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Prosodic Focus Marking in Turkish: An Electrophysiological Study

Türkçede Bürünsel Odak İşlemleme: Elektrofizyolojik Bir Araştırma

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ABSTRACT

Focused elements are generally marked with syntactic canonicity and prosody. Being a scrambled language, Turkish uses both syntactic and prosodic information to mark the focus. However, it does not allow for focus marking in post-verbal position. In this study, the neurophysiological processes of the focus in Turkish are examined by using prosodic and syntactic information. Recent psycholinguistics studies assume that there is an interaction between prosody and syntax through the focus in the online sentence comprehension process. Thirty participants (16 female and 14 male between the ages of 19 and 33), whose native language was Turkish and who spoke monolingual Turkish, and who did not have any neurological, hearing, or linguistic impairments, took part in the experiments measured with Electroencephalogram (EEG). Using an event-related potentials (ERPs) design, this study provides evidence for an interaction between prosody and syntax in Turkish. The experimental design of the study consisted of prosodic, syntactic, and prosodic-syntactic violations. Participants were asked to listen 300 auditory stimuli (100 filler sentences) including sentences with both congruent and incongruent focus. The stimuli consisted of 50 sentences for each experimental condition. All critical words occurred in the sentence-final positions. For the prosodic violation critical words were focused via incongruent focusing on post-verbal position, and for the syntactic violation critical words were manipulated with case marking manipulation (i.e., accusative case versus dative case violations). In addition, for the interaction of prosodic and syntactic violations, critical words were incongruent focused and incongruent case was marked. The results revealed that prosodic incongruity elicited a broadly distributed positivity in posterior regions (400-1200 ms) lateralized to the left hemisphere and a right anterior negativity (RAN) (300-500 ms) effect. Syntactic violations also indicated a distributed anterior negativity (300-500 ms) effect. Supportive evidence for the late interaction of prosodic and syntactic processing in the neural integration of positive 600 (P600) and Closure Positive Shift (CPS) was observed. The findings provide support for recent neurocognitive approaches for late interaction between prosody and syntax in the sentence-final position in Turkish sentences.

Keywords: Focus, prosody, syntax, event-related potentials, auditory sentence comprehension

ÖZ

Odaklı birimler genellikle sözdizimsel düzenlilik ve bürün ile belirlenmektedir. Serbest sözdizimine sahip bir dil olan Türkçe odağı işaretlemek için hem sözdizimsel hem de bürünsel bilgiyi kullanmaktadır. Ancak bu dil, eylem-sonu konumunda odak işaretlemeye izin vermemektedir. Bu araştırmada bürünsel ve sözdizimsel bilgi kullanılarak Türkçede odağın nörofizyolojik süreçleri incelenmiştir. Günümüz psikodilbilim araştırmaları, bürün ve sözdizim arasında süreç-içi tümce anlamlandırma aşamasında odak aracılığıyla bir etkileşim oluştuğunu varsaymaktadır. Bu çalışma kapsamında anadili Türkçe ve tekdilli Türkçe konuşan, herhangi bir nörolojik, duyma ya da dile özgü bozukluğu bulunmayan 30 katılımcı (19-33 yaş aralığında 16 kadın ve 14 erkek) Elektroensefalografi (EEG) ile ölçüm yapılan deneylerde yer almıştır. Olaya ilişkin potansiyeller (OİP) kullanan bu araştırma, Türkçede bürün ve sözdizim arasındaki geç dönem etkileşimini ortaya koymaktadır. Çalışmanın deneysel deseni bürünsel, sözdizimsel ve bürün-sözdizimsel bozulmalar içermektedir. Katılımcılardan bozuk ve düzgün odaklı tümceleri içeren 300 işitsel uyaranı (100 dolgu uyaranı) dinlemeleri istenmiştir. Uyaranlar her bir deney koşulu için 50 tümceden oluşmaktadır. Tüm kritik sözcükler tümce-sonu konumunda bulunmaktadır. Bürünsel bozulmada kritik sözcüklere eylem-sonu konumunda bozuk odaklama yapılarak, sözdizimsel bozulmada kritik sözcükler durum işaretleme (belirtme durumuna karşı yönelme durumu bozulması) ile bozulmuştur. Bununla birlikte bürün-sözdizim etkileşimine ilişkin bozulmada kritik sözcükler hem bozuk olarak odaklanmış, hem de bozuk durum işaretleme yapılmıştır. Bulgular bürünsel bozulmada beynin arka bölgelerinde sol yarıküreye yanallaşmış geniş yayılımlı bir pozitivite (400-1200 ms) ve sağ ön negativite (RAN) etkisi (300-500 ms) olduğunu göstermektedir. Sözdizimsel bozulma ise çiftyönlü ön negativite (300-500 ms) oluştuğunu ortaya koymaktadır. Bürünsel ve sözdizimsel süreçlerde pozitif 600 (P600) ve Pozitif Kapanma Etkisi'nin (KPE) nöral bütünleşmesinin destekleyici etkisine ulaşılmıştır. Bulgular Türkçede tümce-sonu konumunda bürün ve sözdizimi etkileşimine ilişkin günümüz nörobilişsel yaklaşımlarına destek sunmaktadır.

Anahtar Kelimeler: Odak, bürün, sözdizim, olaya ilişkin potansiyeller, işitsel tümce anlamlandırma

Prosody and syntax processing has recently received increased attention in psycholinguistic and neurolinguistics research. The role of prosody and syntax is described with various cognitive functions. Online processing of prosody and syntax interaction in auditory language comprehension has extensively centered on focus processing, prosodic breaks, pitch accents, and intonational phrase boundaries (IPhs). To investigate prosodic processing and its interaction with syntax, researchers have made extensive use of intonational phrase boundaries and focus processing both in silent reading and spoken language comprehension. While the studies using silent reading comprehension are related to implicit prosody (e.g., Hwang & Steinhauer, 2011; Steinhauer, Alter, & Friederici, 1999), the studies using auditory language comprehension investigate prosodic variations and focus processing via pitch accents (e.g., Pannekamp, Toepel, Alter, Hahne, & Friederici, 2005; Bögels, Schriefers, Vonk, Chwilla, & Kerkhofs, 2010; Honbolygó, Török, Bánréti, Hunyadi, & Csépe, 2016).

The aim of the present study was to investigate four event-related potentials in Turkish sentences: A Right Anterior Negativity (RAN) for prosodic violation, a negative 400 (N400) or anterior negativity for syntactic violation, a Closure Positive Shift (CPS) followed by a late positivity effect of positive 600 (P600) for prosody-syntax interaction. As far as is known, this is one of the first studies investigating the event-related potentials (ERPs) effects of prosodic focus processing in Turkish that measures the electrophysiological responses during online auditory sentence comprehension. Neural basis of prosodic and syntactic processing in previous neurolinguistics research (see Friederici, & Eckstein, 2005, 2006; Honbolygó, Török, Bánréti, Hunyadi, & Csépe, 2016) provides a clear effect of an integration of prosodic focus marking and an effect of prosody on syntax, or vice versa. In short, three hypotheses are tested in the present study. Firstly, a RAN effect followed by a P600 is expected in the ERPs for the prosodic incongruity of focus marking on second syllable of the critical word onsets on the post-verbal position in Turkish sentences. Secondly, an N400 or anterior negativity effect followed by a P600 is expected, reflecting the late reanalysis and repair processing in the ERPs for the syntactic incongruity of accusative case vs. dative case marking violation. Thirdly, a CPS effect is predicted, which is followed by a P600 effect, in the ERPs for prosodic boundaries and a neural interaction of prosodic and syntactic processing on Turkish post-verbal position.

Previous definitions and theoretical assumptions on electrophysiological markers of prosodic and syntactic focus processing in different languages and the experimental paradigm conducted in Turkish will be reviewed in the following section. Then, the findings of our auditory data from the EEG experiment and a discussion of prosodic and syntactic processing of focus in Turkish during online auditory sentence comprehension will be presented.

Psycholinguistics Evidence on Prosodic and Syntactic Processing

ERPs provide a high temporal resolution to test the processes in intonational phrase boundaries such as pause durations between syntactic phrases and pitch accent variations (See Itzhak, Pauker, Drury, Baum, & Steinhauer, 2010; Kerkhofs, Vonk, Schriefers, & Chwilla, 2007; Pauker, Itzhak, Baum, & Steinhauer, 2011; Steinhauer et al., 1999; Pannekamp et al., 2005; Wolff, Schlesewsky, Hirotani, & Bornkessel-Schlesewsky, 2008). One possible specific ERP marker for IPhs is a positive shift in boundary positions, which is called CPS (first mentioned by Steinhauer, Alter, & Friederici, 1999). Steinhauer et al. (1999) stated that prosody could induce a reversed garden-path effect in German sentences. Researchers reported a CPS effect about 500 ms in between prosodic boundary and no-prosodic boundary conditions. CPS is found in many studies on different languages where similar ERPs methods were used (see e.g., Chinese: Li & Jang, 2009; Dutch: Bögels et al., 2010; Kerkhofs et al., 2007; English: Itzhak et al., 2010; Pauker et al., 2011; German: Männel & Friederici, 2009; Steinhauer et al., 1999; Steinhauer, 2003; Pannekamp et al., 2005; Hungarian: Honbolygó et al., 2016; Japanese: Wolff et al., 2008; Korean: Hwang & Steinhauer, 2011). These ERP studies generally report that purely prosodic variations play a major role in auditory sentence comprehension. At this point, the question arises whether prosodic boundary manipulations are supposed to affect prosodic processing in Turkish sentence-final position.

