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RESEARCH

Anaphora resolution and word-order across adulthood: Ageing effects on online listening comprehension

Georgia Fotiadou[1], Ana I. Pérez Muñoz[2] and Ianthi Maria Tsimpli[3]

[1] Aristotle University of Thessaloniki, GR

[2] Universidad de Granada, ES

[3] University of Cambridge, GB

Corresponding author: Georgia Fotiadou (geofotia@enl.auth.gr)

In this visual-world paradigm we investigated the processing and interpretation of two overt subject anaphoric expressions in Greek, a null-subject language with a relatively free word-order, in relation to specific linguistic properties and whether these differ across adulthood. Specifically, we explored whether changes in anaphoric type (*o ídhios* vs. *aftós*) and syntactic complexity (SVO vs. OVS word-orders) had similar effects in how reference was processed and finally resolved by young and elderly adults. We analysed (a) fixation duration in subject and object antecedent pictures to examine online processing and (b) offline responses in comprehension questions to investigate final interpretation, i.e., ambiguity resolution. Our offline results revealed that pronominal resolution patterned across age groups: A clear subject preference of *o ídhios* ('the same') was drawn from results irrespective of the word-order used, suggesting that this expression is preferentially linked to an element in prior discourse that has a parallel subject grammatical role, due to its focus feature (though OVS boosted the less preferred object readings). *Aftós* ('he'), a pronoun previously suggested sensitive to topic-shift, was overall proved ambiguous for both young and elderly adults. An age effect was qualified by significant differences in online processing of both subject expressions, as evidenced by fixation on both antecedent pictures. Interestingly, syntactic complexity (OVS structures) interacted with age in the case of *o ídhios*, raising fixation in subject antecedents among young, compared to the elderly adults. Age, but not linguistic manipulation, modulated processing of the anaphoric pronoun *aftós* and of object antecedent pictures overall.

Keywords: anaphora resolution; word-order; overt subject anaphoric expressions; ageing; visual-world paradigm

1 Introduction

Anaphora resolution (AR) is the process of determining the antecedent of a pronoun, a phenomenon that has been extensively investigated across different languages and populations. Evidence demonstrates that the interpretation of an anaphoric pronoun can be influenced by language-specific properties (e.g., Reuland 2011), differences between the first and the second language of bilinguals (e.g., Sorace & Filiaci 2006), working memory load and/or cognitive control (e.g., van Rij, van Rijn & Hendriks 2013), indicating that AR presupposes the interaction of all of the above factors.

Linguistic properties which regulate the prominence (or salience)[1] of an antecedent include its grammatical role (e.g., Stevenson, Crawley & Kleinman 1994; Grosz, Joshi & Weinstein 1995; Bosch, Katz & Umbach 2007), its thematic role (e.g., Schumacher, Backhaus & Dangl

[1] The terms prominent and/or salient are interchangeably used to describe some entity that stands out in the context, is more activated or accessible in memory than others.

2015; Schumacher, Dangl & Uzun 2016; Schumacher, Roberts & Järvikivi 2017), its position in the sentence (e.g., Stevenson et al. 1994) as well as the antecedent's information and discourse status (e.g., Grosz et al. 1995; Kaiser & Trueswell 2008; Colonna, Schimke & Hemforth 2012; Ellert 2013). As these properties always co-exist in AR, it is difficult to unpack the contribution of each factor and to identify which of these factors affect AR earlier or later in processing, during the integration stage when AR is complete.

The relative prominence of competing antecedents is further affected by the parallelism between the subject or object role of the antecedent and the pronoun (e.g., Smyth 1994; Stevenson, Nelson & Stenning 1995), the semantics of the verb (e.g., Grober, Beardsley & Caramazza 1978; Schumacher et al. 2015; 2016; 2017) as well as discourse relations (e.g., Kehler, Kertz, Rohde & Elman 2008; see also Kaiser 2011). Crucially, the type of anaphoric expression (e.g., Gundel et al. 1993; Ariel 2001; Bosch et al. 2007; Kaiser & Trueswell 2008; Schumacher et al. 2015) complicates any attempt to comprehensively describe or predict AR or different anaphoric types even further. This is more so when the referring expressions considered are all pronominal in nature, such as differences in AR depending on the null or overt status of a pronoun in null subject languages (e.g., Carminati 2002; Tsimpli, Sorace, Heycock & Filiaci 2004; Jegerski, Van Patten & Keating 2011).[2]

