Syntax-prosody mapping of Greek subject/object ambiguous clauses

Evidence from both a production and a comprehension task

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Abstract

The aim of the present study is threefold: (a) to explore whether Greek adults, who are non-trained speakers and naïve to the purpose of the study, use distinguishable prosodic cues, while producing subject/object ambiguous sentences, (b) to examine whether the same participants use prosody as an important informative cue, morphosyntax aside, in order to decode such ambiguities and (c) to investigate the linking between comprehension and production and more specifically whether prosodic cues are employed by speakers in production to the same extent as they are by listeners in comprehension. For this purpose a production and an on-line comprehension task were conducted. Results revealed that prosodic cues were used to denote the subject or the object condition, but they were not consistently employed in order for the two to be differentiated. The prosodic patterns which were employed also allowed us to examine the predictions made by three psycholinguistic syntax-prosody mappings. The on-line comprehension task demonstrated that listeners were always sensitive to prosody, even though a preference for the object condition was revealed.

Keywords

syntax-prosody mapping – production – comprehension – subject/object ambiguities

1 Introduction¹

Experimental data has shown that prosody influences parsing especially when listeners are presented with syntactically ambiguous sentences (Beach et al. 1996; Carlson et al. 2001; Clifton et al. 2006; Frazier et al. 2004; Kjelgaard & Speer 1999; Kjelgaard et al. 1999; Marslen-Wilson et al. 1992; Nagel et al. 1996; Price et al. 1991; Pynte & Prieur 1996; Schafer et al. 1996; Schafer et al. 2000a; Schafer et al. 2000b; Schafer et al. 2005; Speer et al. 2003; Weber et al. 2006; among others). It is not clear, however, whether untrained speakers consistently use informative prosodic cues, while producing utterances, which, when seen as lexical strings, could have two syntactic structures. Furthermore, most of the studies have explored prosodic effects on structural ambiguities in English (see references above), while data from other languages are rather scarce (e.g. Ivošević 2008; Kang et al. 2004; Vigário 2003). An additional issue that has not been scrutinized is the linking between comprehension and production and more specifically whether prosodic cues are employed by speakers in production to the same extent as they are by listeners in comprehension. In this study we aim to address the aforementioned issues by exploring prosodic effects on the comprehension and production of subject/object ambiguities by Greek untrained speakers.

Research on the use of prosodic cues during sentence processing is often based on data from speech that has been carefully prepared by trained speakers such as phoneticians (Clifton et al. 2006; Kang et al. 2004; Schafer et al. 1996; Schafer et al. 2000a) or radio announcers and actors (Price et al. 1991; Pynte & Prieur 1996) or even the use of synthesised stimuli (Kjelgaard & Speer 1999). Some researchers (e.g. Allbritton et al. 1996; Schafer et al. 2000b; Fox Tree & Meijer 2000), however, attempted to explore whether the experimental results would be different, if the speakers were untrained and/or naïve, with respect to the purpose of the experiments and the existence of the ambiguous structures, and listeners had to comprehend sentences containing more natural prosodic cues (probably less distinctive), alike the ones presented in daily life.

In order to address this issue, Allbritton et al. (1996) conducted a series of experiments with untrained (undergraduate students) and trained speakers

1 The present paper is an extension of the study reported in Martzoukou & Papadopoulou (2016). In this paper, the production data presented in Martzoukou and Papadopoulou (2016) are compared with the results of a comprehension task, which has been conducted with the same participants. Moreover, contrary to Martzoukou and Papadopoulou's (2016) article, the findings of the present study are extensively examined and discussed through the lens of psycholinguistic algorithms.

(actors and broadcasters). The results revealed that only the trained speakers and only when they were aware of the ambiguities used a compensatory amount of prosodic cues, which helped listeners to decode correctly the utterances.

More recent studies tried to avoid the production of unnatural speech, by using game playing tasks, in which specific syntactic structures were retrieved (Kraljik & Brennan 2005; Schafer et al. 2000b, 2005; Snedeker & Trueswell 2003; Speer et al. 2003, 2011; Warren et al. 2000). The overall results of these studies vary according to the participants' awareness of the ambiguities and their tendency to use informative prosody or not, but also according to the design of each experiment, the actual type of syntactic ambiguity and the syntactic structure that was examined. Moreover, it might be the case that when speakers are aware of the fact that they are contributing to a game, whose outcome depends on how clear their productions are, they use a more careful speech, with more distinctive prosodic cues, in order to help their listeners. Thus, more studies with different experimental techniques are necessary in order for a clearer view to be obtained, on whether speakers consistently use prosodic cues to help listeners.

As for the impact of prosody on comprehension, it has long been noted (Fodor & Bever 1965; Lieberman 1967; Wingfield & Klein 1971; Lehiste 1973, 1991; Price et al. 1991). One of the first studies that examined the impact of prosody on the perception of subject/object ambiguity was performed by Kjelgaard et al. (1999), who used a sentence completion task conducted by 20 young (from 18 to 22 years old) and 20 healthy, elderly (from 64 to 80 years of age) participants. In particular, Kjelgaard et al. (1999) used sentence onsets, like the one presented in (1). Sentences were produced by a female phonetician, native speaker of English, and were verbally presented to participants with a boundary just after the first verb (1a) (subject reading condition), a boundary just after the ambiguous determiner phrase (DP) (e.g. *the car* in (1b)) (object reading condition), or with neutral prosody, namely without any variations in pitch or duration. Participants were instructed to give a sensible continuation of the sentence fragment (see example continuations in (1a) and (1b)).

- (1) Although the two friends pushed the car ...
 a. Although the two friends pushed /² the car ... wouldn't budge.
 b. Although the two friends pushed the car /... it wouldn't budge.

² Slashes indicate prosodic boundaries.

The sentence-onset in (1) is morphosyntactically ambiguous in that the determiner phrase (DP) *the car* could either be the object of the verb *pushed* (object reading condition) or the beginning of the participants' continuations, namely the subject of the main clause to be produced (subject reading condition). Since participants were presented with morphosyntactically ambiguous segments like (1), they would have to decode prosody in order to give a correct continuation. Results from both groups demonstrated a strong preference for the object reading in the condition with neutral prosody, but no such preference was attested in sentences produced with cooperating prosody, in which participants' responses were in line with the prosodic cues. Thus, the overall outcomes revealed that participants were sensitive to prosodic cues (for similar methodology and results, see also Anderson & Carlson 2010; Caroll & Slowiaczek 1987; Kjellaard & Speer 1999; Speer et al. 1996).

In Greek there is only one study which explored the impact of prosody on subject-object ambiguity decoding (Papageli 2010). Papageli (2010) used a judgment task in which participants listened to partially ambiguous sentences, at their own pace (self-paced listening task), and at the end of each fragment they had to decide whether the sentence they heard was grammatical or ungrammatical. The accuracy scores revealed that participants were sensitive to prosodic cues, while the reaction times (RTs) showed a preference for the object reading when prosody was neutral, but there was no such an effect when prosody was natural. In cases in which prosody was natural participants' responses were in line with the prosodic cues. The methodology employed in this study, however, namely the self-paced listening technique, is not appropriate for the investigation of prosodic cues in parsing. In particular, the place and the duration of pauses are part of prosody and that, in a self-paced listening task, their effect is reduced if not totally eliminated, since pauses are placed compulsorily after each segment and their duration depends on the rate with which participants pass from one segment to the other. Moreover, the preference for the object reading in the neutral condition is not in line with the findings reported by Papadopoulou & Tsimpli (2005) who used a self-paced reading task to investigate similar sentences to the ones used by Papageli (2010) and found no preference for either of the two conditions. Therefore, more research is needed regarding the comprehension strategies native speakers of Greek use while processing the prosody of orally presented subject/object ambiguities.