Focus marking and its prosodic features impact syntactic processing which results in early and late ERPs effects (See Eckstein & Friederici, 2005, 2006; Honbolygó et al., 2016). The interplay between prosody and syntax was manipulated at two syntactic parameters in German sentences. The brain responses of prosody displayed a right hemispheric primacy as reported in Eckstein and Friederici (2005), which is called RAN effect[1]. This negativity differs from other ERP components such as N400 and Left Anterior Negativity (LAN) by its amplitude and scalp distribution. Therefore, this process is generally assumed to be purely related to prosodic violation. Eckstein and Friederici

1 RAN effect has also been reported for acoustic stimuli manipulations in Japanese sentences that are not intrinsically linked to prosodic effects (see e.g., Ueno & Kluender, 2003).

(2006) later reported RAN effect with an interaction of prosody and syntax by means of online focus processing. The researchers revealed that a broadly distributed prosodic negativity could influence syntactic parsing during late processing followed by P600. They also reported that the P600 reflected not only syntactic, but also prosodic re-analysis and integration processing. A current study of Honbolygó et. al. (2016) confirmed the RAN hypothesis of Eckstein and Friederici (2005). The researchers stated that RAN effect is elicited by a large prosodic incongruity followed by P600 for Hungarian sentences.

On the syntactic and semantic interpretations of auditory or silent reading processing of language (e.g., Frisch & Schlesewsky, 2001, Hagoort, Brown, & Groothusen, 1993; Kutas & Hillyard, 1980), N400 and LAN effects are two ERPs negativities occurring approximately within similar time ranges but having different topographic scalp distributions. N400 effect was first reported in Kutas and Hillyard (1980) as a negative deflection peaking around 400 ms post-onset for semantically anomalous words. The scalp distribution of this negativity elicits a centro-parietal distributed negativity. N400 effects are generally elicited by various types of linguistic manipulations that are not only for semantically anomalous words, but also for morphosyntactic manipulations. For instance, Frisch and Schlesewsky (2001) observed N400 and P600 effects for case marking violations in incorrect German sentences with different grammatical subjects. N400 was found when arguments were animate, and researchers indicated that animacy constitutes significant information in overcoming comprehension due to thematic competition in German.

The LAN effect is another well-discussed electrophysiological marker for particularly morphosyntactic violations. This electrophysiological marker generally occurs between 300–500 ms after the critical element. In addition, LAN reflects a left-lateralized negativity over the left anterior electrodes. Both N400 and LAN effects are indexed by a large positive shift called P600, which occurs between 500–900 ms after the stimulus post-onset (e.g., Coulson, King, & Kutas, 1998; Friederici, 2002; Friederici & Frisch, 2000; Gunter, Friederici, & Schriefers, 2000). This positive marker is related to N400 or LAN effects on syntactic reanalysis and correction of garden-path effects, grammatical violations, thematic hierarchizing, syntactic integration, repair, or complexity (see e.g., Friederici, 2002; Frisch & Schlesewsky, 2005; Hagoort et al., 1993; Hagoort, Brown, & Osterhout, 1999; Kaan & Swaab, 2003; Osterhout & Holcomb, 1992). Studies have reported these three effects for morphosyntactic case marking violations, namely N400, LAN and P600 effects (see e.g., Friederici & Frisch, 2000; Hopf, Bayer, Bader, & Meng, 1998). Since all these components were obtained in studies on linguistic processing of morphosyntactic information, they are likely to reflect the case marking manipulation in this study.

Prosodic Focus Processing in Turkish and the Present Study

A widely accepted linguistic theory for Turkish sentences suggests that Turkish is a phonologically or prosodically phrase level (Φ-level) language (e.g., Güneş, 2013, 2014; Kabak & Revithiodou, 2009; Kan, 2009; Kühn, 2013). While the canonical word order in Turkish is assumed to be SOV (subject-object-verb), Turkish exhibits a scrambled word order, and thus elements can occur both in pre-verbal and post-verbal positions in Turkish (See Erguvanlı, 1984; İşsever, 2007, 2008; Kelepir, 2001; Kornfilt, 2003, 2005; Kural, 1992, 1997). Since main prominence must precede the verb in all word order permutations in Turkish, any element with a high tone is not allowed to follow the verb. Post-verbal position is the preferred place for constituents that provide background information (i.e., discourse entities, which the speaker assumes the hearer already knows), hence these constituents do not bear focus feature (F) (See Erguvanlı, 1984; Göksel, 1998; Göksel & Özsoy, 2000, 2003; Güneş, 2013; Özge & Bozşahin, 2010). The fact that post-verbal position does not receive focus in Turkish allows us to control the position of critical words in both prosodic and syntactic manipulations in a completely crossed manner in this study.

The prosodic focus is realized through higher tone of the leftmost element of verb phrase (VP) in the SOV (subject-object-verb) order, that is, the focused object *bavul-u* 'suitcase-ACC' in the linguistic sample of (1a). In the cases of SVO (subject-verb-object) order, the focused object is the *uçak-ta* 'plane-LOC' as in (1b) since default focus occurs pre-verbally in this word order. However, the sentence in (1c) demonstrates an incongruent prosodic focus occurring post-verbally, that is, the focused object *bavul-u* 'suitcase-ACC' in sentence-final position. Prosodic violation in the present study is realized by locating the focused objects in the post-verbal position of Turkish. In this position, there is an obligatory IPh (i.e., the closure of the clause) appearing after the verb *unuttu* 'forget-PAST'. In this way, the prosodically marked post-verbal object signals a second IPh (IPh2) when the object is focused in sentence-final position. Prosodic focus violation between post-verbal object and the syntactic VP domain (i.e., the domain includes the verb and its complements) allows linguists to test the evidence for RAN and CPS effects in Turkish sentences. In the present study, a RAN followed by P600 is observed in SVO order as shown in (1c) where the prosodically focus is marked incongruently.

(1) Prosodic violation of focus processing in Turkish

a. [(Yolcu)$_{\Phi}$	(uçakta)$_{\Phi}$	(BAVULU$_{F}$	unuttu)$_{\Phi}$]$_{IPh}$
passenger	plane.LOC	suitcase.ACC	forget.PAST
‘The passenger forgot THE LUGGAGE on the plane’			
b. [(Yolcu)$_{\Phi}$	(UÇAKTA$_{F}$	unuttu	bavulu)$_{\Phi}$]$_{IPh}$
passenger	plane.LOC	forget.PAST	suitcase.ACC
‘The passenger forgot the luggage ON THE PLANE’			
c. *[(Yolcu)$_{\Phi}$	($_{VP}$uçakta	unuttu)$_{\Phi}$]$_{IPh1}$	[(BAVULU$_{F}$)$_{\Phi}$]$_{IPh2}$
passenger	plane.LOC	forget.PAST	suitcase.ACC
Intended meaning: ‘The passenger forgot THE LUGGAGE on the plane’			

Note. The abbreviations in (1) are as follows: Φ: phonological phrase; F: focused word; IPH: intonational phrase; IPH1: first intonational phrase; IPH2: second intonational phrase; VP: verb phrase; LOC: locative; ACC: accusative; PAST: past tense. An asterisk (*) marks conditions containing a syntactic and/or prosodic incongruities.

Many studies use various methodologies to monitor online processing of word order in Turkish such as self-paced reading or listening, auditory moving-window/ self-paced-listening task, eye-tracking, or sentence completion task. These studies are generally classified according to their post-verbal scrambling (e.g., Aydın, & Cedden, 2010), pre-verbal scrambling processing (e.g., Kahraman & Hirose, 2018; Özge, Marinis, Zeyrek, & Özge, 2013; Uzun, Arslan, & Aydın, 2020), pre-verbal scrambling processing of the effect of first language (L1) and second language (L2) (e.g., Bayrak-Kurt, 2020; Cedden & Aydın, 2019), and prosody-syntax interface (e.g., Atasoy, Höhle, Bastiaanse, & Popov, 2020; Bekar, 2016; Deniz & Fodor, 2017). Moreover, studies are also classified according to their relative clause attachment of Turkish L2 (e.g., Dinçtopal-Deniz, 2010), pre-verbal ditransitive processing (e.g., Kahraman, Sato, & Sakai, 2010; Kahraman, 2013), sentence comprehension processing on aphasia (e.g., MacWhinney, Osmán-Sági, & Slobin, 1991), pre-verbal scrambling on aphasia (e.g., Duman, Aygen, Özgirgin, & Bastiaanse, 2007), and pre-verbal and post-verbal scrambling on aphasia (e.g., Maviş, Arslan, & Aydın, 2019).

In terms of syntactic violations in the present study, instead of a word order violation, the case marking between the accusative case and the dative case was manipulated as seen in the linguistic samples of (2), since case marking in Turkish is encoded with a final suffix alternation. According to (a), the object in the pre-verbal position is focused (i.e., the focused object *uçak-ta* ‘plane-LOC’) and case marking is congruent in the post-verbal object. However, while the focused object remains in the same position, case marking of the post-verbal object is the dative case, which leads to a morphosyntactic violation in (2b). In (2c), for both prosodic and syntactic violation, the focused object and incongruently dative marked object is located in the post-verbal position.