Although AR in null subject languages has been extensively studied in recent years, comparisons between different types of *overt* pronouns in null subject languages remain under-researched. The main question here is whether the lexical, phonological and syntactic properties that an anaphoric expression has *independently of context*, contribute to AR in null (and non-null) subject languages, and how these properties interact with linguistic factors affecting antecedent prominence (lexical, sentence or discourse-based). Studies on anaphoric type in AR assume that different anaphoric expressions are used depending on interpretative preferences determined by topic prominence,[3] parallelism between the subject/object position of antecedent and anaphoric expression or any of the other linguistic factors mentioned above. Accordingly, studies focusing on overt and null pronouns assume (mostly implicitly) that the phonological difference between the two types of pronouns affects syntactic and interpretative preferences.[4] As pronominal inventories can include more than one overt pronoun in null subject as in non-null subject languages (e.g., Gürel 2003; 2004), it is useful to examine how possible lexical or other differences between them affect AR in null subject languages where the primary distinction identified previously in AR studies is between null and overt pronouns.

Apart from linguistic factors, individual differences and cognitive skills contribute to AR. It is broadly accepted that AR is relevant to the interface between language and discourse (Sorace & Filiaci 2006), and thus is affected by language attrition due to bilingualism or cognitive decline in healthy ageing (Tsimpli et al. 2004; Hendriks, Koster & Hoeks 2014), although not equally across anaphoric expressions (Kaltsa, Tsimpli & Rothman 2015). Recent research attempted to evaluate changes in the interpretation of ambiguous pronouns across the lifespan by manipulating topic-shift (Hendriks et al. 2014) and working memory (WM) load (van Rij et al. 2013). A possible source of divergent anaphora resolution among the elderly, when compared to the young, has been associated with ageing and age-related decline in their working memory capacity (cf. Fraundorf, Watson &

[2] The role of pronoun type in AR has also been studied in non-null subject languages where the focus is usually between personal and demonstrative pronouns in subject position (e.g., Sauermann & Gagarina 2017).

[3] We use the term *topic* to describe the entity that the discourse is about. Topic in our discussion here fits the definition of the backward-looking centre in Centering Theory (e.g., Brennan, Friedman & Pollard 1987) and illustrates the most prominent discourse referent of the previous clause, also referred to in the critical one.

[4] Studies focusing on different demonstrative-personal pronouns in non-null subject languages focus (mostly implicitly again) on the effects their lexical differences have on AR.

Benjamin 2012). Nevertheless, healthy ageing and AR is still under-researched especially in relation to how AR changes in young and elderly adults when linguistic factors are manipulated.

Besides, most of previous research has tried to understand AR by using offline measures (e.g., preferences, judgments and reaction times measuring how fast participants arrive at judgments making use of explicit knowledge). Given that the interpretation of ambiguous anaphoric pronouns requires the integration of several lexical, morpho-syntactic and extra-linguistic factors, measures detecting early reactions to the stimuli are essential.

Our study aims to fill this gap by investigating how AR can be predicted by the combination of two linguistic factors, namely type of overt subject anaphoric expression and syntactic complexity, in a null subject language (Greek) in relation to effects of ageing on AR online processing. The overt subject expressions tested include the pronoun *aftós* ('he') and the anaphoric expression *o ídhios* (lit. 'the same') on the basis of specific linguistic properties (namely word-order of antecedents' introduction in the preceding clause) and whether these differ across adulthood. The study is novel in that it is the first to include an experimental investigation of the comparison of these two overt anaphoric expressions using eye-tracking data in young and elderly healthy adults.