Turning now to the production of subject/object ambiguities and the prosodic phrasing used by speakers, there is only one study which examined the exact prosodic mapping untrained speakers use while producing ambiguous sentences and also compared the prosodic patterns with the ones suggested by different theories on prosodic phrasing (Anderson & Carlson 2010). More

specifically, in Anderson & Carlson's (2010) production task, 16 participants were instructed to read aloud 36 locally ambiguous sentences, after answering a relevant comprehension question by circling the correct answer between two options presented in written form. The results revealed that speakers used different prosodic cues to mark the subject and different ones to mark the object reading. In particular, the duration of the verb was significantly longer in the subject than in the object reading condition, while the ambiguous DP was significantly longer in object than in the subject reading condition. As for the intonation pattern, speakers nearly always placed the biggest boundary after the DP in the object reading condition, and almost always placed the biggest boundary after the verb in the subject reading condition. Contours with equal boundaries at these two locations were rarely produced. The researchers claimed that the overall results from the subject/object ambiguities reveal that speakers use prosody in order to disambiguate their ambiguous utterances, while the prosodic patterns they use are in line with the predictions made by the syntax-prosody mappings suggested by both Cooper & Paccia-Cooper's (1980) and Watson & Gibson's (2004) algorithms. These two algorithms as well as the one suggested by Gee & Grosjean (1983) will be also examined in the light of the production data of the present study.

In particular, Cooper & Paccia-Cooper (1980) assume that the presence of a boundary mainly depends on the number of the syntactic constituents preceding or following the possible boundary (key boundary). More specifically, the likelihood of a boundary is calculated by counting the number of the nodes which dominate the words on the left and the right side of the key boundary, but which do not dominate both of these words. Not all nodes, however, have the same strength. Nodes referring to minor categories (function categories) as well as the non-terminal nodes on the left side of the boundary which do not branch are assigned the value of zero. On the other hand, the unit of strength of the nodes located on the left side of the boundary is multiplied by two.

For example, if we have the totally ambiguous sentence in (2), in which the DP *to ku'bi* (the button) can be the subject of the main or the object of the subordinate verb, and we want to denote the subject-reading condition, then the tree-diagram, according to more recent syntactic representations (Adger 2003; Carnie 2010; Kratzer 1996), would be the following (Figure 1):

- (2) Optionally transitive verb; subject / object reading

<i>ka'ʒos</i>	<i>'erave</i>	<i>to</i>	<i>ku'bi</i>	<i>'ylistrise</i>
While	was sewing _{-3SG}	the _{-N.SG.NOM/ACC}	button _{-N.SG.NOM/ACC}	slip _{-PST.3SG}
<i>sto</i>	<i>'patoma</i>			
on the floor				
'While (s)he was sewing the button (she/he) slipped on the floor'.

FIGURE 1 Tree diagram in line with the subject reading

If we consider for instance the boundary between the *'erave* and *to ku'bi*, it has the strength of value of 4. The dominating nodes on the left are the VP and the V. The VP, though, is considered to be non-branching since the NP is a null subject (minor category), and thus only the V is counted, which is multiplied by two since it is located on the left side of the boundary. On the right side, the dominated nodes are the NP and the N and therefore they add the strength value of two (one for each node). Similarly, in the case of the boundary between *to ku'bi* and *'ylistrise*, the value of the nodes on the left is two, since NP is considered to be non-branching, due to the fact that D is a functional word and is not counted, while the strength value on the right is two (one for V and one for VP), again due to the fact that PP represents a minor category.

Cooper & Paccia-Cooper (1980) also calculated the bisection values by counting the number of the lexical words in the sentence (i.e. *'erave*, *ku'bi*, *'ylistrise*, *'patoma*) and dividing it by two. Then they counted the number of category words from either the beginning or the end of the sentence to the boundary, whichever is less, and they divided it by the point of bisection. The product of the boundary strength and the bisection element is the degree of possibility of the boundary to appear. For example, the product of the boundary between *'erave* and *to ku'bi* is 0.5 [=1(*'erave*) / (4/2)], while the boundary between *ku'bi* and *'ylistrise* is 1 [=2 (*'erave*+*ku'bi* or *'ylistrise*+ *'patoma*) / (4/2)]. Hence, according to Cooper & Paccia-Cooper (1980), the boundary in the subject-reading condition can be expected to appear between the DP *to ku'bi* and the verb *'ylistrise* (Table 1).

TABLE 1 Boundary likelihood quantities predicted by the Cooper & Paccia Cooper's (1980) algorithm in the subject reading condition

	<i>ka'ʒos</i> while	<i>'erave</i> was sewing	<i>to</i> the	<i>ku'bi</i> button	<i>ʕylistrise</i> slipped	<i>s</i> on	<i>to</i> the	<i>'patoma</i> floor
Boundary strength	0+0		2+2	0+1	2+2	2+1	0+1	0+1
Bisection Values	0		0.5	0.5	1	0.5	0.5	0.5
Product	0		2	0.5	4	1.5	0.5	0.5

On the other hand, Gee & Grosjean (1983) claimed that syntax-based algorithms, like the one suggested by Cooper & Paccia-Cooper, may make different predictions, depending on the specific syntactic phrase structure which would be used. For this reason, Gee & Grosjean (1983) suggested a new algorithm, which “treats the issue of prosody directly and on its own terms” (Gee & Grosjean 1983: 431). In particular, Gee & Grosjean’s algorithm is based on the prosodic hierarchy (see Beckman & Pierrehumbert 1986; Nespor & Vogel 1986[2007]; Pierrehumbert & Beckman 1988; Selkirk 1978/1980a, 1980b, 1981, 1984, 1986), as well as on the claim that functional words bear little or no stress and thus they cannot stand as Phonological Words (PWs) by themselves, but mainly act as syllables attached to a sister constituent next to them (a similar view was also expressed by Selkirk 1986, 1995; Selkirk & Shen 1990; and Truckenbrodt 1999). Therefore, functional words cannot serve as heads of Phonological Phrases (PPhs), and the boundaries between them and the following lexical words are marked with zero (0). An example of this can be seen in Figure 2 in which the boundary between *to* and *ku'bi* is 0, since the neuter article *to* (the) is a functional word. Gee & Grosjean’s algorithm applies separately to main and subordinate clauses. It requires the formation of PPhs and Intonational Phrases (IPs) and the possibility of a boundary to occur depends on the value between the two phrases. This value is equal to the number of branching nodes dominated by the node dominating this boundary, including in the count the word boundary node itself.³

Thus, the boundary between the subordinate verb and the ambiguous DP is 8, while between *ku'bi* and *ʕylistrise* is 5. Thus the intonational boundary is predicted to be between *'erave* and *to ku'bi*. Interestingly, it can also be considered as though it predicts the possibility of a second, probably less distinctive,

3 Steps 7 to 9 of the algorithm make little difference and were not applied to the present study.

FIGURE 2 Intonational boundary likelihood quantities predicted by the Gee & Grosjean's (1983) algorithm in the subject reading condition

boundary to occur between the DP *ku'bi* and the main verb, since the value at this place is 5 (see Figure 2).

Lastly, Watson & Gibson (2004), who tested the validity of both the aforementioned algorithms, concluded that, even though Gee & Grosjean's made many more correct predictions (over 70%) compared to Cooper & Paccia-Cooper's algorithm (less than 40%), both of them are complex and they are applied to complete sentences. Therefore, both of them assume that speakers plan whole sentences and have complete knowledge of the utterances they are going to produce, before they start speaking (but see Ferreira 1996; Levelt 1989; Roelofs 1998).

Though considering these shortcomings, Watson & Gibson postulated a new algorithm, one which can be applied incrementally and which combines the aforementioned algorithms into a simpler one. Thus, they suggested that the likelihood of a boundary between the left-hand side (LHS) and the right-hand side (RHS) constituents increases not only with the number and the type of syntactic brackets, but also with the size of each constituent (in terms of phonological phrases). Moreover, they assume that intonational boundaries are more likely to occur at the end of phonological boundaries than at the end of word boundaries. Watson and Gibson incorporated their hypotheses with the semantic well-formedness constraint named Sense Unit Condition (SUC), which was suggested by Selkirk (1984). According to SUC, the elements of a PPh or an IP must form a sense unit. These definitions, contrary to previous algorithms, do not refer to a specific syntactic or prosodic theory and, thus, as Watson and Gibson claim, they are in line with all phrase structure systems.

