the visual masked priming technique was conducted. The following sections present a discussion of the experimental results in relation to the study's objectives and research questions.

Processing of Inflection and Derivation in L1

Regarding the processing of inflectionally and derivationally complex words, related primes facilitated reaction times to the target items statistically significantly in transparent conditions (39.89 ms and 38.80 ms priming effect respectively). This means that inflected and derived complex words are stored in native Turkish speakers' mental lexicon in a decomposed manner, not as whole forms. This result lends support to the findings of previous research conducted both on Turkish and other typologically different languages *(e.g., Silva and Clahsen, 2008 for English; Kırkıcı &andClahsen, 2013 for Turkish; Jacob et al., 2017 for German)*. The studies of Kırkıcı and Clahsen (2013) and Jacob et al. (2018) found comparable priming effects for inflection and derivation in native Turkish speakers, as well.

Moreover, no significant difference was found between the reaction times given to these two types of word pairs (derivational transparent and inflectional transparent). This can be considered as a convincing implication that inflectionally and derivationally complex words are represented similarly in the mental lexicon. This result is in contradiction with realization-based morphological theories (Matthews, 1991; Anderson, 1992). Instead, the results support dual-route models, where both inflected and derived words undergo morphological decomposition. Furthermore, the indication that inflected and derived words are decomposed during the early stages of visual word recognition supports the economy of storage principle. The reasons behind this may be the facts that Turkish is a rich language in terms of morphological processes and the number of words to be represented in the lexicon is quite high, which generates an immense amount of memory load (Frauenfelder & Schreuder, 1992). For the attenuation of this load, the decompositional track is better compared to full listing of all words. Besides, according to Hankamer (1989), a native speaker of Turkish who is educated is required to store more than 200 billion words. He also suggests that this number is well beyond the capacity of the mind, and the richness of Turkish in terms of morphology supports relying on decompositional processes.

One explanation for the lack of significant difference between inflectional and derivational processing could be the nature of Turkish morphology itself. As an agglutinative language, Turkish maintains consistent morpheme boundaries, making decomposition more efficient regardless of whether the affix is inflectional or derivational. Thus the current study highlights the importance of considering linguistic typology when interpreting morphological processing mechanisms.

The Effect of Semantics

In order to check whether semantics plays a major role in early morphological processing, opaque items (+M –S +O) were implemented for the experiment. The difference between related and unrelated conditions of opaque words (both inflectional and derivational) were found to be not significant. This was due to the fact that related items *(e.g., çilek 'strawberry')* were reacted to as slow as unrelated items *(e.g., konum 'location')* during the recognition of targets *(e.g., ÇİL 'freckle')*. This suggests that opaque items did not facilitate priming. These results imply that even though the presentation of the prime stimulus was very short (50 ms), semantic properties of words are significant in early visual word recognition. The finding that semantic transparency influences early morphological processing presents an intriguing contradiction to some established views in the literature. This finding runs counter to several studies arguing that early morphological processing is blind to semantic properties (e.g., Rastle et al., 2004; Longtin et al., 2003), and challenges morpho-orthographic accounts of early word recognition. Similarly, the finding in this study appears to contradict Şafak's (2015) observation that morphological processing in Turkish operates independently of semantic relatedness between complex words and their stems.

On the other hand, these results support previous studies, which posit that semantics plays a role in the early stages of morphological processing (e.g., Diependaele et al., 2011; Feldman et al., 2012). The presence of priming only for transparent items indicates that the visual word recognition system of Turkish speakers may be particularly sensitive to semantic coherence when analyzing morphologically complex words.

The Effect of Orthography

In this study, aside from transparent and opaque items, there are also form items, which are morphologically and semantically unrelated, but orthographically related (-M -S +O). The integration of this set of control items *(e.g., araba 'car' – ARA 'to call/to search')* allowed the experiment to check the role of word form properties in early visual word recognition. Form items did not produce any significant priming effects as related and unrelated primes elicited similar response latencies. This result is in line with earlier cross-linguistic findings (e.g., Rastle et al., 2000; Kırkıcı & Clahsen, 2013; Heyer & Clahsen, 2014; Jacob et al., 2018), which postulate that L1 processing of morphologically complex words is independent of orthographic relatedness. The lack of priming effects for form items despite orthographic overlap between primes and targets suggests that orthographic similarity alone is insufficient to trigger significant facilitation. This pattern indicates that early morphological processing in Turkish is primarily guided by morphological structure with semantic constraints, while being relatively blind to purely orthographic properties.