The structure of the article is as follows. We first frame the study of the anaphoric type based on previous studies on AR, followed by the role of ageing in the interpretation of reference and we next outline AR in the Greek paradigm. We then present our study, a visual-world paradigm, and our results from the on-line eye-tracking data and the offline interpretative preferences, as found in two age-groups of Greek monolingual adults. Finally, we discuss the implications of our findings in relation to the role of ageing in AR processing and the relative contribution of anaphoric type and syntactic complexity in young and elderly monolingual Greek adults.

1.1 Previous research on anaphora resolution

Prior work on AR has resulted in a great number of theoretical accounts that uniformly assume that, when the language under investigation allows for null subjects, the most prominent/salient entities are referenced with the most reduced anaphoric expression, i.e., the null form. Although the availability of null and overt pronouns is a grammatical property in null subject (*pro*-drop) languages, final interpretation of the subject pronoun (or *pro*) is regulated by various discourse factors. To this aim, researchers examined discourse notions such as Topicality (Givón 1983), Accessibility (Ariel 1990), Givenness (Gundel et al. 1993), or Informativeness (Allen 1997) to illustrate a hierarchy associating salient entities with the use of pronominal reference.

Accordingly, Arnold formulated the Expectancy Hypothesis through the investigation of the first-mention advantage. In two visual-world paradigm experiments Arnold, Eisenband, Brown-Schmidt & Trueswell (2000) investigated adults' on-line pronoun resolution: first mention and recency were the factors examined as potential contributors to referent accessibility. In their first experiment, the two competing antecedents either matched or not in gender: In the same gender condition, the pronoun was temporarily ambiguous since it could refer to either entity, although visual cues provided evidence for only one possible antecedent. Results revealed that when the gender matched and the pronoun referred to the second-mentioned entity, gaze data differed from all the other conditions in that participants looked equally at both subject and object antecedents, although the target was the object one. No differences were found across conditions in the accuracy rates of the comprehension questions. In their second experiment, the authors increased the accessibility of the first-mentioned antecedent adding an interim sentence, where a pronoun repeated reference to this participant. They found that on-line processing of the

target picture was enhanced across conditions in that effects appeared earlier than in the experiment with no interim sentence. In this experiment, however, accuracy decreased when the pronoun referred to the second-mentioned antecedent. Results suggested that participants *expected* the pronoun to refer back to the first-mentioned entity, unless grammatical cues (i.e., matching of the gender) biased interpretation to the object antecedent. Noticeably, it is not easy to conclude whether it is first-mention or subjecthood that guides interpretation in English, which was the language used in these experiments. Indeed, we may assume that a match between the grammatical role of the subject pronoun and the antecedent, i.e., a parallelism effect, is the one directing the processing and interpretation of the pronoun (Stevenson et al. 1995).

Much of previous research on AR on null subject languages such as Greek, Italian and Spanish focuses on the interpretation of null and overt subject pronouns in intra-sentential anaphora contexts (e.g., Tsimpli et al. 2004; Filiaci 2010). The findings typically converge on the conclusion that the most salient entities are referenced with the most reduced anaphoric expression, namely the null pronoun. Carminati (2002) suggested that null pronouns in Italian show a bias for subject antecedents, while overt pronouns prefer the less prominent discourse entities (i.e., usually the non-subject antecedent), as they are more informative. Carminati's proposal has been supported by similar findings from Italian, Greek, Spanish and Catalan (e.g., Dimitriadis 1996; Alonso-Ovalle, Fernandez-Solera, Frazier & Clifton 2002; Miltsakaki 2002; 2007; Filiaci 2010; Jegerski et al. 2011; Keating, VanPatten & Jegerski 2011) although some studies have also found cross-linguistic differences among null subject languages (Tsimpli et al. 2004; Filiaci 2010), and even intra-language differences (Carminati 2002; but see also Tsimpli et al. 2004). Overall, these findings suggest that overt pronouns trigger a preference for non-salient antecedents in Italian, Catalan and Greek vs. Spanish, with Spanish not exhibiting a strong preference.