FIGURE 3 Intonational boundary likelihood quantities predicted by the Watson & Gibson's (2004) algorithm in the subject reading condition

Lastly, Watson & Gibson (2004) claimed that their algorithm, apart from being simpler, in certain cases it was found to better predict boundaries on speakers utterances.

To increase clarity of understanding the new algorithm, let us reconsider the example analyzed by the previous psycholinguistic algorithms. In Figure 3 the phonological phrases are indicated by large spaces between the elements. The length of the constituents is demonstrated by the horizontal arrows, while the cases in which the constituent boundaries, that are relevant to Left-hand side/Right-hand side Boundary (LRB), coincide with the phonological ones are indicated by dotted vertical lines. Moreover, the LRB values are presented above the sentence. In particular, the top left value represents the values of the LHS constituents, while the top right value represents values of the RHS constituents. Lastly, the bottom value (+1) is the value added at each phonological phrase boundary.

Therefore, according to the LRB, the most likely place for a boundary to occur is between *'erave* and *to ku'bi*. At this point the total value of the boundary is 6. More specifically, the completed constituent *ka'θos 'erave* offers the value of 2 to the LHS components, since there are overall two phonological phrases, while the RHS value is 3. Finally, a value of 1 is added to the LRB, due to the fact that this is a phonological phrase boundary. The lowest possibility of a boundary to occur is in places where there is a relation of head—argument or no syntactic constituents have been completed, such as in case between *to ku'bi* and *'ylistrise*. More specifically, the total value of RHS elements is 0, since no constituent has been completed, whereas the LHS constituent is 1 due to the completed DP.

The review of previous work presented in this section indicates that the extent to which prosodic cues are employed by untrained speakers to disambiguate ambiguous utterances is not resolved. This issue is addressed in our study, since our experiments have been conducted with untrained speakers. Moreover, we think that the Greek data we report on are enlightening

regarding the use of prosodic cues in the comprehension and production of subject/object ambiguities from various respects. The Greek language, apart from the fact that it has different prosodic characteristics compared to those of English (see Arvaniti 2000; Arvaniti & Baltazani 2000; Arvaniti et al. 1998), is also typologically different from English in that it allows null subjects and it is highly inflected in both the nominal and the verbal domain. In addition to this, the way subject/object ambiguities—actually, structural ambiguities in general—are parsed by Greek speakers is far from established. On the one hand, the data thus far are contradictory and point to divergent parsing routines from the ones employed in English, while on the other hand, the use of prosodic cues in the disambiguation of such structures has not been thoroughly investigated. A further issue that has not been systematically addressed in the literature, but is tackled in our study, is the possible differences between comprehension and production in the use of prosody. Finally, the findings of the production task of the present study are also used as the basis for the examination and the empirical evaluation of the predictions of the mappings between syntax and prosody presented above (Cooper & Paccia-Cooper's, Gee & Grosjean's, and Watson & Gibson's), a research line that has not received a lot of attention thus far in the literature and one that, to our knowledge, has exclusively focused on English.

In the next section we present the two experiments we carried out in the order in which they were actually conducted on participants. Participants were the same for both tasks in order for safer conclusions to be drawn as to whether individuals use prosodic cues both while comprehending and producing lexical strings to which two syntactic analyses could be assigned. Participants first completed the comprehension task and then the production one, so as their continuations in the comprehension task be spontaneous and authentic and not influenced by the continuations given in the production task, given that both tasks contain similar experimental items.

2 Sentence completion task

2.1 *Predictions*

According to previous studies (e.g. Anderson & Carlson 2010; Carroll & Slowiaczek 1987; Kjelgaard & Speer 1999; Speer et al. 1996), participants are expected to be sensitive to prosodic cues. In particular, it is anticipated that they correctly decode prosody in both the subject and the object reading condition. Moreover, no preference for one of the two conditions is expected to be found, since sentence-onset fragments are presented with cooperative prosody.

TABLE 2 Means (and standard deviations) of age and years of education per group

Participants	Number	Age	Years of education
Females	15	26.8 (3.32)	16 (2.12)
Males	15	27 (5.54)	15 (1.78)
TOTAL	30	27 (4.49)	15 (2.06)

2.2 Method

2.2.1 Participants

Thirty unimpaired adult native speakers of Greek participated in the comprehension task. None of them was a linguist, a trained speaker (i.e. radio producer, actor/actress) or a professional musician. Furthermore, none of them reported to have any neurological or learning problem. Half of the participants were females (age range: 18–35) and half were males (age range: 18–39) (for more information see Table 2). All of them had received between 12 and 17 years of education. Participants took part in the experiment voluntarily. They were notified that they were at liberty to abstain from participation in the study and free to withdraw their consent to participation at any time. Moreover, all participants were assured that full anonymity and confidentiality will be preserved.

2.2.2 Materials

In this task we used temporally ambiguous sentences, like the ones employed by Papangeli (2010) (see also Martzoukou et al. 2017 for the design of the materials). Twelve optionally transitive verbs, each consisting of 3 to 4 syllables with the stress on the antepenultimate or the penultimate syllable, were used once in structures in line with the subject reading and once in structures in line with the object reading. Therefore, the experimental items consisted of twenty-four temporally ambiguous sentences. As mentioned in the Introduction, Greek neuter (NEUT) articles and nouns share the same form for both the nominative (NOM) and the accusative case (ACC). Therefore, in both (3a) and (3b), the sentences are ambiguous up to the DP, since the DP could either be the subject of the main verb, or the object of the subordinate one. The ambiguity, however, is resolved by means of morphology. In particular, the ending *-e* of the verb *ʹylistrise* indicates the third person singular and thus it refers to the one who was sewing the buttons, while the ending *-an* (*ʹylistrisan*) indicates the third person plural and therefore the subject of the verb refers to the DP *ta kuʹbja* (the buttons).

- (3) a. Optionally transitive verb; subject reading

ka'ðos 'erave *ta* *ku'bja* *'ylistrisan*
 while was-sewing_{-PST-3SG} the_{-N.PL.NOM/ACC} button_{-N.PL.NOM./ACC} slip_{-PST.3PL}
sto 'patoma
 to the floor
 'While (s)he was sewing the buttons slipped on the floor.'

- b. Optionally transitive verb; object reading

ka'ðos 'erave *ta* *ku'bja* *'ylistrise*
 while was-sewing_{-PST-3SG} the_{-N.PL.NOM/ACC} button_{-N.PL.NOM./ACC} slip_{-PST.3SG}
sto 'patoma
 to the floor
 'While (s)he was sewing the buttons [(s)he] slipped on the floor.'

For the present task, sentences were cut off prior to the point of ambiguity resolution, i.e. before the verb of the main clause, with the use of Praat 6030 (Boersma & Weenink 2017). In particular, the experimental items consisted of 24 sentence-onset fragments (4). The prerecorded sentence fragments were verbally presented to the participants of the study and were produced with prosody favoring either the subject or the object interpretation.⁴

- (4) Optionally transitive verb; subject / object reading (experimental item)

ka'ðos 'erave *ta* *ku'bja*
 while was-sewing_{-PST-3SG} the_{-N.PL.NOM/ACC} buttons_{-N.PL.NOM/ACC}
 'While (s)he was sewing the buttons ...'

For example, participants of this experiment would hear *While (she) was sewing the buttons ...* twice, once produced with prosody favoring the interpretation of *the buttons* as the subject of the following verb (subject reading) and once as the object of the verb *sewing* (object reading). Sentences produced with prosody favoring the subject reading contained embedded verbs (e.g. *sewing*) with longer duration (mean duration = 0.537m/s) than in the object reading (mean duration = 0.421m/s) followed by a phrase accent, which marks the boundary of the intermediate phrase (see Appendix 1).

4 The prosodic contours were assigned to either the subject or the object reading based on previous work (for English: Anderson & Carlson 2010; for a preliminary study in Greek: Martzoukou et al. 2013). In this task, we wanted to explore whether the prosodic patterns used are indeed comprehended as expected.