General Discussion

To sum up, the following general conclusions can be drawn based on the findings of the current research. First, complex words with inflectional and derivational suffixes are stored in the mental lexicon in a decomposed fashion (i.e., root+suffix) and they yield equivalent priming effects. Second, native Turkish speakers' early visual word recognition is affected by the semantic transparency of items, that is transparent items were responded to significantly faster than opaque items. Finally, the morphological processing of complex words in Turkish is not affected by form properties. Hence, it can be argued that priming effects are obtained in the absence of orthographic relatedness.

The significant priming effects for transparent items indicate that decomposition occurs during processing, which appears to support Taft and Forster's (1975) full decomposition hypothesis. However, the absence of priming for opaque items challenges the strict version of this theory, which would predict decomposition regardless of semantic transparency. Similarly, the results do not align with Butterworth's (1983) full listing hypothesis, which would predict no priming effects for any condition, as all words would be accessed as whole units without decomposition.

Instead, the findings of the current study most closely resemble predictions from hybrid models such as Pinker's (1999) Words and Rules Theory, which proposes that both direct access and decomposition routes are available during processing. However, the findings suggest a modification to this theory, particularly for agglutinative languages. Rather than distinguishing between regular and irregular forms (as Words and Rules Theory does for English), the processing distinction in Turkish appears to be primarily based on semantic transparency. Transparently related forms undergo decomposition, while semantically opaque forms may be processed through direct access despite their regular morphological structure.

This pattern supports a dual-route model that is semantically constrained, where the decomposition route is favored for semantically transparent forms, and the direct access route is employed for forms where decomposition would yield semantically incongruent constituents. Such a model would be particularly adaptive for processing in agglutinative languages like Turkish, where decomposition is typically the more efficient strategy but must be constrained by semantic plausibility to prevent misanalysis.

For further studies, as there was a significant priming effect caused by the semantics of words, further research can be conducted with different SOAs (e.g., 30 ms, 80 ms, 130 ms) in order to examine the time course of morphological processing. Moreover, only semantically related items (-M +S –O) such as *klavye 'keyboard' – FARE 'mouse'*, which are not implemented in the present study, can also be employed to better understand the role of semantics in early word recognition.

Ethics Committee Approval

An ethics committee approval was granted by Hacettepe University, Ethics Committee before the experimental session started. Date: May 24, 2016. E-35853172-431-1640

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No potential conflict of interest was reported by the authors

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Appendices

Appendix 1: Inflectional Transparent Items

Prime Conditions		**Target**
Unrelated	**Related**	
gider	adamı	ADAM
gidip	babam	BABA
elimi	çaldı	ÇAL
gören	değer	DEĞ
budur	dersi	DERS
zorlar	emindi	EMİN
suya	fonu	FON
önüne	geçti	GEÇ
uçmak	yürüdü	YÜRÜ
güçlü	halde	HAL
suyu	indi	İN
salla	jetin	JET
üstüme	kamuda	KAMU
açın	ligi	LİG
ağlar	maaşı	MAAŞ
övgü	notu	NOT
vuran	ürünü	ÜRÜN
girip	oranı	ORAN
sürdü	tarzı	TARZ
gözü	payı	PAY
düşüş	riski	RİSK
laflar	sitede	SİTE
baktı	sordu	SOR
yazdı	telim	TEL
yapar	tenin	TEN
zevki	uğrar	UĞRA
coşkun	vadede	VADE
ölçmek	yalıda	YALI
olma	kalktı	KALK

asık	zili	ZİL

Appendix 2: Inflectional Opaque Items

Prime Conditions		Target
Unrelated	Related	
içki	ayı	AY
uyur	azim	AZ
sürer	bacak	BACA
uçtu	bela	BEL
düzey	borsa	BOR
ekip	boya	BOY
cini	boza	BOZ
uzan	çayır	ÇAY
zorla	daire	DAİR
girdi	demir	DEM
tepki	döviz	DÖV
ruhu	fena	FEN
sona	film	FİL
yüzey	gitar	GİT
yerli	halka	HALK
ilde	gene	GEN
diyor	hazır	HAZ
yumak	martı	MART
topu	sekiz	SEK
gördü	otur	OT
akın	özür	ÖZ
üçgen	pasta	PAS
dilli	serum	SER
adlı	sıra	SIR
koydu	şahin	ŞAH
bitti	şarkı	ŞARK
dikiş	okul	OK
sevme	hasta	HAS
batı	illa	İL
kumsal	haciz	HAC