Previous evidence reporting clear differences between two overt pronouns comes from Turkish (e.g., Gürel 2003; 2004). Gürel tested native speakers of Turkish with sentences containing a null pronoun (*Ø* or *pro*), or the Turkish overt forms *o* ('s/he') and *kendi-* ('self'). The author found that *o* only allowed disjoint reading, whereas the null pronoun and *kendi-* were unconstrained in binding, bringing up similarities to Greek. More specifically, Gürel suggested participants interpreted the overt *o* pronoun as referring to a non-subject entity, whereas null and *kendi-* pronouns were equally interpreted as the subject of the main clause or another entity (not) included in the previous context.

1.2 Age differences and cognitive decline in anaphora resolution

The vulnerability of the interfaces vs. that of pure grammatical aspects of language has been put forward by previous research in bilingualism and attrition (e.g., Tsimpli et al. 2004; Sorace & Filiaci 2006), since processing demands the coordination of various types of information, grammatical and discourse linked ones. Interpretation of reference presupposes cognitive control in the manipulation of linguistic (morpho-syntactic) and extra-linguistic (pragmatic) factors in real time. When competing antecedents are involved, it can be a process of disambiguation more difficult than structural ambiguity. Thus, when grammar does not disambiguate, as in the case of different gender cues, AR illustrates preferences and not categorical judgments, which however involve the integration of linguistic information (the form of the expression, the search for the optimal antecedent, the linguistic properties of the sentences in which the form and the antecedent appear), world knowledge and processing capacity. Under this rationale, AR should provide evidence of differences in the way people interpret specific anaphoric expressions and whether interpretations vary according to one's cognitive abilities and whether they change over the years.

The idea stems from the fact that people with a high working memory (hence WM) capacity may be more sensitive to sentence ambiguity (e.g., Dwivedi & Golhawk 2009). Besides, WM capacity has been correlated with readers'/listeners' ability to override a first, incorrect analysis of a sentence in view of new, conflicting information in sentences which include local ambiguity (as in *garden-path* structures) (Novick, Trueswell, & Thompson-Schill 2005). Crucially, separable syntactic, semantic and phonological components to WM, all of them being specialized WM capacities have been associated with the maintenance of different types of information (e.g., Waters & Caplan 2001). Adding to this, age related effects are attested in sentence comprehension of *garden-path* structures (e.g., Stine-Morrow, Ryan & Leonard 2000; DeDe, Caplan, Kemtes & Waters 2004) and are often correlated with measures of tasks tapping into WM abilities (e.g., Christianson, Williams, Zacks & Ferreira 2006), although no clear-cut relation between sentence comprehension and WM capacity is always reported.

Under this rationale, van Rij et al. (2013) implemented a computational model simulating the interpretation of subject pronouns. They suggested that WM load reduces individuals' sensitivity to the various discourse related cues, resulting to a divergent interpretation of the pronouns examined. Their empirical testing of the model confirmed that WM constraints affect adults' pronoun resolution. Actually, in a dual-task experiment, they manipulated WM load (with a digit task) and topic-shift (in a four sentence story-reading task, using a moving-window paradigm). They analysed online and off-line measurements and found that in the high WM load condition participants selected less often the subject of the first sentence only in stories with topic-shift, although story type yielded no differences in response times or during processing (contrary to their expectations). Moreover, WM load rendered the reading of stories slower in both story types.

Finally, Hendriks et al. (2014), examining referential choice across lifespan, suggested that WM and age-related effects condition AR. More specifically, using picture-based stories, the authors suggested that, in production, older adults were less strategic in encoding/retrieving the most important information from the discourse than younger ones and, therefore often overused ambiguous pronouns. They attributed their results to reduced cognitive capacities which help keep track of the prominence of discourse referents (see also Hendriks, Englert, Wubs & Hoeks 2008 for a theoretical explanation based on the framework of bidirectional Optimality Theory; bi-OT).[5] In comprehension instead, they found that, as in other studies (e.g., Light & Capps 1986; Titone, Prentice & Wingfield 2000), elderly adults did not appear to have problems with disambiguating the pronoun on the basis of the information presented in the immediately preceding sentence. Interestingly, both production and comprehension results correlated positively with participants' WM scores, in the case of children and elderly adults, while no such evidence was found for young adults (as in the case of van Rij et al. 2013). Similarly, age differences across children and adults were demonstrated in Papadopoulou, Peristeri, Plemenou, Marinis & Tsimpli (2015), who investigated the interpretation of null and overt anaphoric pronouns in children and adult Greek native speakers, using a self-paced listening and judgment task combined with pictures that matched in grammaticality. The authors found that the overt pronoun elicited a strong preference for the object antecedent in both children and adults, whereas children differed from adults in allowing null