On the other hand, productions which were in favor of the object reading contained embedded verbs with shorter duration and final DPs with longer durations (mean duration = 0.668 vs. 0.528 in the subject reading condition), compared to the corresponded components of the subject reading condition (see Appendix 1). In the object reading the DPs were the units which resulted into phrase accents and not the embedded verbs as in the subject reading. Therefore, in order for participants to offer a correct continuation they would have to correctly comprehend the sentence-onsets fragments.

Sentence-onset fragments were extracted from utterances produced by speakers of a previous production task (Martzoukou et al. 2013). In this task, speakers were instructed to silently read in their head small passages consisting of three sentences, with the temporal ambiguous one in the middle, trying to memorize it and produce it in the most natural way “as if they narrated it to a friend”. For the present task, the recordings of two participants (a male and a female),⁵ who had successfully employed appropriate prosody to differentiate between the two meanings of the experimental item pairs, were selected. Their productions were fluent and clear, in that they contained the fewest mispronunciations, hesitations and stutters and the least background, irrelevant, environmental noises. The two versions of each sentence were extracted from the same participant, in order to preclude the possibility that the speaker’s voice would affect the participants’ responses. None of the speakers was a trained speaker (e.g. radio broadcaster, actor or linguist), while all of them were naïve to the experimental manipulations.

Moreover, eighteen unambiguous sentence-onset fragments, nine in favor of the subject reading (5a) and nine in favor of the object reading (5b), were used as fillers. The unambiguous sentences favoring the subject reading contained an intransitive embedded verb (5a), while the unambiguous sentences which were in favor of the object reading contained a (optionally) transitive verb followed by a DP, marked for the accusative case (5b).

(5) a. Intransitive verb; subject reading (filler)

ka'θos jev'matize to ti'lefono
 while was-dining_{-PST-3SG.} the_{-N.SG.NOM/ACC} phone_{-N.SG.NOM/ACC}
 ‘While (s)he was dining, the phone ...’

5 The male participant was 28 years old with 16 years of education and the female participant was 29 years old with 18 years of education. Both participants use the standard Modern Greek variety.

- b. Transitive/optionally transitive verb & DP in accusative; object reading (filler)

e'no *'eftiaxne* *ti* *va'litsa*
 whilst was-preparing_{-PST-3SG.} the_{-F.SG.ACC} suitcase_{-F.SG.ACC}
 'Whilst (s)he was preparing the suitcase ...'

The 24 ambiguous and the 18 unambiguous sentence-onset fragments were divided into two lists, each one containing a total of 21 sentence-onset fragments and both experimental conditions, but only one version of each experimental item.

2.2.3 Procedure

Participants were informed they were going to listen to sentence-onset fragments and they were instructed to verbally give a sensible continuation for each of them (see also Martzoukou et al. 2017). Experimental items, as well as fillers, were presented in a pseudo randomized order with the use of the Windows Media Player software. Before the main experiment, there was a practice session which contained two sentence-onset fragments, one in favor of the subject and one of the object reading, in order not only to regulate the desired intensity of the sound (Logitech Speakers Z130—5 watts), but also for participants to become familiar with the task. Each list started with a sentence onset of a filler.

All participants listened to both lists, half of them, however, first listened to list A, while the other half first listened to list B. Materials, as well as participants' answers, were recorded using an OLYMPUS digital voice recorder (VN-8500pc). Each list contained only one version of each experimental item (e.g. either the subject or the object reading condition), in order for participants not to be alerted by the ambiguities. The experiment was divided into two sessions, one for each list, which participants undertook with a period of at least one week between them, in order to avoid possible interference effects of memory.

2.3 Data analysis

For each of the 30 speakers, there were 42 sentence-onsets, thus a total of 1,260 sentence continuations. Participants' sentence completions were analyzed according to their syntactic structure. Each continuation was transcribed together with the corresponding sentence onset. Participants' sentence completions were defined as indicating the subject or the object reading on the basis of their morphosyntactic structure. In particular, completions starting with a third person plural verb and not containing an overt subject, were considered as taking the given DP as the subject of the main verb, and thus as being

TABLE 3 Examples of correct and incorrect responses for each condition

Subject reading	Correct responses		Incorrect responses
<i>ka'ðos 'erave / ta ku'bja</i> 'While (s)he was sewing, the buttons ...'	<i>ɣlistrisan</i> 'slip _{-PST-3SG}	<i>sto'patoma</i> on the floor'	<i>'tripise to'ðaxti'lo tis me ti ve'lona</i> 'she stuck her finger with the needle'
	<i>'espasan</i> 'broke _{-PST-3SG}		<i>to ti'lefono 'xtipise</i> 'the phone rang'
Object reading	Incorrect responses		Correct responses
<i>ka'ðos 'erave ta ku'bja /</i> 'While (s)he was sewing the buttons, ...'	<i>ɣlistrisan</i> 'slip _{-PST-3SG}	<i>sto'patoma</i> on the floor'	<i>'tripise to'ðaxti'lo tis me ti ve'lona</i> 'she stuck her finger with the needle'
	<i>'espasan</i> 'broke _{-PST-3SG}		<i>to ti'lefono 'xtipise</i> 'the phone rang'

Note: The symbol “/” stands for phrase accents

correct responses for the onsets produced with prosody favoring the subject reading condition. On the other hand, continuations starting with a verb in the third person singular (with or without an overt subject) or in any other person accompanied by an overt subject, either a DP or a pronominal, were considered as being in line with the onsets produced with prosody in favor of the object reading condition (see Table 3 for examples). The coding of the participants' responses was independently conducted by the two researchers and no disagreement in the coding was attested between them.

As for the fillers such as in (5a) and (5b), correctness of responses was evaluated according to their grammaticality. In order for the continuations to be correct, participants should have taken into account, besides the prosodic cues, the intransitivity of the embedded verb (subject reading (5a)) and the case of the DP (accusative in the object reading condition (5b)).

The coding of the participants' responses was conducted independently by two of the researchers and later comparisons revealed no disagreement in the coding. Correct responses were given indicator 1, while incorrect responses were given indicator 0. The Shapiro-Wilk Test was used in order to check the normality of data distribution. For normally distributed data, parametric tests were conducted, whereas non-parametric tests were used for the analysis of non-normally distributed data.

TABLE 4 Ungrammatical responses

Condition	Sentence—onset	Sentence-completion
OR	<i>an ce 'ipe tin a'liθça</i> 'Although (s)he told the truth ...'	<i>'ipe 'psemata</i> '(s)he told lies.'
	<i>'otan 'espase tin pça'tela</i> 'When (s)he broke the platter ...'	<i>tin 'espase</i> '(s)he broke it.'
SR	<i>an ce mi'luse / ta peðja</i> 'Although (s)he was talking, the children ...'	<i>ton a'kuyane me prosoçi</i> '(they) listened to him carefully.'

OR: Object reading, SR: Subject reading

2.4 Results

2.4.1 Fillers

As far as the fillers are concerned, participants performed at ceiling (99.7%), in that they gave sensible continuations, based on the transitivity/intransitivity of the embedded verb and the case marking of the DP. There were only 3 cases, in which the continuations were incorrect in terms of content (see Table 4).

2.4.2 Experimental items

The descriptive analysis demonstrated that although overall the participants were sensitive to the distinguishable prosodic cues, they were more accurate in the object (94%) than in the subject reading condition (83%) (Figure 4, overleaf).

A nonparametric, two-related samples, Wilcoxon signed ranks test revealed a statistically significant difference between the two conditions ($z_1 = 2.528$, $N\text{-Ties} = 30$, $p = .011$, two-tailed, $z_2 = 2.004$, $N\text{-Ties} = 12$, $p = .045$ two-tailed) in that participants performed better in the object compared to the subject reading condition.

2.5 Discussion

Results revealed that participants scored at ceiling on the fillers, which indicates that the presence of morphosyntactic information aids participants to process the sentences. Turning to the experimental items, participants were sensitive to the prosodic cues to a notable extent (above 80%). This result supports previous studies which also show sensitivity to prosodic hints dur-

FIGURE 4 Mean percentages (and standard deviations) for the experimental items

ing comprehension (e.g. Anderson & Carlson 2010; Carroll & Slowiaczek 1987; Kjelgaard & Speer 1999; Speer et al. 1996). Our participants, however, exhibited significantly better performance on the object compared to the subject reading condition. This finding was not expected as all sentence-fragments were presented with cooperative prosody and indicates an advantage for the object-reading condition. We will further discuss this finding in the general discussion.