(2) Prosodic violation of focus processing in Turkish

a.	[(Yolcu)$_{\Phi}$	UÇAKTA$_{F}$	unuttu	bavulu)$_{\Phi}$]$_{IPh}$
	passenger	plane.LOC	forget.PAST	suitcase.ACC
	‘The passenger forgot the luggage on the plane’			
b.	[(Yolcu)$_{\Phi}$	(UÇAKTA$_{F}$	unuttu	bavula)$_{\Phi}$]$_{IPh}$
	passenger	plane.LOC	forget.PAST	suitcase.DAT
	Intended meaning: ‘The passenger forgot the luggage on the plane’			
c.	*[(Yolcu)$_{\Phi}$	($_{VP}$uçakta	unuttu)$_{\Phi}$]$_{IPh1}$	[(BAVULA$_{F}$)$_{\Phi}$]$_{IPh2}$
	passenger	plane.LOC	forget.PAST	suitcase.DAT
	Intended meaning: ‘The passenger forgot the luggage on the plane’			

Note. The abbreviations in (2) are as follows: Φ: Phonological phrase; F: Focused word; IPH: Intonational phrase; IPH1: First intonational phrase; IPH2: Second intonational phrase; VP: Verb phrase; LOC: Locative; ACC: Accusative; PAST: Past tense. An asterisk (*) marks conditions containing a syntactic and/or prosodic incongruities.

The linguistic approach of prosodic focus interpretation ending after the verb in a canonical sentence (see e.g., Erguvanlı, 1984; Göksel, 1998; Göksel & Özsoy, 2000, 2003; Güneş, 2013; Özge & Bozşahin, 2010) has been widely accepted, therefore when a post-verbal element is focused in SVO order, this triggers prosodic incongruity. In addition, if a second IPh reading begins with incongruent prosodic focusing on post-verbal position, then it might be possible to test the prosodic boundary effect of CPS between the post-verbal object and the syntactic VP domain.

This study uses ERPs to report the emergence of the interaction between the processing of prosodic and syntactic information during online sentence comprehension in Turkish. The following three hypotheses were tested in the current study.

Prosodic incongruity could be recognized just after the second syllable of the critical word onsets on post-verbal position of Turkish declarative sentences in the current study. As cited above, the post-verbal position is generally accepted as a non-focused position in Turkish (e.g., Erguvanlı, 1984; Göksel, 1998). To indicate the prosodic focus manipulation on post-verbal position, a RAN effect distributed in the right hemisphere peaking around 300-500 ms followed by a late positivity effect of P600 was hypothesized. Eckstein and Friederici (2005), who first cited the RAN effect in German sentences, referred to this anterior negativity as reflecting a mismatch for prosodically incongruent words or an absence of prosodic information in a sentence. Prosodic information is discussed for the right-hemispheric pathway (e.g., Meyer, Alter, Friederici, Lohmann, & von Cramon, 2002; Sammler, Grosbras, Anwander, Bestelmeyer, & Belin, 2015). Since RAN reflects a pure aspect of auditory sentence comprehension processing, a RAN in the ERPs followed by a late positivity effect in Turkish for the main effect of prosodic incongruity on post-verbal position was presented.

H1. The prosodic incongruity of focus marking in the post-verbal position would elicit a right anterior negativity (RAN) in the ERPs, which is a purely prosodically driven ERP followed by a late positivity effect.

Since the use of prosody is strongly related to its syntactic structure, case marking features of the critical words from accusative case to dative case were violated to observe the syntactic incongruity. It was hypothesized that two negativity effects differ in their scalp distributions. First, an N400, which is a specific ERP component considered as a correlate of accessing the lexicon or semantic memory access (Kutas & Hillyard, 1980) or syntactic processing and syntax learning (see e.g., Delogu, Brouwer, & Crocker, 2019; Frisch & Schlesewsky, 2001; Qi et al., 2017) was assumed. The next hypothesized ERP component for syntactic incongruity is a distributed anterior negativity like a LAN effect, which has been well-discussed for morphosyntactic violations (see e.g., Coulson et al., 1998; Friederici, 2002; Friederici & Frisch, 2000; Gunter et al., 2000). Since syntactic manipulation is interpreted directly with a prosodic comprehension processing, it is not hypothesized to be a pure effect of the LAN. Therefore, a pure effect of N400 or a distributed anterior negativity between 300 and 500 ms followed by a late positivity effect of P600 between 500 and 800 ms time windows was expected.

H2. The syntactically incongruent critical word would elicit an N400 or a distributed anterior negativity in the ERPs at the point of case marking violation. In the next time-window, a P600 effect reflecting late processing of syntactic reanalysis and repair is expected.

The following approach was taken to detect an intonational phrase boundary effect, which is observed between the pre-verbal and post-verbal positions in Turkish sentences. CPS was hypothesized between 400 and 1200 ms followed by a late positivity effect of P600 between 500 and 800 ms for prosodic repair and reanalysis processing. CPS strongly refers to intonational phrase boundaries, reflecting a neuropsychological processing for prosodic and syntactic interaction in various languages, as cited in previous sections (see e.g., Bögels et al., 2010; Honbolygó et al., 2016; Hwang & Steinhauer, 2011; Steinhauer et al., 1999). From this point on, for the auditory sentence comprehension processing effect of intonational phrase boundary between pre-verbal and post-verbal positions, a CPS is hypothesized that is followed by a P600.

H3. A CPS effect during the phrase boundary between pre-verbal and post-verbal positions followed by a P600 would reflect a neural interaction between prosodic and syntactic information in the ERPs.

METHOD

Participants

Thirty (M = 23.4, 16 female and 14 male, all right-handed) native and monolingual Turkish participants with no neurological, hearing, or linguistic impairments were included in the Electroencephalogram (EEG) experiments. The Turkish version of the hand preference task of Chapman and Chapman (1987) was used to determine the hand dominance of the participants (for the Turkish version, see Nalçacı, Kalaycıoğlu, Güneş, & Çiçek, 2002). Participants were undergraduate students at Ankara University. The study was approved by the Ethical Board (*No: 13-430-12, Date: 27 August 2012*) of Ankara University. All the participants were compensated with 50 TRY for their participation and time spent.

Measures

Experimental Stimuli. The experimental stimuli consisted of 50 sentences for each of the following four experimental variables: Syntactically and prosodically congruent (PSC), prosodically incongruent (PI), syntactically incongruent (SI), and syntactically and prosodically incongruent (PSI). The most frequent word order with post-verbal constituent is SOV order in Turkish. Therefore, SVO sentences are used for the experiment, excluding the other word order possibilities with post-verbal constituents (OVS, VSO, and VOS)[2]. Experimental design of the present study involved the manipulation of four experimental variables that were completely crossed as seen in Table 1. Additional 100 grammatical sentences were included as filler sentences in order to maintain the same number of congruent and incongruent sentences throughout the entire set. Filler conditions were composed of grammatically congruent conditions (the same as condition PSC) to balance the experiment.

Table 1. Sample Stimuli for the Experimental Conditions

Con.	Sample Stimuli				Prosody	Syntax
PSC	[(Yolcu)$_{\Phi}$	(UÇAKTA	unuttu	**bavulu**)$_{\Phi}$]$_{IPh}$	congruent	congruent
	passenger	plane.LOC	forget.PAST	luggage.ACC		
	'The passenger forgot the luggage in the plane'					
PI	*[(Yolcu)$_{\Phi}$	(uçakta	unuttu)$_{\Phi}$]$_{IPh}$	[(**BAVULU**)$_{\Phi}$]$_{IPh}$	incongruent	congruent
	passenger	plane.LOC	forget.PAST	luggage.ACC		
	Intended meaning: 'The passenger forgot the luggage in the plane'					
SI	*[(Yolcu)$_{\Phi}$	(UÇAKTA	unuttu	**bavula**)$_{\Phi}$]$_{IPh}$	congruent	incongruent
	Passenger*	plane.LOC	forget.PAST	luggage.DAT		
	Intended meaning: 'The passenger forgot the luggage IN THE PLANE'					
PSI	*[(Yolcu)Φ	(uçakta	unuttu)Φ]$_{IPh}$	[(**BAVULA**)$_{\Phi}$]$_{IPh}$	incongruent	incongruent
	passenger	plane.LOC	forget.PAST	luggage.DAT		
	Intended meaning: 'The passenger forgot THE LUGGAGE in the plane'					

Auditory stimuli included a subject (e.g., *yolcu* 'passenger'), a finite transitive verb (e.g., *unuttu* 'forget.PAST') together with its direct object (e.g., *bavulu* 'luggage.ACC') and a locative adjunct (*uçakta* 'in the plane'). For all experimental sentences in Table 1, the variables of prosody and syntax as either congruent or incongruent on the critical word (i.e., the direct object) were manipulated in relation to its position. Syntactically congruent and incongruent conditions were created by manipulating different case markers (See Table 1 for conditions PSC/PI and SI/PSI respectively). Syntactic congruity was provided by the appropriate accusative suffixes for nouns ending with consonant [–ı/–i/–u/–ü] or vowel [–yı/–yi/–yu/–yü] (see the conditions PSC and PI in Table 1). These suffixes depend on

2 Slobin and Bever (1982) examined the relative frequencies of the word order possibilities in terms of NNV (noun-noun-verbs), NVN, and VNN sequences in Turkish. Their results showed that the relative frequency of NNV sentences is 56% and that of NVN was 38%. The most frequent order with post-verbal constituents (i.e., NVN and VNN) in their data was the subject-first construction: SVO (66%). The other word order possibilities with post-verbal constituents in their data were used less frequently: 34% for OVS sentences, 6% for VSO. VOS order was not present in the speech samples collected by Slobin and Bever (1982). See Batman-Ratyosyan and Stromswold (1999) for the frequency of occurrence of word order types in Turkish adapted from Slobin and Bever (1982). For the similar results, see also Maviş et al., (2019); Özge, Küntay, and Snedeker (2019).

whether the vowel in the syllable preceding it is front or back, and rounded or unrounded: *duvar–ı* (wall–ACC), *kalem–i* (pencil–ACC), *oyun-u* (game–ACC), *üzüm–ü* (grape–ACC). In syntactically incongruent conditions, verbs misleadingly assign the dative case to their object NPs, when in fact they should assign the accusative case (see the conditions of PSI/SI in Table 1). In such ungrammatical sentences containing dative objects, Turkish vowel harmony (e.g., Kabak, 2011) dictates that the choice of appropriate vowels for dative suffixes [–a/–e] depends on whether the vowel in the syllable preceding it is front or back: *duvar–a* (wall–DAT), *kalem–e* (pencil–DAT).