Appendix 3: Derivational Transparent Items

Prime Conditions		Target
Unrelated	Related	
doğu	açan	AÇ
pula	adaş	AD
vurgu	başla	BAŞ

sizin	canlı	CAN
eroine	davacı	DAVA
ayın	elle	EL
bunlar	farklı	FARK
başlı	seçim	SEÇ
annem	hızlı	HIZ
kaseti	imzalı	İMZA
bazda	istek	İSTE
şıklar	jöleli	JÖLE
andan	kaçış	KAÇ
boğmak	liseli	LİSE
genler	mayalı	MAYA
saati	akıllı	AKIL
zulada	naneli	NANE
dağı	olgu	OL
teki	örtü	ÖRT
sonsuz	pahalı	PAHA
görsel	planlı	PLAN
arzda	raylı	RAY
hayatı	renkli	RENK
yeşile	şakacı	ŞAKA
keser	taşlı	TAŞ
evim	uçan	UÇ
yönü	kurum	KUR
çıktı	yapan	YAP
girer	yatak	YAT
donmuş	zırhlı	ZIRH

Appendix 4: Derivational Opaque Items

Prime Conditions		**Target**
Unrelated	**Related**	
atıcı	bakla	BAK
yoksa	barış	BAR
özgür	basit	BAS
ürktü	bilek	BİL
kesme	çanak	ÇAN
köylü	damat	DAM
içici	dekan	DEK

yazıp	delil	DELİ
geçip	falan	FAL
kumun	fişek	FİŞ
uygun	gerek	GER
şansı	güreş	GÜR
yuttu	halat	HALA
sesin	kabak	KABA
atmak	kalıp	KAL
dergi	kanal	KAN
yorum	kaygı	KAY
büyür	kazan	KAZ
ölmek	masal	MASA
çıkan	milli	MİL
konum	çilek	ÇİL
yüklü	niyet	NİYE
tüyü	odak	ODA
üstün	paket	PAK
adlar	senet	SEN
önde	sevk	SEV
planı	sokak	SOK
alıp	üst	ÜS
birer	yanıt	YAN
verir	yazık	YAZ

Appendix 5: Form Items

Prime Conditions		**Target**
Unrelated	**Related**	
dolu	aday	ADA
sende	ajans	AJAN
yanı	aktif	AK
görüş	araba	ARA
dönüp	aşırı	AŞI
yüzüm	balo	BAL
ünlü	beyaz	BEY
sınav	çağrı	ÇAĞ
ikide	darbe	DAR
olsam	devre	DEV
yoktu	dikkat	DİK

yılım	disko	DİSK
aitti	dolap	DOL
tipim	efekt	EFE
güne	esas	ES
rayı	evre	EV
artar	gazoz	GAZ
uslu	golf	GOL
çeken	hapis	HAP
cine	iris	İRİ
ahlakı	karton	KART
senin	kolay	KOLA
tıpta	külah	KÜL
hapı	morg	MOR
dedem	namaz	NAM
günde	silah	SİL
pili	solo	SOL
sorsa	takas	TAK
bölüm	taraf	TARA
aylar	zarif	ZAR

Appendix 6: Manipulation Checklist

Lütfen alıştırma kısmında görmüş olduğunuz sözcükleri işaretleyiniz.

- ☐ Kalorifer
- ☐ Mavi
- ☐ Bulutlar
- ☐ Gez
- ☐ Çanta
- ☐ Kumurta
- ☐ Pırlanta
- ☐ Baklava
- ☐ Kumanda
- ☐ Çaycı
- ☐ Lastik
- ☐ Otur
- ☐ Kıvrıl