3 Production task

The results from the comprehension task revealed that participants consistently use the available prosodic cues and decode sentences based on them. We wanted, however, to explore whether the same participants provide listeners the needed prosodic cues, when they have the role of the speakers producing morphosyntactically, totally ambiguous sentences.

3.1 Predictions

According to Anderson & Carlson (2010), participants are expected to use different prosodic patterns to mark the object reading (longer duration DPs, shorter duration of verbs) and the subject reading (longer duration of main verbs, shorter duration of DPs) condition. As for the intonation pattern and the placement of the phonological boundaries, each of the syntax-prosody mappings (Cooper & Paccia-Cooper 1980; Gee & Grosjean 1983; Watson & Gibson 2004) makes different predictions.

In particular, if we consider the ambiguous sentence presented in (5), the tree-diagram for the object reading condition would be as follows (Figure 5) (for the tree-diagram for the subject reading condition see Figure 1).

FIGURE 5 Tree diagram in line with the object reading

Based on the above tree-diagram, Cooper & Paccia-Cooper's (1980) algorithm makes for the object reading a similar prediction as in the subject reading (see Table 1), namely that the boundary will be between the DP and the main verb. On the other hand, both Gee & Grosjean's (1983) and Watson & Gibson's (2004) algorithms predict different patterns in the object reading compared to the patterns presented in the subject reading (see Figure 2 and Figure 3 respectively). All three algorithms, though, predict that the boundary will be between the critical DP and the main verb. Table 5 summarizes the predictions of all three mappings in both conditions (subject vs. object reading).

Based on the findings from the comprehension task, we expect participants to use different prosodic patterns, for the subject and the object condition, both as far as the intonation and the duration of the verbs and the DPs are concerned. Therefore, the algorithms which are closer to our prediction are the ones suggested by Gee & Grosjean (1983) and Watson & Gibson (2004), since they predict different prosodic cues in each of the two conditions. However, since the participants of both tasks are untrained speakers, we expect them

TABLE 5 The predictions for the subject and the object reading conditions, according to the three psycholinguistic accounts

Boundary likelihood quantities							
Cooper & Paccia-Cooper (1980)							
Subject reading	(ka'θos 'erave)	2	(to ku'bi)	4	(ʻylistrise)	1.5	(sto 'patoma)
Object reading	(ka'θos 'erave)	2	(to ku'bi)	6	(ʻylistrise)	1.5	(sto 'patoma)
Gee & Grosjean (1983)							
Subject reading	(ka'θos 'erave)	8	(to ku'bi)	5	(ʻylistrise)	3	(sto 'patoma)
Object reading	(ka'θos 'erave)	3	(to ku'bi)	7	(ʻylistrise)	3	(sto 'patoma)
Watson & Gibson (2004)							
Subject reading	(ka'θos 'erave)	6	(to ku'bi)	2	(ʻylistrise)	2	(sto 'patoma)
Object reading	(ka'θos 'erave)	1	(to ku'bi)	6	(ʻylistrise)	2	(sto 'patoma)

not to apply the corresponded prosodic cues to their utterances consistently (e.g. Allbritton et al. 1996).

3.2 *Method*

3.2.1 Participants

Participants were the same as in the comprehension task (Table 2).

3.2.2 Materials

The experimental items consisted of 12 totally ambiguous sentences. Sentences had 14 to 17 syllables and the same verbs as in the comprehension task (for the verbs used see also Appendix 1). The ambiguity of these sentences resulted from the argument structure of the embedded verb and the morphosyntactic features of the following DP. More specifically, the embedded verb was an optionally transitive verb in third person singular (e.g. *'erave* 'sew') with a null subject while the following DP was a singular noun in neuter gender (e.g. *to ku'bi* 'the button'). Recall here that neuter nouns share the same form for both the nominative and the accusative case. Therefore, the nouns of the experimental items were ambiguous regarding their syntactic function as subject or object, since nominative and accusative cases are identical. Contrary to the comprehension task in which the DP was in plural and thus the ambiguity was resolved at some point within the sentence, in these cases, sentences remained ambiguous until the completion of the utterance, since the subject of the main verb (*'ylistrise*)

could be the ambiguous DP (*ku'bi*) or the same as the subject of the subordinate verb. For each of the ambiguous sentences two pictures were created, so that each picture depicted one possible interpretation of the sentence (see example (6)). Thus, the experimental items consisted of 12 ambiguous sentences and 24 pictures.

- (6) Optionally transitive verb; subject / object reading (experimental item)

ka'ðos 'erave to ku'bi 'ylistrise
 while was-sewing-3SG the-N.SG.NOM/ACC button-N.SG.NOM/ACC slip-PST.3SG
sto 'patoma
 on the floor

'While (s)he was sewing the button [(s)he] slipped on the floor.'

Furthermore, two unambiguous sentences were constructed for each of the 12 experimental sentences, thus in total 24 unambiguous sentences, accompanied by an equivalent number of pictures, which served as fillers. These sentences had a similar structure to that of the experimental items, but differed in that the ambiguity was resolved via the case of the DP, which was morphologically marked for nominative or accusative case. For example, in sentence (7a), the DP is marked for nominative case and, hence, it is analyzed as the subject of the main verb. On the other hand, in (7b) the DP is marked for accusative case and, thus, it is construed as the object of the subordinate verb. There are no empirical data from Greek that would determine which prosodic patterns should be expected in sentences like the ones we used in the present study. Thus, the unambiguous sentences were included in the study for control purposes, namely, for the baseline prosodic patterns for the subject and the object reading to be extracted from them.

- (7) a. Optionally transitive verb & DP in nominative; subject reading (filler)
ka'θos 'erave i 'fusta 'ylistrise sto 'patoma
 while was-sewing-3SG the-F.SG.NOM skirt-F.SG.NOM slip-PST.3SG to the floor
 'While (s)he was sewing the skirt slipped to the floor'.

- b. Optionally transitive verb & DP in accusative; object reading (filler)
ka'θos 'erave ti 'fusta 'ylistrise sto 'patoma
 while was-sewing-3SG the-F.SG.ACC skirt-F.SG.ACC slip-PST.3SG on the floor
 'While (s)he was sewing the skirt (she/he) slipped on the floor'.

Lastly, we constructed an additional ambiguous filler sentence for each of the 12 experimental items. In these sentences the DP, as also illustrated on the accompanied picture (8), is both the object of the subordinate verb and the subject of the main verb. Thus, prosodic cues would reveal which of the two interpretations each participant wants to imply. This type of fillers was intended to provide data that would indicate a possible preference for the object or the subject interpretation. The ambiguous filler sentences and their accompanied pictures were twelve.

- (8) Optionally transitive verb; subject / object reading (filler).
ka'θos 'eravan to nifi'ko
 while was-sewing-3SG the-N.SG.NOM/ACC wedding dress-N*SG*^{NOM}/ACC
'ylistrise sto 'patoma
 slip-PST.3SG to the floor
 'While they were sewing the wedding dress (the wedding dress) slipped to the floor'.

The in total 48 sentences (12 experimental sentences and 36 fillers) and the 60 pictures (24 pictures for the experimental sentences and 36 for the fillers) were presented to participants by means of the PowerPoint software. Materials were divided into two presentations, each consisting of 12 experimental sentences accompanied with pictures depicting one of their two possible readings and 18 filler sentences (12 unambiguous and 6 ambiguous) accompanied with their corresponding pictures. The experiment was divided into two sessions (one for each presentation), which participants undertook with a period of at least 5 days between them. All participants saw both presentations.

3.2.3 Procedure

Participants were informed that they were going to be, at the same time, visually presented with sentences, each one to be accompanied by two pictures. They were instructed to read each of the sentences carefully and silently and to try to understand and memorize it. Then, after observing carefully the two pictures, which were marked as picture A and picture B, and whenever they would feel ready, they would have to verbally choose the picture they believed that each sentence described. After the picture selection, only the correct picture would remain on the screen (without the written sentence), in order to help them remember the sentence. The participants had to produce the sentence that described the picture naturally, as if they were talking to a friend. Sentences were presented to participants in a pseudo randomized order, without having any commas, and in one line. There were two pictures above each sentence; one of them illustrated the meaning of the sentence, whereas the other picture illustrated different items (e.g. a skirt slipping and not a button) but a similar action (see example (9)).