Furthermore, incongruent prosodic focusing is provided with incongruent focus in post-verbal position (see Table 1 for the conditions of PSI and PI). Being an agglutinative language, the canonical word order of Turkish is SOV (e.g., Erguvanlı, 1984; Göksel, 1998). As mentioned before, prosodic incongruence is manipulated with post-verbal focusing, which is an inappropriate position for prosodic focus in Turkish (Erguvanlı, 1984; Göksel, 1998, 2013; Güneş, 2013, 2014; İşsever, 2000; Kan, 2009; Özge, 2003), and the phonetic features of a focused element in post-verbal position is generally observed with a significant-fall in fundamental frequency (F0) curves of sentence intonation.

EEG Recording. The EEG was recorded in the electrophysiology laboratory of Ankara University Brain Research Center using the Brainamp DC EEG-ERP system with 32 channels appropriate for 10-20 systems and 32 Ag/AgCI electrodes (Electrocap International). Bipolar horizontal and vertical Electrooculograms (EOGs) were simultaneously recorded, especially for eye artifact control (one placed above the left eye and one placed below the left eye). All electrodes were referenced to the average of two linked ear lobes. The ground electrode was placed above the right eye. The EEG channels were filtered using a band-pass of 0.1 Hz-25 Hz sampling at 500 Hz. Impedance was kept under 5 kΩ.

Procedure

A set of 300 sentences was presented in a randomized order across six blocks containing 50 trials. Participants listened to the auditory stimuli, which were presented using a high-quality loudspeaker. They were seated inside the EEG Lab at approximately 70 centimeters (cm) from the stimuli screen. They were instructed to look at the fixation cross point (+) on the screen to minimize their eye movement artifacts. There were two fixation cross points: White fixation cross for the stimulus screen and blue fixation cross for the response screen. The white fixation cross point appeared in the middle of the screen for 500 ms and immediately afterwards, the auditory stimulus was presented while the fixation cross remained on the screen for another 1500 ms. Later, the blue fixation cross point appeared on the response screen. At that moment, participants had to judge whether the sentence was congruent by pressing *yes* (with the left button) or incongruent by pressing *no* (with the right button) within 3000 ms. There was a 1500 ms inter-stimulus interval (ISI) between each trial (See Figure 1). Between the blocks, six short resting periods of up to five minutes were given to the participants. Each session took approximately 50-60 minutes.

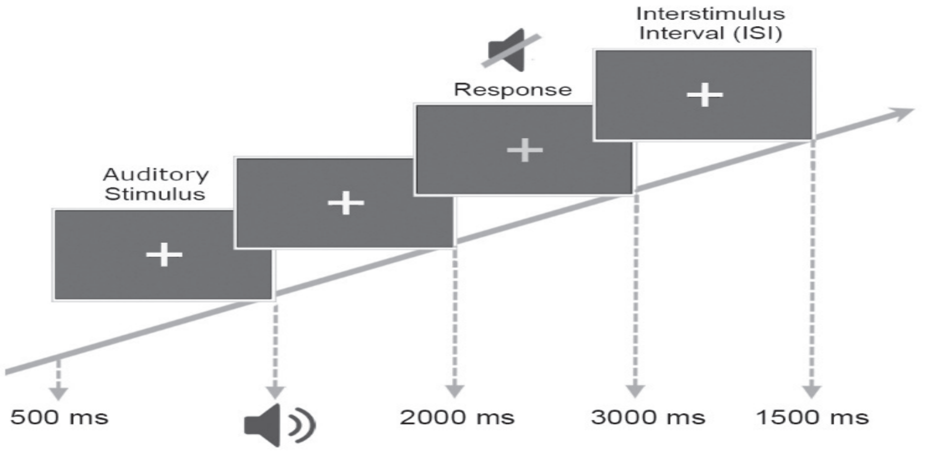


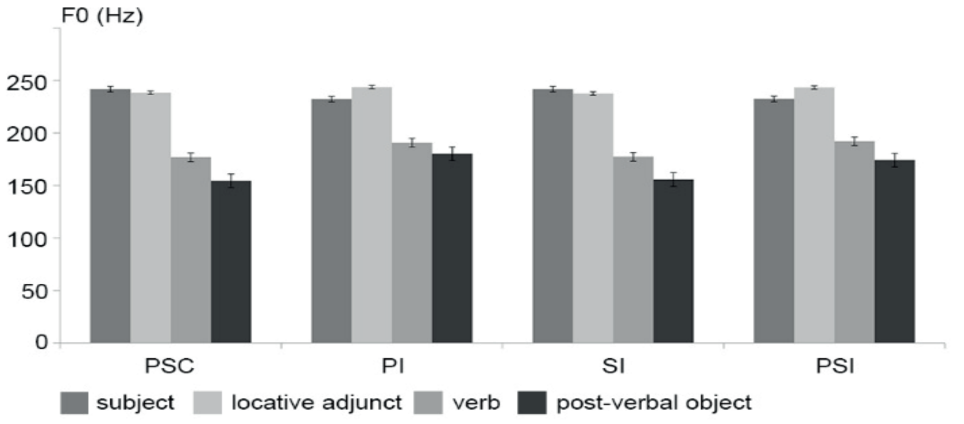
Figure 1. Auditory Stimulus Design of Experimental Procedure

Data Analyses

Acoustical Analyses of the Stimuli. A female native and monolingual speaker of Turkish produced 300 sentence pairs using a Shure Beta dynamic microphone with a 44.100 Hz sampling rate and 16-bit resolution Pulse Code Modulation (PCM) Waveform Audio File format in PRAAT 6.1.09 software (Boersma, 2006). Auditory data was used for EEG recordings. All the critical words were equal for their lexical stress features and all critical words had lexical stress in their final syllables. This phonological feature of critical words was checked in the spoken language dictionary of Turkish by Ergenç (1995). In order to prevent specific phonological issues (i.e., consonant cliticizations such as the semi-vowel /y/ used in *halı–yı* (carpet–ACC) in the final syllable), the second syllable of the critical word onsets (i.e., -*lı*- in ha-*lı*-yı [carpet-ACC]) was marked for trigger points of the experimental design. The experiment was written in Psych Toolbox. Data was spliced using PRAAT 6.1.09 Software according to the conditions.

A cross-splicing was used in PRAAT 6.1.09 (Boersma, 2006) to reduce most of the articulation issues (e.g., clicks, cracking noises) during the auditory recordings. Zero-crossing points of all the critical word positions were marked during phonological transitions, and critical words were switched according to their prosodic features. All experimental sentences were analyzed by their word onset times for their F0 (Hz) and duration (ms) values. To produce prosodically incongruent versions of syntactically congruent stimuli (i.e., the condition PI), the critical word from a non-focused post-verbal position that was prosodically incongruent was replaced, and vice versa. To create syntactically incongruent versions of prosodically congruent stimulus (i.e., the condition SI), the critical word from a syntactically incongruent sentence was replaced, and vice versa. Finally, to create both prosodically and syntactically incongruent stimulus, the critical word from a focused position of a syntactically incongruent sentence was replaced. Onset of the critical words with prosodically identical conditions (PSC/SI and PSI/PI) was equalized to minimize phonological differences in the articulation in pre-verbal positions that would affect the ERPs responses. All the recordings were checked for coarticulation and they were normalized at the same amplitude.