[5] Hendriks et al. (2014: 393) put forward an asymmetric Grammar Hypothesis, according to which grammar defines different correspondences between meaning and form for production and comprehension. Thus, language speakers optimize their production taking the perspective of their listeners and choose the referring expression that best suits the listener's understanding. Since production is not part of our methodology, we will no longer discuss the matter.

pronouns to refer to either subject or object antecedents; divergent anaphora resolution was associated with differences in language experience.[6]

Overall, these results shed some light to the idea that age-related individual differences may play a role in AR especially when additional linguistic factors increase complexity and the disambiguation of the pronoun demands more cognitive resources.

1.3 Word-order and anaphora resolution in Greek

Greek is a head-initial *pro*-drop language with a rich inflectional system that distinguishes subject and object positions with morphological case (nominative and accusative, respectively): Grammatical functions are marked with morphological case while subjects and objects show relative freedom in word-order patterns (Roussou & Tsimpli 2006). According to an early account (Philippaki-Warburton 1982), the basic word-order in Modern Greek is verb-subject-object (VSO; see 1a), implying that the subject occupies its canonical subject position only in this word-order. Tsimpli (1990; 1995) also suggested that the subject occupies a position lower than the verb. In the subject-verb-object order (SVO; see 1b) the subject occupies a Topic position which is adjoined to the Tense projection, and the same analysis is offered for the verb-object-subject (VOS; see 1c), the only difference being in the directionality of the adjunction which in VOS is to the right of the Tense projection. In both of these word-orders the grammatical subject is a *pro*, occupying the canonical subject position while the overt subject is a topic. In fact, a postverbal subject is possible in a wide-focus question of the 'What happened?' type. Nevertheless, the most frequent word-order in corpora is SVO (Lascaratou 1989), which has been shown to be easier to process (Kail & Diakogiorgi 1994).

(1) a. *VSO*
Sinandise o Janis ton Kosta.
met.3SG the.NOM Janis.NOM the.ACC Kostas.ACC
'Janis met Kostas.'

b. *SVO*
O Janis sinandise ton Kosta.
the.NOM Janis.NOM met.3SG the.ACC Kostas.ACC
'Janis met Kostas.'

c. *VOS*
Sinandise ton Kosta o Janis.
met.3SG the.ACC Kostas.ACC the.NOM Janis.NOM
'Janis met Kostas.'

One of the word-order patterns associated with changes in information structure (i.e., object topicalization or object focusing) is object-verb-subject (OVS; see e.g., Tsimpli 1995; 1998; Alexiadou 1999). In (2a), the OVS order includes a preposed object (e.g., *ton Kosta* = 'the.ACC Kostas.ACC') which may be interpreted as given information (i.e., already mentioned in the previous context) and topicalised while *doubled* by a pronominal clitic attached to the verb. Although the OVS order in Greek is also found in object focusing (2b), it is only in topicalization structures such as (2a) that a pronominal clitic

[6] Early acquisition of the discourse level (information structure) is evidenced in the spontaneous production of Greek monolingual children aged 1;9–2;2 years (Tsimpli 2005): Null subjects were used when the referent was easily recoverable from the context, while preverbal overt (nominal or pronominal) subjects were used for focused instances and post-verbal ones for non-focused instances.

is required to double (the structure known as *clitic-left-dislocation*; CLLD).[7] The marked nature of the OVS order makes it more demanding in processing, albeit frequent in use.