- (9) An example of the pairs of pictures presented to participants (left: experimental item, right: filler item).

This procedure was followed in order to ensure that participants would pay attention to the pictures. Participants were never presented with the two pictures depicting the two different conditions of the same sentence either in the same slide or in the same session, in order not to be alerted to the ambiguities. Moreover, the filler and the experimental sentences accompanying the pictures involved one subordinating conjunction, *ka'θos* (= while), twelve different subordinating verbs and twelve different VPs within the main clause. The DPs, though, following the subordinating verb, were thirty-six, twelve for the experimental items, twelve for the ambiguous and twelve for the unambiguous fillers. We asked participants to memorize the sentences and not just to read them aloud, since, it has been claimed that the production of recalled sentences is closer to natural speech, as far as prosody is concerned, than is the read speech (Bock 1982; McDonald et al. 1993; Potter & Lombardi 1990; Fox Tree & Meijer 2000).

The whole procedure and especially participants' productions were recorded using the recorder Marantz (PMD661) and an external condenser microphone (RODE M3). In cases in which participants chose the wrong picture, they were informed about their false choice and the experimental presentation continued with the next pair of pictures, without participants producing the corresponding sentence. Each session lasted around 20 to 25 minutes depending on the time participants needed in order to read, understand, memorize and produce the sentences (for the procedure see also Martzoukou & Papadopoulou 2016).

3.3 *Data analysis*

3.3.1 ToBI analysis

For each of the 30 speakers, there were 60 sentences, thus a total of 1,800 recorded utterances. The acoustic and phonological analyses of both the ambiguous and the unambiguous sentences were performed by means of the computer programme Praat version 5.1.0.7 (Boersma & Weenink 2017) and the Greek Tones and Break Indices (GrToBI) (Arvaniti & Baltazani 2000). All sentences were acoustically annotated by examining the pitch contour demonstrated on the spectrograph of Praat and by codifying it according to the conventions imposed by GrToBI. Analysis was focused on prosodic phrasing and more specifically on identifying the location of phrase accents⁶ within the utterances, and it was conducted by two trained coders (one of whom was the first author) who reached an overall agreement. Based on the aforementioned predictions, the critical part is from the beginning of the embedded verb until the end of the ambiguous DP, since the phrase accent could be located either just before or just after the ambiguous DP. Examples (10) and (11) depict the intonation pattern (blue line) as it is presented on Praat and the decoding as it is conducted by the decoders for the subject (10) and the object reading condition (11) of one experimental item using GrToBI.

(10) Subject reading condition

ka'ðos 'erave / to ku'bi 'ylistrise
while was-sewing_{-3SG} the_{-N.SG.NOM/ACC} button_{-N.SG.NOM/ACC} slip_{-PST.3SG}
sto 'patoma
on the floor
'While (s)he was sewing the button (she/he) slipped on the floor'.

6 Analysis revealed the existence of PPhs marked with the use of phrase accents and no intonational boundary to appear.

(11) Object reading

ka'ðos 'erave to ku'bi / 'ylistrise
while was-sewing-3SG the-N.SG.NOM/ACC button-N.SG.NOM/ACC slip-PAST.3SG
sto 'patoma
on the floor
'While (s)he was sewing the button [(s)he] slipped on the floor.'

As is also presented in the examples, the phrase accents which were found in all sentences were the H- or the !H-, whereas the most common pitch accents were the L*+H and in much lesser extend the H*. The L*+H pitch accent marks the boundary. Therefore, in the subject reading (example (10)) we can see that the boundary is between the verb and the DP, while in the object reading (example (11)) is at the end of the DP.

3.3.2 Duration measurement

The durations of the embedded verb and the ambiguous DP were measured for each of the 720 totally ambiguous utterances. According to the phrase-final lengthening phenomenon, the duration of a word appearing at the end of a phrase is expected to be longer than in any other phrasal position (Beckman & Edwards 1990; Boomer 1965; Cooper & Paccia-Cooper 1980; Klatt 1975; Oller 1973). Therefore, since the phrase accents were expected to be located just after the embedded verb or just after the following DP, the duration of both the embedded verb and the ambiguous DP was calculated in each of the 720 ambiguous experimental utterances.

3.3.3 Statistical analysis

The data were then imported to the SPSS program and statistical analyses, both for the participants (1) and the items (2), were undertaken. The Shapiro-Wilk Test was used in order to check the normality of data distribution. For normally distributed data, parametric tests were conducted, whereas non-parametric tests were used for the analysis of non-normally distributed data.

3.4 Results

3.4.1 GrToBI analysis—unambiguous fillers

We first report on the results from the investigation of the prosodic cues used by participants, while producing the unambiguous filler items. This analysis will provide the baseline prosodic patterns for the subject and the object interpretation. The remaining items, ambiguous fillers and experimental sentences, will be evaluated according to these baseline patterns.

Seven out of the 360 cases in which the DP was the subject of the main verb were excluded from any further analysis (1.9% of the data), since in 5 of them participants indicated wrong pictures and in 2 utterances participants changed the case of the DP from nominative to accusative. Moreover, there were 9 productions in which participants placed two phrase accents (always marked with H-), one just after the embedded verb and one just after the DP.

It could be claimed that the pattern of the two phrase accents is predicted by the Gee & Grosjean's (1983) algorithm. This prediction though is not clear, since the value associated with this boundary is 5, which is not distinct enough from 3, the following value (see Figure 3). Moreover, the pattern of the two phrase accents was also found in the object reading conditions, as it will be shown later on; this indicates that the two phrase accents do not clearly constitute another pattern of the subject reading condition. For this reason, we refer to such cases as a worth-mentioned intonation pattern, but we decided to exclude them from any further statistical analysis, since they are too few (only 9 instances) to be further analyzed as a separate intonation pattern and cannot be merged with any of the two conditions (subject vs. object reading), since they appeared in both cases.

As for the remaining 344 utterances, the phonetic transcription revealed that in 336 utterances (97.7%), participants placed a phrase accent, which marks the boundary of the intermediate phrase (H-), just after the embedded verb while in only 8 cases (2.3%) did they produce a phrase accent at the end of the DP. Therefore, the results of the subject condition revealed that the most common intonation pattern attested was characterized by the production of a phrase accent just after the embedded verb.

As far as the unambiguous sentences in which the DP was the object of the subordinate verb are concerned, participants twice exhibited wrong picture matching and twice they used two phrase accents, one after the embedded verb and the other after the DP. These cases were excluded from any further analysis (1.1% of the data). From the remaining 356 utterances, there were only 4 cases in which participants placed the phrase accent just after the embedded verb, whereas in the remaining 352 sentences (98.9%), the intonation pattern was characterized by the presence of a phrase accent just after the DP.

FIGURE 6 Preference (%) for the subject or the object intonation phrasing for the condition of the ambiguous fillers

3.4.2 GrToBI analysis—ambiguous fillers

Participants' productions on the unambiguous fillers gave us a very clear intonation pattern for the subject and the object reading condition (see previous section); namely, a phrase accent just after the embedded verb indicated the subject reading (almost in 98 % of the cases) and a phrase accent just after the DP signaled the object reading condition (almost in 99 % of the cases). Having these patterns as baseline, we explored which intonation pattern participants would use in totally ambiguous cases, i.e. cases in which according to the pictures, the object of the subordinate verb is also the subject of the main verb.

From the in total 330 utterances⁷ there were two cases in which two participants chose an incorrect picture and 8 cases in which participants used two phrase accents, one before and one just after the DP. These cases (3 % of the data) were excluded from any further analysis. From the remaining 320 utterances, 152 (47.5 %) were produced with intonation favoring the object reading, namely by using a phrase accent just after the DP, while 168 (52.5 %) were produced with intonation in line with the subject reading, i.e., with the use of a phrase accent just after the embedded verb. A descriptive analysis revealed a slight preference for the intonation pattern in line with the object reading condition (see Figure 6).