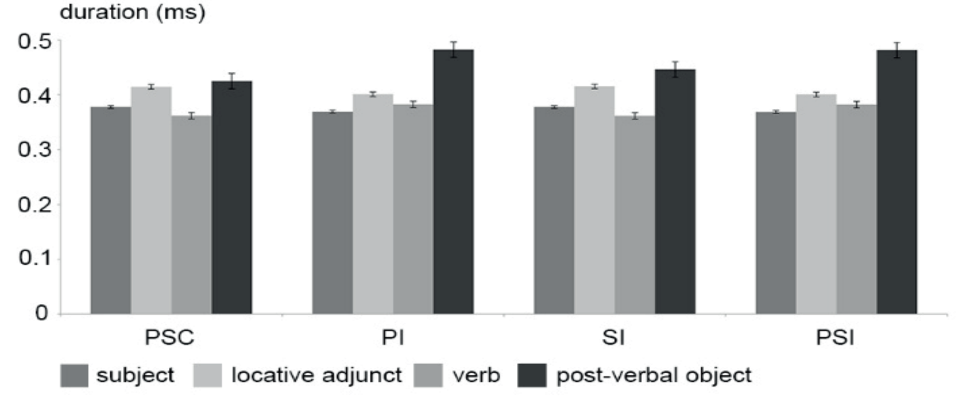
In order to confirm prosodic features of the critical nouns in the post-verbal positions, two main parameters were selected for phonetic analysis according to their acoustic characteristics. In particular, F0 and duration were analyzed for acoustic calculation. As described in Beckman (1996), F0 and duration exhibit a large part of the prosodic information and prosodic phrasing. As mentioned above, PRAAT 6.1.09 software (Boersma, 2006) was used for duration and F0 analyses by visual inspection for each experimental sentence in reference to previous studies that used cross-splicing method (e.g. Eckstein & Friederici, 2005, 2006). Firstly, the word onset and offset times of each word for the duration analysis were specified. Subtraction was used to calculate mean values of duration. The mean values indicated coherent results between experimental conditions. As noted previously, the critical words in PSC and PI conditions share the same prosodic features in their post-verbal positions due to their common prosodic incongruity. The critical words in SI and PSC conditions also bear the same prosodic congruity in their post-verbal positions. Since focusing –as an intonational prosodic feature– might extend the duration, mean values indicated compatible results between conditions (See Figure 2).



Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 2. Acoustic Measurement of the Fundamental Frequency (Hz) of Word Onset Positions

For the intonational contours, F0 mean values were analyzed. The calculation of F0 values were conducted to 75 Hz and 500 Hz of frequency range. As the mean values of duration show, F0 analyses also indicated similar acoustic characteristics between PSI/PI and PSC/SI conditions due to their prosodic congruity. To assure the acoustic features of the critical words in PSI and PI conditions, it is crucial to note here that the F0 means were lower in post-verbal positions than mean values of the critical words in PSC and SI conditions (See Figure 3). This result indicated that both the duration and F0 had compatible phonetic features in accordance with prosodic manipulation in post-verbal positions.



Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 3. Acoustic Measurement of the Durations (ms) of Word Onset Positions

Independent samples t-test was used for statistical analysis for the Condition (PSC, PI, SI and PSI), Parameter (F0 and duration) and Position (subject, locative adjunct, verb, and critical word). All the critical words of PSI and PI conditions displayed lower overall F0 values than they did in PSI and SI conditions (See Figure 3). For the duration means, the critical words shared coherent differences both in PSC/SI and in PSI/PI conditions. Statistical differences of the critical words between condition pairs of PSC/SI and PSI/PI were highly significant in F0 means ($t(98) = -11.958$, $p < .001$) and in duration means ($t(98) = -5.641$, $p < .001$). All statistical differences were ascertained before the critical word onsets in each experimental condition. These results indicated that experimental paradigm ensures the reliable acoustic phonetic features for all the critical words in post-verbal positions of Turkish experimental sentences.

Electrophysiological Analysis. Thirty participants were included in the electrophysiological analysis. EEG data were aligned to a −200 ms before and +1500 ms after the second syllable onset of the critical word trigger point (in total 1700 ms). All answers were included in the analysis. It was considered preferable to use a 70% success rate of ERP results for each participant during the online EEG recordings.

Manual rejection contained strong muscle artifacts, alpha waves, electrode drifts and other technical artifacts. Independent component analysis was used to reject eye blinks and eye movements. The data were filtered with a 0.1 Hz high-pass (low cutoff) and 25 Hz low-pass (high cutoff). Mean ERPs were computed separately for each participant before the grand means were calculated. The averaged data were aligned to −200 ms and 0 ms for baseline correction.

Three time-windows were selected based on visual inspection of 25 ms time windows for statistical analyses of ERPs and difference topographies: 300-500 ms (anterior negativities), 500-800 ms (P600), and 400-1200 ms (CPS). All the statistical analyses were done with unfiltered data. Four-way repeated measures of ANOVAs were calculated for the mean amplitudes including the factors Syntax (*Levels*: Congruent, incongruent) and Prosody (*Levels*: Congruent, incongruent), and for the topographical variables, Hemisphere (*Levels*: Left, right) and for the Region (*Levels*: Anterior, central, posterior). The four regions of interest (ROIs) for the lateral electrodes were left anterior (F3, F7, FC3, FT7), left central (C3, T7), left posterior (CP3, TP7, P3, P7, O1), right anterior (F4, F8, FC4, FT8), right central (C4, T8) and right posterior (TP8, CP4, P8, P4, O2).

ROIs for midline electrodes (Fz, FCz, Cz, CPz, Pz) were also calculated both for prosodic and syntactic effects. Multiple ROIs were used to indicate the effects of different ERP components. While the components of anterior negativities were predicted for the lateral electrode analysis, the CPS, N400 and P600 components were expected for the midline electrode analysis.

Based on interactions in the statistical analyses, following Eckstein and Friederici's (2006) analysis procedure, separate follow-up analyses were performed to determine the differences between condition pairs. In order to examine the impact of prosodic violations on syntax, separate follow-up analyses in prosodically congruent (SI vs. PSC) and prosodically incongruent (PSI vs. PI) conditions testing the variable of Syntax in each ROI were calculated. Moreover, to examine the impact of syntactic violations on prosody, follow-up analyses in syntactically congruent (PI vs. PSC) and syntactically incongruent (PSI vs. SI) conditions testing the variable of Prosody in each ROI were performed. For both the main effects of Prosody or Syntax and for interaction analyses, the threshold for significance was $p < .05$. The mean amplitude difference for reliable main effects is shown in parentheses (Δ in μV).

RESULTS

Behavioral Data

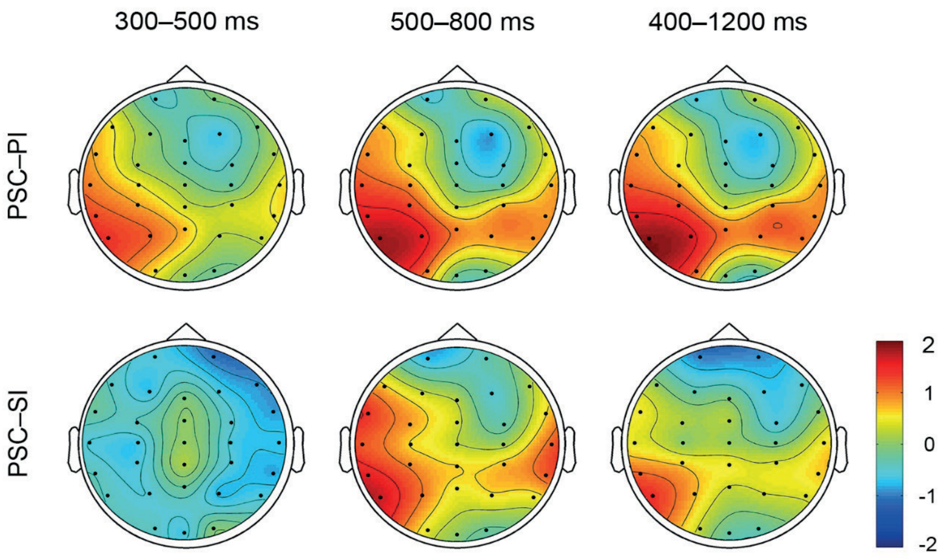
Behavioral data results confirmed that all participants did pay attention to the auditory sentences (across conditions 91.7% correct answers). Accuracy across the four sentence types were as follows: For the PSC: 48/50 (95%, *MD* = 49, ranged between = 40–50), the PI: 40/50 (80%, *MD* = 42, ranged between = 24–47), the SI: 47/50 (93%, *MD* = 49, ranged between = 42–50), the PSI: 49/50 (98%, *MD* = 49, ranged between = 46–50). Friedman ANOVA for the congruency judgment of the conditions revealed significant main effects: $\chi 2$ (3) = 65.6, $p < 0.001$, effect size $r = 0.73$. Subsequent Wilcoxon post-hoc tests showed that PI condition was rated significantly less acceptable than SI, PSC and PSI conditions: PSC vs. PI, $p < 0.001$, effect size $r = 0.86$; PSI vs. PI, $p < 0.001$, effect size $r = 0.87$; SI vs. PI, $p < 0.001$, effect size $r = 0.85$. The difference between SI and PSI was also significant ($p < 0.001$, effect size $r = 0.84$). On the other hand, the median score of PSCs was *not* significantly different from the median score of SI with a p-value = 0.47, effect size $r = 0.35$ and the median score of PSI with a p-value = 0.15, effect size $r = 0.45$.

Electrophysiological Data

In order to understand the interactions between Prosody and Syntax, a higher-level ANOVA with both the experimental variables was conducted: Prosody and Syntax, in three-time windows (See in Table 2). In the follow-up analysis, pairwise analyses for the condition pairs were computed.