(2) a. *OVS*
Ton Kosta ton sinandise o Janis.
the.ACC Kostas.ACC him met.3SG the.NOM Janis.NOM
'Kostas, Janis met him.'

b. *OVS*
TON KOSTA sinandise o Janis.
the.ACC Kostas.ACC met.3SG the.NOM Janis.NOM
'It is Kostas that Janis met.'

Finally, notice that although Greek bears similarities to Italian, two *pro*-drop languages which allow postverbal subjects, they differ in that a vP peripheral New Information Focus position hosting postverbal subjects (Belletti 2009) is assumed only for Italian. In fact, a subject DP and an object DP cannot both occur in the same domain in Italian, but they can in Greek, where they spell out different features depending on their grammatical function (for a discussion see Roussou & Tsimpli 2006). Moreover, empirical data from research examining production and interpretation of pronominal pre- and postverbal subjects (Tsimpli et al. 2004) confirm differences between Greek and Italian.

When it comes to reference, previous psycholinguistic studies in Greek suggest that the null and overt options are ambiguous, although they exhibit specific preferences with respect to their choice of antecedent. Thus, there is a strong bias for the null pronoun in the Greek example in (3) to co-refer with the discourse salient subject antecedent (e.g., *o astinomikós* = 'the.NOM policeman.NOM') to maintain topichood, rather than the object (e.g., *ton klefti* = 'the.ACC thief.ACC') (e.g., Tsimpli et al. 2004; Papadopoulou et al. 2015).

(3) O astinomikós ídhe ton kléfti ótan Ø éstrive
the.NOM policeman.NOM saw.3SG the.ACC thief.ACC when Ø was-turning.3SG
sti ghonía.
in.ART.SG.ACC corner
'The policeman saw the thief when (he) was turning the corner.'

In contrast, the interpretation of the unstressed overt anaphoric expression *aftós* in (4) is associated with a preference for a less prominent referent, i.e., the object antecedent, marking topic-shift (e.g., Dimitriadis 1996; Miltsakaki 2002; 2007; Papadopoulou et al. 2015). This preference has been found in different types of behavioural tasks (e.g., self-paced reading or listening) for the pronouns *aftós* ('he', 'this one') and *ekínos* ('that one') but no experimental research has examined the anaphoric preferences of *o ídhios* ('the same'/'himself') as yet. Noticeably, these overt subject expressions also have other functions: *aftós* is similar to the demonstrative 'this (one)' and *ekínos*, more marked, is used as the demonstrative 'that (one)' indicating a proximal/distal difference in reference.[8]

[7] The process involved in focusing disallows the presence of a clitic pronoun, as it is suggested to be related to a gap and not to an overt pronominal element inside the sentence (as is the case of CLLD) (see Skopeteas 2016 for a review).

[8] The distinction between *aftós* ('he'/'this one') and *ekínos* ('that one') in the Greek paradigm is beyond the scope of the present paper and will not be further discussed (but see Miltsakaki 2007 on the topic). Similar research investigating overt pronouns to demonstratives in partial NSL, like Finnish (e.g., Kaiser & Trueswell 2008), suggest that demonstratives are used to tracking back less salient referents, offering evidence in favour of the referential form hierarchies proposed by various researchers such as Gundel, Hedberg & Zacharski (1993), Givón (1983) and Ariel (1990).

O ídhios has been suggested to be a pronominal anaphor (see Varlokosta & Hornstein 1993 and Everaert & Anagnostopoulou 2013 for relevant discussion), which behaves similarly to 'himself' with respect to emphatic uses.[9]

(4) a. O astinomikós ídhe ton kléfti ótan **aftós** / the.NOM policeman.NOM saw.3SG the.ACC thief.ACC when he.NOM / **ekínos** / **o ídhios** éstrive sti ghonía. that-one.NOM / the same.NOM was-turning.3SG in.ART.SG.ACC corner 'The policeman saw the thief, when he / that one / the same was turning the corner.'

b. Ton kléfti ton ídhe o astinomikós ótan **aftós** / the.ACC thief.ACC him saw.3SG the.NOM policeman.NOM when he.NOM / **ekínos** / **o ídhios** éstrive sti ghonía. that-one.NOM / the same.NOM was-turning.3SG in.ART.SG.ACC corner 'The thief saw him, the policeman, when he / that one / the same was turning the corner.'