A parametric Paired Samples T-Test, though, revealed no statistically significant preference between the two intonation patterns [$t_{1(29)} = .645$, $p = .524$, two-tailed; $t_{2(10)} = .923$, $p = .366$, two-tailed].

7 Keep in mind that one sentence could not be depicted in such a way that the subject of the main verb to be also the object of the subordinate verb, thus there were 11 sentences, instead of 12.

After analyzing the unambiguous filler-items and extracting the expected intonation pattern for each of the two conditions (subject vs. object reading), we move on to the analysis of the globally ambiguous experimental items, whose ambiguity was resolved via the accompanied picture which depicted the one or the other meaning.

3.4.3 GrToBI analysis—experimental items

The data of the experimental items were in total 720 utterances, 360 cases in which pictures indicated the object reading and 360 cases in which pictures indicated the subject reading condition. In the subject condition, there were 26 cases in which participants pointed to a wrong picture and 19 cases in which participants used two phrase accents, one before and one just after the ambiguous DP. These cases were excluded from further analysis (12.5 % of the dataset). From the remaining utterances, there were 214 cases in line with the subject reading and 101 cases produced in a way that denoted the object reading.

As for the condition in line with the object reading, there were 9 cases in which participants indicated a wrong picture and 10 productions in which participants used two phrase accents. All 19 cases were excluded from any further analysis (5.3 % of the data). From the remaining utterances there were 246 cases in which the object reading was correctly indicated and 95 productions in line with the subject reading.

The descriptive statistics, based on the analysis of the intonation pattern, revealed that in the subject reading condition, participants used the correct intonation pattern (by correct we mean the expected one, according to the results of the unambiguous fillers), in the amount of 67.9 %. Similarly, in the object reading condition, participants used the correct prosodic cues in the amount of 72 % (Figure 7).

Within group comparisons, using Paired Samples T-tests, there appeared no significant difference between the two conditions [$t_{1(29)} = 1.101$, $p = .280$, two-tailed; $t_{2(11)} = .236$, $p = .817$, two-tailed].

3.4.4 Duration of the embedded verb (V)—experimental items

The results revealed that overall the participants produced the longer embedded verbs in the subject [546 m/s (SD = 79.99)], than in the object condition [439 m/s (SD = 45.78)] (Figure 8).

Paired Samples T-tests showed that the difference of the duration between the two conditions is statistically significant [$t_{1(29)} = 8.081$, $p < .001$, two-tailed; $t_{2(11)} = 12.442$, $p < .001$, two-tailed].

FIGURE 7 Correct usage (%) of intonation pattern per condition

FIGURE 8 Means (and standard deviations) of the V-duration of the correct utterances per condition

3.4.5 Duration of the DP—experimental items

The descriptive data manifested that, as was expected, participants produced longer DPs in sentences favoring the object reading [580 m/s (SD = 82.34)], compared to their utterances in line with the subject reading [510 m/s (SD = 80.26)] (Figure 9).

Statistical analysis revealed significant difference of the duration of the DP between the subject and the object reading [$t_{1(29)} = 5.512, p < .001$, two-tailed; $t_{2(11)} = 12.427, p < .001$, two-tailed].

3.4.6 Consistency of the applied prosodic patterns

In order to examine whether participants consistently used prosody to distinguish between the two meanings, i.e., the subject and the object meaning, a further analysis was conducted. In this analysis, we only calculated the pairs of sentences in which participants employed the proper prosodic cues for both conditions (the subject and the object reading) of each sentence. Specifically, indicator 1 was given to pairs in which both sentences were produced with the appropriate prosody, whereas indicator 0 was given to pairs in which either

FIGURE 9 Means (and standard deviations) of the DP-duration of the correct utterances per condition

only one or none of the sentences was produced with the correct prosodic information. Pairs in which one sentence was correctly produced in terms of prosody but for the other sentence the wrong picture was selected were not included in the analysis. The descriptive statistics revealed that overall participants used distinguishable prosody 48% of the time, i.e. at chance level (see Appendix 2 for the individual data).

3.5 Discussion

The purpose of conducting the production task was to examine whether participants use disambiguating prosodic cues while producing totally ambiguous sentences. According to the algorithm suggested by Cooper & Paccia-Cooper, no difference is expected to be found between the subject and the object reading conditions of the present study. On the other hand, Gee & Grosjean's (1983) as well as Watson & Gibson's (2004) algorithms predict distinct prosodic cues in the subject and the object reading conditions. Our predictions were in line with the ones made by the two latter algorithms in that, based on the results of the comprehension task and the findings reported by Anderson & Carlson (2010), participants were expected to use different prosodic cues to mark the subject and different ones to mark the object reading condition. =00

The results are in line with the predictions made by Gee & Grosjean's (1983) and by Watson & Gibson's (2004) algorithms, but not with the ones suggested by Cooper & Paccia-Cooper's mapping. Therefore, the less syntactic based mappings seem to be more suitable for the prediction of the intonation pattern, even when more recent syntactic representations are used.

These findings revealed that native speakers of Greek use different prosodic patterns on their subject and object utterances while producing morphosyntactically ambiguous sentences. Therefore, the overall outcomes are in line with

the claims made by several studies, according to which even untrained speakers use distinct prosodic cues in the subject and the object reading conditions (e.g., Kraljik & Brennan 2005; Schafer et al. 2000b, 2005; Speer et al. 2003, 2011; Warren et al. 2000).

An additional analysis was conducted in order to explore the frequency of the expected prosodic contours as a means of distinguishing between the two meanings of each sentence. The analysis indicated that although participants of the current study did use different prosodic patterns to produce the two different conditions, as in previous studies (Kraljik & Brennan 2005; Schafer et al. 2005; Speer et al. 2003, 2011; Warren et al. 2000), they did not consistently use prosodic cues to differentiate between the two meanings of each given sentence.

4 General discussion

The main aim of the present study was to explore whether untrained speakers use prosodic cues while comprehending and producing subject/object ambiguities in Greek.

As far as the sentence completion task is concerned, even though participants were sensitive to prosody cues, as already mentioned, they performed more accurately on the object than the subject reading condition. The preference for the object reading condition was attested in several studies exploring the comprehension of subject/object ambiguities with written stimuli, namely without the use of prosodic cues (Christianson et al. 2001; Ferreira & Henderson 1991; Frazier & Rayner 1982; Frenck-Mestre & Pynte 1997; Mitchell & Holmes 1985; Pickering & Traxler 1998; Staub 2007; van Gompel & Pickering 2001; Warner & Glass 1987). This preference has been attributed to the fact that the transitive structure is considered to be the simplest structural analysis for the parser, with the less computational demands, since it does not require the construction of a new syntactic phrase or a new θ -domain (Crocker 1999; Frazier 1978, 1987; Pritchett 1988). On the other hand, though, it could be claimed that the processor just adopts the most frequent structure in a specific language. This possibility cannot be excluded, since the transitive analysis might indeed be the most common construction, as it appears to be in English (Pickering & van Gompel 2006). A self-passed reading task has been conducted in Greek by Papadopoulou & Tsimpli (2005), who tested fragmented stimuli containing a temporal conjunction, such as *when*, and optionally transitive verbs like the ones used in the present study. The results revealed no preference for either the object or the subject readings.

Interestingly, the results of the present sentence completion task, contrary to the findings of previous studies exploring prosody (e.g., Anderson & Carlson 2010; Carroll & Slowiaczek 1987; Kjelgaard & Speer 1999; Kjelgaard et al. 1999; Speer et al. 1996; for Greek, Papageli 2010) showed that the preference for the object reading was prevalent, even though the experimental items were presented with cooperative prosody (see also Martzoukou et al. 2017). These findings could be due to the fact that the utterances used in the present study were produced by untrained speakers, who were naive to the experimental manipulations and were instructed to memorize and produce small passages that contained the partially ambiguous sentences. Consequently, their productions did not contain overstated intonation patterns, exaggerated duration differences and numerous, long pauses. Thus, we think that the experimental stimuli of the present experiment were more natural compared those of previous studies in which orally presented items were carefully prepared by phoneticians or phonologically trained speakers (Clifton et al. 2006; Kang et al. 2004; Price et al. 1991; Pynte & Prieur 1996; Schafer et al. 1996, 2000a) or read speech was used (e.g., Anderson & Carlson 2010). Therefore, further research is needed in order to reach to safe conclusions as to whether the reported asymmetry between the subject and the object reading is related to the acoustic properties of the stimuli or to a more general parsing property of language.