The 300-500 ms Time Window

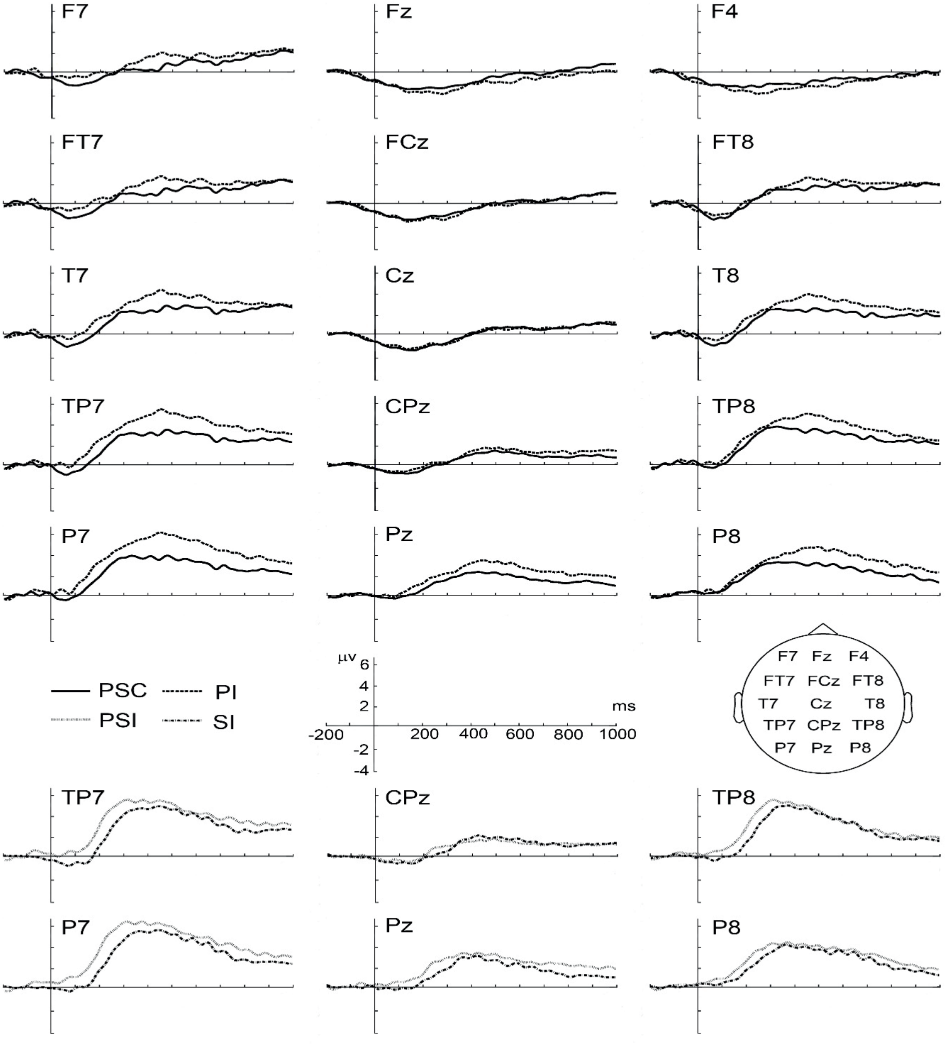
The visual inspection of the waveforms showed a RAN-like effect comparing the PI and PSC conditions, and statistical analysis confirmed these observations, as seen in Figure 4. A significant main effect of Prosody and a reliable two-way interaction between Prosody and Region were at the lateral and midline electrodes in the 300-500 ms time window (See Table 2).



Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 4. Difference Topography Maps of Subtracted ERPs of Prosodically and Syntactically Congruent Conditions from Incongruent Conditions (300-500 ms, 500-800 ms, 400-1200 ms)

Analyses also detected a significant three-way interaction between Prosody, Region and Hemisphere at the lateral electrodes in this first stage (See Table 2), which indicated a small negativity distributed over the right frontal scalp for prosodically incongruent sentences. To examine the effect of a syntactic violation on prosodic processing, follow-up analyses were performed in syntactically congruent (PI vs. PSC) and syntactically incongruent (SI vs. PSI) conditions, testing the variable of Prosody in each ROI. The follow-up analyses indicated significant differences between PI and PSC (syntactically congruent) conditions in the right anterior ROI; F (1,29) = 9.802, p < .05, Δ = −0.38 μV (See Figure 5).

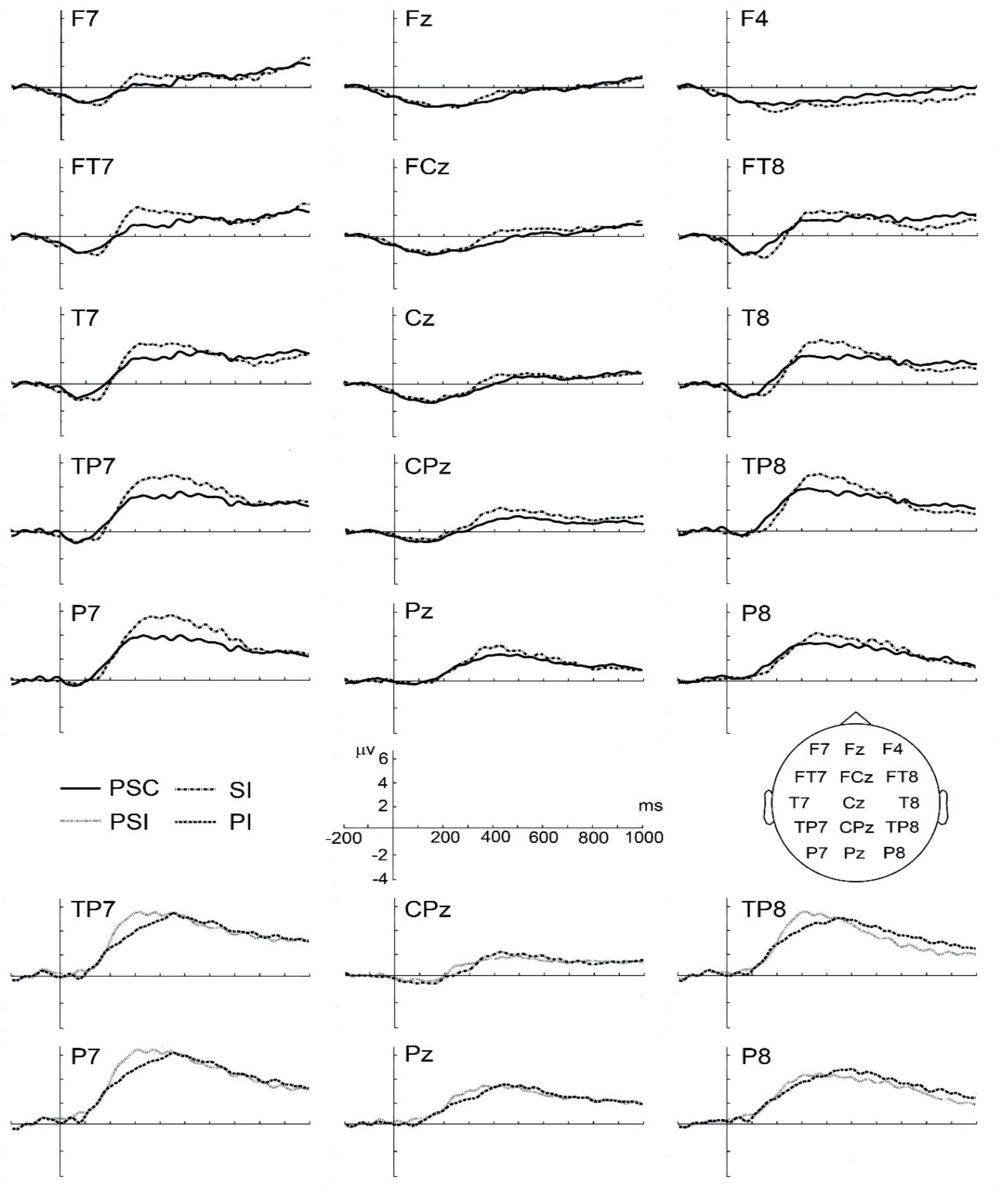


Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 5. Pairwise Presentation of the Averaged ERPs for Syntactically Congruent (PI vs. PSC) and Syntactically Incongruent (PSI vs. SI) Conditions Testing the Variable of Prosody

Moreover, the follow-up analyses revealed significant differences between SI and PSI (syntactically incongruent) conditions in the lateral electrodes [left central: F (1,29) = 26.984, $p < 0.001$, Δ = +0.99 μV; left posterior: F (1,29) = 29.761, $p < 0.001$, Δ = +1.31 μV] (see Figure 5). This result confirmed *H1* on RAN effect that prosodically incongruent sentences yielded more positive waveforms than congruent sentences in the anterior site of the scalp and a small negativity distributed over the right frontal scalp when syntax was incongruent or congruent.

As shown in Figure 4, visual inspection of the subtracted ERP waveforms of SI from PSC condition in the 300-500 ms time windows provided no evidence of distributed anterior negativity and N400 effects. This was confirmed by *H2* on distributed anterior negativity effect with statistical analyses at the 300-500 ms interval that is characteristic of this response (see Table 2). A significant two-way interaction between Syntax and Hemisphere at lateral electrodes indicated the negativity to be most pronounced in the right electrodes. However, there was neither Syntax × Region interaction nor a three-way interaction of Syntax, Region and Hemisphere, indicating that the syntactic negative effect did not differ by region (see Table 2). Resolving this effect, follow-up analyses for each region detected a reliable early negativity for PI compared to PSI in the lateral electrodes [right central: F (1,29) = 8.214, $p \leq .05$, Δ= −05, Δ= −05, Δ=; left central: F (1,29) = 9.704, $p < .05$, Δ = −05, Δ c (See Figure 6). Therefore, the observed interaction between Prosody and Syntax at the lateral and midline electrodes in the 300-500 ms time window (See Table 2) reflected the fact that a temporal negativity was present for syntactically incorrect sentences, but this effect was only observed when prosody was incongruent.



Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 6. Pairwise Presentation of the Averaged ERPs for Prosodically Congruent (SI vs. PSC) and Prosodically Incongruent (PSI vs. PI) Conditions Testing the Variable of Syntax

The 500-800 ms Time Window

In the 500-800 ms time window, significant main effects of Prosody were found, as well as a Prosody × Region interactions in the midline and lateral electrodes (see Table 2) because prosodically incongruent sentences yielded positive waveforms in the parietal site of the scalp (see Figure 4). Subsequent follow-up analysis showed a significant main effect of Prosody between PI and PSC conditions (midline: F (1,29) = 10.789, $p <$ .01, $\Delta = +1.66\mu V$; left posterior: F (1,29) = 8.833, $p <$. 05, $\Delta = +0.98\mu V$), as well as between SI and PSI conditions (midline: F (1,29) = 8.376, $p < .05$, $\Delta = +0.79\mu V$). The results reflected the fact that P600 response to prosodically incongruent sentences started in this interval and had a central posterior focus (see Figure 5). These results supported our late positivity predictions for P600 component on the first and second hypotheses for prosodic incongruity (*H1*) and syntactic incongruity (*H2*).

For the syntactically incongruent structures, there was a reliable broadly distributed positivity in the lateral and midline electrodes (see Figure 4). The lateral- and midline-analyses revealed a main effect of Syntax and a significant Syntax × Region interaction in the 500-800 ms time window. A highly significant interaction between Syntax, Region and Hemisphere in lateral electrodes was explored in this stage (see Table 2) and resulting from a significant positivity for syntactically incongruent structures compared to congruent ones in the left centro-parietal region (see Figure 4 and Figure 6). Pairwise comparison showed that the differences between PSC and SI (prosodically congruent) conditions were significant in midline and lateral electrodes (midline: F (1,29) = 9.769, $p < .05$, $\Delta = +1.39\mu V$; left posterior: F (1,29) = 10.548, $p < .05$, $\Delta = +0.90\mu V$), but this effect was only observed when prosody was congruent.

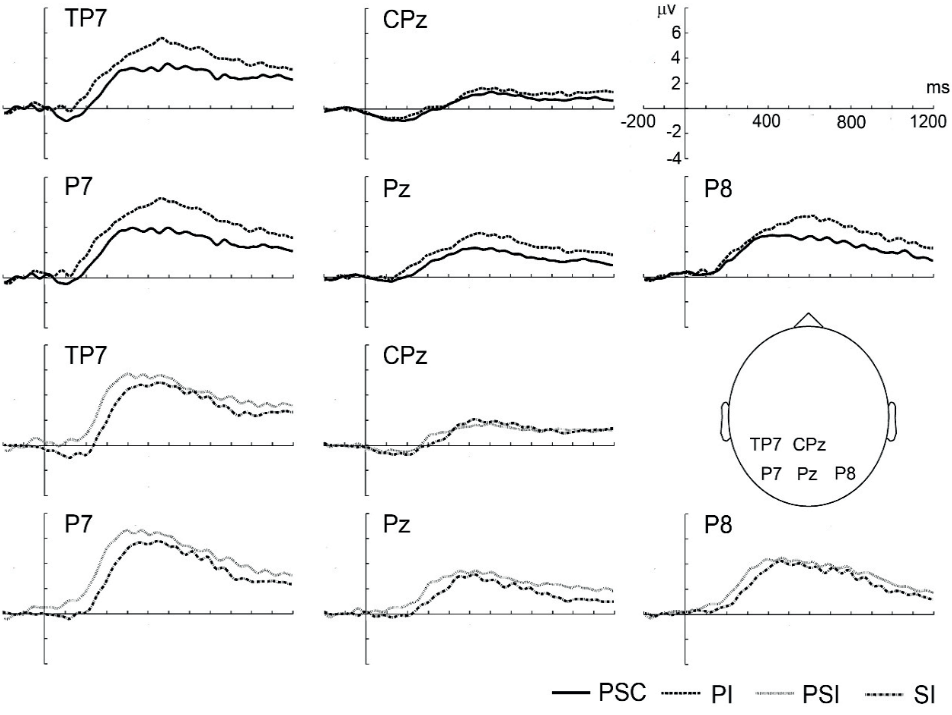
Table 2. Results of the ANOVAs Testing the Effects of Prosody and Syntax in Lateral and Midline Electrodes

		300-500		500-800		400-1200	
	df	**F**	**p**	**F**	**p**	**F**	**p**
Lateral							
P	1,29	12.964	≤.001	4.745	<.05	5.513	<.05
P × R	2,58	17.665	<.0001	15.888	<.0001	19.084	<.0001
P × H	1,29	4.828	<.05	.913	.347	2.131	.155
P × R × H	2,58	4.546	<.05	1.539	.226	2.183	.126
S	1,29	.874	.358	4.929	<.05	.170	.683
S × R	2,58	.527	.523	6.862	<.05	2.168	.148
S × H	1,29	6.404	<.05	3.204	.084	7.988	<.01
S × R × H	2,58	.871	.419	10.446	<.0001	4.771	<.05
P × S	1,29	10.644	<.005	.562	.459	.001	.990
P × S × R	2,58	.160	.732	1.818	.184	3.989	<.05
P × S × H	1,29	2.376	.134	4.529	<.05	1.561	.222
P × S × R × H	2,58	.003	.995	.961	.378	.868	.422
Midline							
P	1,29	27.574	<.0001	13.390	≤.001	15.180	≤.001
S	1,29	11.688	<.005	8.762	<.01	3.153	.086
P × R	4,11	11.692	<.0001	7.381	<.0001	7.783	<.0001
S × R	4,11	1.354	.263	4.693	<.01	1.679	.185
P × S	1,29	4.396	<.05	3.564	.069	.924	.344
P × S × R	4,11	.298	.743	.993	.392	2.260	.090

Notes. P: Prosody, S: Syntax, R: Region, H: Hemisphere

The 400-1200 ms Time Window

A robust posterior positivity was explored, which was confirmed to be a broadly distributed positivity effect for prosodic phrasing between pre-verbal and post-verbal positions and prosody-syntax interaction (see *H3*). To do this, syntactically congruent (PI vs. PSC) and syntactically incongruent (PSI vs. SI) conditions were compared. Figure 7 shows this comparison of congruent condition versus prosodically incongruent condition in the 400-1200 ms time window.



Note. PSC: syntactically and prosodically congruent; PI: prosodically incongruent; SI: syntactically incongruent; PSI: syntactically and prosodically incongruent.

Figure 7. Pairwise Presentation of the Averaged ERPs of The 400-1200 Ms Time Window for Syntactically Congruent (PI vs. PSC) and Syntactically Incongruent (PSI vs. SI) Conditions Testing the Variable Prosody

As Figure 4 and Figure 7 display, analysis of the 400-1200 ms time window revealed a robust posterior positivity for intonational phrase boundary and prosody-syntax interaction. The ANOVAs (see Table 2) for the 400-1200 ms time window found a reliable main effect of the variable of Prosody, as well as Prosody × Region interactions for both lateral and midline electrodes. This was the evidence of a bilaterally distributed positivity for the prosodically incongruent conditions (PI and PSI compared to PSC and SI). Resolving this effect, follow-up analyses for each region detected a reliable late positivity for SI compared to PSI (midline: F (1,29) = 11.098, $p < .001$, $\Delta = +0.90\mu V$; left posterior: F (1,29) = 9.061, $p < .05$, $\Delta = +0.52\mu V$), but this effect was not observed when syntax was congruent, that is, for PI compared to PSC.

The influence of the variable and visual inspection of the waveforms in the 400-1200 ms time window revealed significant interactions: Syntax × Hemisphere and Syntax × Region × Hemisphere for lateral electrodes only (see Table 2). Follow-up analyses of ROI levels found a significant difference only between SI compared to PSC (midline: F (1,29) = 8.495, p < .05, Δ = +0.77μV; left posterior: F (1,29) = 11.383, p < .01, Δ = +0.34μV). This confirmed the results from the omnibus analyses, which revealed an interaction between Prosody and Syntax (see Table 2). A left posterior positivity for the syntactically incorrect sentences was only observed when prosody was congruent, while for the prosodically incorrect sentences, it was only observed when syntax was incongruent.

DISCUSSION

In the present study, prosody-syntax interaction during focus processing in Turkish sentences in their post-verbal positions was investigated. Scrambling to post-verbal position in Turkish allows us to manipulate the variable of Prosody as either congruent (as a non-focused post-verbal element) or incongruent (as a focused post-verbal element) for the critical words. Two hypotheses for the prosodic processes were critically addressed. Firstly, since no F0 excursion was found in the post-nuclear position that marked the beginning of a new or second IPh in the post-verbal position, a CPS effect was expected. Secondly, given that prosodic focus manipulation might represent an incongruent prosodic information, a RAN effect followed by a P600 was assumed. The first hypothesis of the study for the prosodic responses between 400-1200 ms showed a robust CPS effect. As for the second hypothesis, findings for the prosodic incongruity elicited a weaker RAN effect followed by a P600, even though this negative effect does not seem to be as notably explicit as a classical RAN effect in the previous literature (e.g., Eckstein & Friederici, 2005; Honbolygó et al.,2016).