Dimitriadis (1996) used corpus-data to support that specific reference routines are inherent in the lexical entries of pronouns (and *pro*), according to which, overt pronouns (e.g. *aftós/ekínos*) cannot be construed with the most salient entities. Miltsakaki (2002; 2007), using corpus-data and sentence-completion tasks, suggested also that overt pronouns are preferentially anchored to the less salient antecedents. She claimed that this choice is led by the semantic relations between the predicates of the matrix and subordinate clauses, while order of mention of the referents in dependent clauses (intra- and inter-sententially) does not affect the choice.

Research investigating the processing load of backward anaphora and its resolution (Kaltsa et al. 2015; Papadopoulou et al. 2015), followed Tsimpli et al. (2004), creating a self-paced listening with sentence-picture matching grammaticality judgment task. Participants were presented with a picture and paced themselves through listening to a segmented (single) sentence, comprised of a main SVO clause and a subordinate one, introduced by an overt (*aftós*) or null pronoun. At the end of each sentence participants had to judge whether the picture-probe matched (or not) the sentence they had just heard. The pictures depicted the events mentioned in the subordinate clauses in three alternations: the action was performed either by the subject or the object of the matrix clause they had listened to, or by a third new entity (as in Tsimpli et al. 2004). Papadopoulou et al. (2015) tested monolingual children and adult speakers of Greek and found that the overt pronoun elicited strong preference for object antecedents across age groups, while only adults preferred to link the null pronoun to the most prominent/salient antecedent, i.e., the topic, contra Dimitriadis (1996) and Tsimpli et al. (2004). Offering an explanation to this finding, they suggested that the null option is unmarked in the grammar, allowing interpretation to either antecedent, while topic bias is actually the outcome of its contrast to the overt pronoun, also available. Moreover, as already mentioned, children differed from adults in allowing attachment to both subject and object antecedents in the null condition. Kaltsa et al. (2015) compared young and older adult monolingual speakers of Greek to heritage speakers and attriters in a Swedish-speaking environment. They found that, while monolinguals clearly preferred an object interpretation of the overt pronoun,

[9] *O ídhios* is different from *aftós* and *ekínos* in that *o ídhios* includes the definite article, the interpretation in anaphoric use is non-literal only and ídhios is an adjective. Although these differences may be important for syntax, we will not discuss them any further in relation to AR as *o ídhios* only functions pronominally when appearing with the determiner.

the bilingual groups exhibited ambiguity, suggesting that the overt pronoun is vulnerable at the level of interface interpretation. They also spotted divergence in the preferences of younger compared to older participants in that the latter were more flexible in accepting either reference, while the former were shown to be more rigid in their choices.

The only eye-tracking research in Greek so far (Cunnings, Fotiadou & Tsimpli 2017) proposed that the topic-shift preference of overt pronouns in Greek may not be absolute. The study examined pronoun processing and resolution of L2 English among Greek speaking young adults: In their visual-world paradigm (following Arnold et al. 2000) they manipulated a purely grammatical cue, namely the gender of the subject and object competitors, creating ambiguous and unambiguous sentences (when different gender was used). Participants were simultaneously exposed to pictures depicting the two actors next to an object mentioned in the sentence (and a filler picture). Thus, the ambiguity of the *aftós* pronoun (when subject and object antecedents matched in gender) was resolved through visual cues. The authors investigated whether participants transfer L1 Greek to L2 English preferences. Relevant to the present research, they found that the L1 and L2 English speakers exhibited a subject antecedent preference during the pronoun time window. In other words, despite the fact that overt subject pronouns in Greek index a topic-shift, there was a general preference for the subject antecedent (i.e., discourse topic) to guide AR in English L2. On the other hand, in a second experiment investigating AR in Greek, the L1 Greek speakers' eye-movements demonstrated no clear preference during processing of the overt pronoun, a finding that suggests that processing of overt pronouns in Greek does not necessarily trigger a topic-shift interpretation. In the comprehension questions, the participants exhibited a subject preference for the ambiguous pronoun in the subject bias ambiguous condition and an object preference in the object bias ambiguous condition, corroborating previous proposals. Interestingly, the attested object antecedent bias of the overt pronoun *aftós* found in previous judgement and self-paced reading or listening tasks (e.g., Tsimpli et al. 2004; Papadopoulou et al. 2015) may have been affected by the disrupted prosody imposed by the task methodology itself. Alternatively, the object antecedent bias may tap into processes that are not as early as the eye-movement data obtained during listening to continuous language stimuli. It is therefore likely that initial processing of the pronoun is not linked to a strong object or non-topic preference but instead it is genuinely ambiguous.