Turning to the production task, the participants were instructed to read, memorize and produce small sentences, after they had selected the picture that each sentence corresponded to. This procedure was chosen in order for more natural speech to be obtained, since it has been argued that recalled utterances are closer to natural speech, than read speech (Bock 1982; McDonald et al. 1993; Potter & Lombardi 1990; Fox Tree & Meijer 2000). The results showed that participants use different prosodic cues to mark the object reading and different ones to mark the subject reading condition. More specifically, they tend to place a phrase accent (H-) just before the embedded verb in the subject condition, while in the object condition they place only one phrase accent (H-), just after the ambiguous DP. A similar pattern is indicated by both the durations of the verbs and the DPs, in that they last longer when they are at the end of a PPh. The prosodic patterns found in the present study (duration of the verbs and the DPs in each condition as well as the placement of the phrase accent in the subject and the object reading condition) are exactly the same as the one described by Anderson & Carlson for English (2010).

As for the syntax-prosody mappings suggested by Cooper & Paccia-Cooper (1980), Gee & Grosjean (1983) and Watson & Gibson (2004), it seems that the most suitable ones are those which are not strictly based on syntactic map-

pings, namely the two latter ones. In Gee & Grosjean's algorithm the possibility of a boundary to occur depends on the value between the two phrases. Until now we took into consideration the biggest values of the algorithm namely 8 in the subject reading condition and 7 in the object reading condition. A closer look though reveals that in the subject reading condition there is also a smaller boundary predicted between the DP and the verb. Thus, if we assume that Gee & Grosjean's algorithm predicts two phrase accents in the subject reading condition, then we could claim that, compared to the other algorithms, Gee & Grosjean's can better describe the results of the present study, since it is the only one which predicts a second phrase accent just after the DP in the subject reading condition. A closer analysis of the production data, however, revealed that, even though our participants used different prosodic patterns for the subject and the object readings to the degree of approximately 70%, they did not consistently use prosody (below 50%) to distinguish between the subject and the object meaning of each sentence (see also Appendix 2). Also notice that this is in sharp contrast with the morphosyntactically unambiguous fillers which are almost always (above 95%) produced with the expected distinctive prosodic contours. In other words, it appears that, when the sentence is morphosyntactically ambiguous, prosody is not consistently activated to act as a disambiguating cue. Therefore, in such cases, it could be assumed that speakers rely more on the linguistic context or on pragmatics and not on the use of prosody, in order to denote the intended meaning. In this sense, our findings are consistent with the claim that untrained speakers do not consistently use informative prosodic cues, especially if they are not instructed to do so (Allbritton et al. 1996; Snedeker & Trueswell 2003).

The present data offer the possibility of a direct comparison between the two modalities, as the two tasks have been conducted with the same participants. Interestingly, the findings indicate differences between the two modalities, in that listeners rely on prosodic cues to a greater extent (88.5% for both conditions) than speakers do (70% for both conditions; below 50% in the second analysis). These findings are in line with those reported in Allbritton et al. (1996) and Snedeker & Trueswell's (2003), but they are inconsistent with the outcomes reported by Schafer et al. (2005), Speer et al. (2003, 2011), Kraljic & Brennan (2005) and Warren et al. (2000), who argue that prosody is consistently employed by both speakers and listeners. These differences are due to the participants' characteristics (trained vs. untrained speakers) and their awareness of the ambiguities as well as the design of each experiment.

5 Conclusions

The present findings support previous work that prosodic cues are employed by both listeners and speakers in order to clarify the meaning of morphosyntactic ambiguities. Moreover, the prosodic patterns used by Greek speakers for both the subject and the object readings are the ones suggested by Gee & Grosjean (1983) and Watson & Gibson (2004), and also attested in English by Anderson & Carlson (2010). The present results, however, depart from previous findings in two respects: (a) the prosodic contour of the object reading was significantly better comprehended than was that of the subject reading, and (b) the expected prosodic patterns in the production task were not used systematically to distinguish between the two possible meanings. Additionally, the data pointed to differences between the two modalities, suggesting that prosody is a more reliable cue in comprehension than in production.

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Appendix 1

Durations of the verb, the DP and the pauses and pitch range for the utterances produced by the female and the male speaker.

Gender	Items	Conditions	Verb (ms)	Pause (ms)	DP (ms)	Pitch range (Hertz)
Female	ka'θos sxe'ðiaze/ta 'skitsa	S	0.631	no	0.482	229.788
Female	ka'θos sxe'ðiaze ta 'skitsa/	O	0.619	no	0.638	243.999
Female	ka'θos cini'γuse̞ta ku'ne̞la	S	0.626	no	0.522	256.838
Female	ka'θos cini'γuse ta ku'ne̞la/	O	0.481	no	0.766	247.539
Female	ka'θos 'eplen̞eta po'tirja	S	0.431	no	0.493	264.795
Female	ka'θos 'eplene ta po'tirja/	O	0.335	no	0.778	232.070
Female	ka'θos 'esproxn̞eta tra'pezja	S	0.498	no	0.543	180.524
Female	ka'θos 'esproxne ta tra'pezja/	O	0.452	no	0.744	185.086
Female	ka'θos ci'tuse̞ta afto'cinita	S	0.606	0.143	0.661	198.872
Female	ka'θos ci'tuse ta afto'cinita/	O	0.404	no	0.958	280.595
Female	ka'θos 'potize̞ta lu'luðja	S	0.551	no	0.572	173.661
Female	ka'θos 'potize ta lu'luðja/	O	0.379	no	0.756	182.389
Male	ka'θos 'erave̞ta ku'bja	S	0.318	no	0.453	40.482
Male	ka'θos 'erave ta ku'bja/	O	0.215	no	0.511	60.425
Male	ka'θos 'ðjavaze̞ta 'γramata	S	0.483	0.091	0.462	59.002
Male	ka'θos 'ðjavaze ta 'γramata/	O	0.374	no	0.608	51.095
Male	ka'θos 'psekaze̞ta 'fila	S	0.546	0.062	0.367	48.533
Male	ka'θos 'psekaze ta 'fila/	O	0.434	no	0.524	73.272
Male	ka'θos kse'skonize/ta 'rafça	S	0.745	no	0.633	50.708
Male	ka'θos kse'skonize ta 'rafça/	O	0.607	no	0.482	53.276
Male	ka'θos 'epsine̞ta ku'lurja	S	0.475	no	0.535	48.649
Male	ka'θos 'epsine ta ku'lurja/	O	0.314	no	0.574	55.468
Male	ka'θos ma'jireve̞ta ma'karɔɲa	S	0.535	no	0.612	60.349
Male	ka'θos ma'jireve ta ma'karɔɲa/	O	0.438	no	0.679	47.838

Appendix 2

Frequencies and percentages of accurate responses for both the subject and the object condition of each experimental sentence per participant.

Participants	Both conditions frequencies	Both conditions percentages
1	3/12	25
2	1/12	8.3
3	4/12	33.3
4	7/12	58.3
5	8/12	66.7
6	5/12	41.7
7	11/12	91.7
8	4/12	33.3
9	8/12	66.7
10	6/12	50
11	5/12	41.6
12	8/12	66.7
13	1/12	8.3
14	4/12	33.3
15	2/12	16.7
16	8/12	66.7
17	11/12	91.7
18	9/12	75
19	6/12	50
20	7/12	58.3
21	7/12	58.3
22	8/12	66.7
23	10/12	83.3
24	6/12	50
25	3/12	25
26	6/12	50
27	5/12	41.7
28	5/12	41.7
29	3/12	25
30	2/12	16.7
TOTAL	173/360	48