For the syntactic incongruity, case marking violation was created using an incorrect dative case instead of the accusative case. A slightly right lateralized negativity between 300-500 ms was observed, which was followed by a P600. This positivity was lateralized more in the left hemisphere than the right hemisphere. Findings supported a late neural interaction of the Prosody and Syntax, specifically in P600 (See Eckstein & Friederici, 2005) and CPS. In the following sections, the ERP findings for each component are separately discussed.

A Posterior Positivity for Prosodic Boundaries: CPS

ERP data displayed a long-lasting positivity between the 400-1200 ms time window after the critical word onset of the stressed syllable. Since the prosodic assignment of focusing should not be congruent in the post-verbal position (e.g., Erguvanlı, 1984; Göksel & Özsoy, 2003; Güneş, 2013, 2014; Kan, 2009), the intonational phrase between verb and the post-verbal constituent evoked a new or second prosodic boundary when this sentence-final position was manipulated with incongruent focusing. Due to the lack of focus position in the post-verbal area, a CPS effect was expected to be elicit between the PI and PSC conditions, as well as between the SI and PSI conditions. This positive shift primarily indicated a closure of a prosodic phrasing between the post-verbal constituent and the syntactic VP domain. Topographically, as discussed by Steinhauer (2003), CPS effect is generally accepted as a bilateral, centro-parietal positive deflection with a large amplitude, which is most prominent at the midline electrodes. Results of the current study descriptively supported this long-lasting prosodic effect, which was elicited as a posterior positive ERP response in Turkish sentences at the lateral and midline electrodes.

The connection between the prosodic focus and CPS effect was found in many studies which used auditory dialogues (e.g., Hruska & Alter, 2004; Hruska, Alter, Steinhauer, & Steube, 2001; Magne et al., 2005; Toepel, Pannekamp, & Alter, 2007). Toepel et al. (2007) asserted that CPS effect is elicited by the stress pattern of focus feature. In their study, where context-free (single sentences) and context-bound (auditory dialogues) structures were separated[3], CPS became relevant to focused and accented positions of the auditory dialogues, when the context-induced focus and accent positions were similar. In contrast to this interpretation, the present study focused on context-free process of the CPS effect and the focus relation. In addition, the elicitation of CPS was preceded by single sentence processing instead of being a contextually triggered ERP data. Thus, the results mainly indicated an interaction between syntax and prosody, rather than an interaction between pragmatics and prosody. On the other hand, the interpretation of CPS suggested an intonational phrase boundary effect between the domain of post-verbal constituent and the VP domain, which includes the verb and its complements in Turkish. Task-dependent results about long-lasting posterior positivity served as a preliminary neurophysiological evidence for the prosodic focus characteristics of post-verbal position in Turkish sentences.

3 Similar interpretations on CPS effects for dialogue comprehension have been strongly discussed in previous studies (see e.g., Hruska & Alter, 2004; Hruska et al., 2001; Magne et al., 2005).

Repair and Reanalysis: P600

As a well-known neurophysiological marker, P600 is widely accepted with repair and reanalysis processes for syntactic comprehension (e.g., Hagoort et al.,1993; Kaan, Harris, Gibson, & Holcomb, 2000). In this study, findings showed the P600 effect both in syntactically and prosodically incongruent conditions (i.e., SI and PI); however, it was slightly lateralized to the left hemisphere in syntactically incongruent condition (i.e., SI)[4]. The positivity effect that was observed in prosodically incongruent conditions (i.e., PI) seems also to be related to syntactic repair or reanalysis processes, since prosodic focus interpretation conveys a new information of the sentence by using both prosodic and syntactic strategies.

Anterior Negativities: Main Effects of Prosody and Syntax

For the main effect of prosody, a right-lateralized anterior negativity peaking around 400 ms after the stressed syllable of the critical word was observed. As has been widely discussed by Eckstein and Friederici (2005), this effect refers to the RAN, which reflects pure aspects of prosodic sentence processing. Hypothesis for pure prosodic incongruity (i.e., PI condition) was a similar effect to RAN, which was elicited between 300-500 ms after the stressed syllable onset of the critical word. In the present study, this right anterior negativity effect was referred to as a weaker right-lateralized anterior negativity, in contrast to N400 effect, which might induce a pure prosodic negativity[5].

For the main effect of syntax, a distributed anterior negativity for the case marking manipulation (i.e., accusative case vs. dative case) was found in Turkish sentences. Even though findings for the early effects of Syntax between 300-500 ms indicated significant ERPs for the main effects of Condition and Region, there was no evidence of an electrophysiological interaction between the Hemispheres. Therefore, in this study, a LAN or an N400 effect for case marking violations was not cited directly (see also, Coulson et al., 1998; Gunter et al., 2000; Friederici, 2002; Friederici & Frisch, 2000). Furthermore, it is important to note that findings for the case marking interpretations seem to be related to phonotactics alternations in Turkish. Thus, the pure syntactic effect

4 As seen in Table (2), a significant interaction between Syntax, Region, and Hemisphere at lateral electrodes ($p < .0001$), while there was no significant interaction for Syntax × Region × Hemisphere ($p > .05$) and Syntax × Hemisphere ($p > .05$).

5 N400 for prosodic mismatch has a biphasic characteristic with P600 in previous studies including the CPS effect (e.g., Bögels, Schriefers, Vonk, & Chwilla, 2011; Bögels et al., 2010; Steinhauer et al.,1999).

was also a part of prosodic focus marking manipulation, but not considered directly as a case marking violation measuring only the main effect of syntactic processing. These phonotactics alternations on final suffixes of the critical words might not be enough to observe a strong LAN effect for the syntax.

The Interaction of Prosody and Syntax

Since the focus marking processing in a language has both a relation with prosody and syntax (See Eckstein & Friederici, 2005, 2006; Sammler et al., 2015), one of the main purposes of the current study was to investigate the interaction of these components. In this study, the neurophysiological markers of prosody and syntax could be significant for the processing of prosodic boundary in Turkish sentences. A statistically significant interaction of Prosody, Syntax and Hemisphere ($p < .05$, see Table 2), which was elicited between 500-800 ms time windows was found. As previously mentioned, findings for P600 effect were slightly lateralized to the left hemisphere for the syntactically incongruent condition (i.e., SI), in contrast to the prosodically incongruent condition (i.e., PI). Indeed, it became clearer that the prosody and syntax interaction of P600 was observed (see Figure 4) when difference topographies between the syntactically incongruent (i.e., SI) and prosodically incongruent (i.e., PI) conditions were compared. It is also noteworthy that prosody has an interactive process with syntax, rather than a unique immediate effect in Turkish sentences.

The neurophysiological interaction between prosody and syntax was also related to a second late interaction effect (i.e., CPS) in Turkish sentences, but this effect interacted with the Region, in contrast to P600 effect, which interacted with the Hemisphere. Since prosodic boundaries between VP domain and post-verbal positions in Turkish sentences are accepted to have strong association with CPS effect (See Erguvanlı, 1984; Göksel, 1998; Göksel & Özsoy, 2000; Güneş, 2013, 2014), this ERP component is likely to be a certain indicator for prosodic reanalysis or repair processing. Even if the CPS effect is generally interrelated to a purely prosodic component, prosodic boundaries carry new information of the sentence, and herewith, a new prosodic focus structure of the sentence processing (see Bögels et al., 2010, 2011; Steinhauer et al., 1999). For this reason, a late interaction of CPS effect was not only derived from prosodic levels, but also from syntactic levels of sentence representation.

CONCLUSION

This study presented the first data depicting the neurophysiological processing of focus marking using both prosodic and syntactic information in an SOV word order language that does not allow prosodically marked elements in its post-verbal positions. Preliminary data confirmed that the CPS marker might be a prosodic phrase marker for the focused elements in post-verbal position, which signals a separate prosodic boundary effect in Turkish sentences. The present study revealed a weaker RAN followed by a P600 marker, which signaled a prosodic incongruity by inacceptable focusing marking in Turkish sentences. Syntactic mismatch, on the other hand, indicated only a left lateralized P600, but not a left anterior negativity.

The study has certain limitations in that the usage of the critical word appearing at the end of the sentence stimulus may lead to bogus ERPs. The position of a critical word was significant for the processing of any event-related potential, which is specifically associated with prosodic incongruity. Since any constituent of a sentence occurring within the entire pre-verbal area is accepted as a focus in Turkish sentences, prosodic incongruity might be much easier to observe as a pure effect than a focused constituent occurring on post-verbal position.

Overall, the present study supported neurocognitive approaches with the late interaction effects between prosodic and syntactic information in the ERP correlates of violation detection in the later stages (i.e., P600 and CPS) of integration in the processing of the sentences, which includes focused constituents in the post-verbal position in Turkish. Future work is needed to determine the nature of prosodic focus marking on pre-verbal position to avoid any closure effects of post-verbal position in Turkish sentences.

Ethics Committee Approval: The study was approved by the Ethical Board (No: 13-430-12, Date: 27 August 2012) of Ankara University.

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