Finally, turning to properties of the subject expression *o ídhios* ('the same') which lacks any experimental research evidence, Varlokosta & Hornstein (1993) suggested that *o ídhios* qualifies as a regular pronoun, similar to *aftós*, when occurring in subject position. i.e., it does not require a sentence internal antecedent. The expressions differ in that *o ídhios* is necessarily focused, while *aftós* may but need not be focused. We assume that the lexical meaning of *o ídhios* (literally 'the same') carries an inherent focus feature which adds to its saliency and which in turn is responsible for imposing a preference for an antecedent in a parallel (grammatical subject) role. When in non-subject position, *o ídhios* has different properties and shows a mixed behavior with respect to an anaphor/bound variable status: It functions as an anaphor when non-emphatically used, or as an emphatic element modifying a discourse topic, in which case it does not need an antecedent in the sentence (cf. Iatridou 1986; Anagnostopoulou & Everaert 2013).[10]

Overall, when anaphora resolution does not involve categorical judgment but grammatical preference instead, different interpretive effects of null and overt subject pronouns are found in Greek (Table 1). As in a number of null-subject languages, null pronouns

[10] The Greek anaphor/logophor system is argued to have a short distance anaphor (*ton eaftó tu* = 'the self him') and a long distance one (*ton ídhio* = 'the same'), but a discussion on the matter is beyond the scope of this paper, as they occur as objects.

Table 1: Greek subject pronouns and their interpretation.

Null	***aftós* 'he/this (one)'**	***o ídhios* 'the same/himself'**
Maintain topic	Topic-shift	Emphatic
most prominent referents	less prominent referents	subject antecedent preference
Preference for subject but not very strong	Preference for object but attrited in bilingualism	No experimental data

are the default option, co-referential with the previously mentioned subject, topic, or most prominent antecedent, although prior evidence from Greek is not very strong (cf. Dimitriadis 1996). On the other hand, overt subject pronouns (like *aftós*) constitute the 'marked' option indicating topic-shift and are thus often construed as co-referential with the syntactic object. However, previous studies (e.g., Tsimpli et al. 2004; Kaltsa et al. 2015; Papadopoulou et al. 2015; Cunnings et al. 2017) reveal vulnerability of the overt pronoun and suggest that topic-shift properties of overt pronouns may not be absolute in the language. In the absence of empirical evidence, the subject expression *o ídhios* is theoretically expected to behave similarly to *aftós*. Interestingly, behavioural and corpus studies so far (e.g., Miltsakaki 2007) have revealed no effects of word-order intra- or extra-sententially on speakers' interpretive preferences of *aftós*.

2 The current study

The main aim of the present study was twofold. First, we investigated the online processing and interpretation of two overt anaphoric expressions in Greek (*aftós* and *o ídhios*) manipulating word-order (SVO vs. OVS) in the presentation of subject and object antecedents within the preceding clause. In addition, we explored whether the effects of type of anaphoric expression and word-order on AR could be explained by age differences across adulthood (young vs. elderly adults). To the best of our knowledge, the present study is the first to address these issues in Greek.

To this end, we monitored eye movements during a visual-world paradigm in which short texts were aurally presented in Greek (see Table 2). Each text started with a sentence introducing three actors (e.g., 'a hunter, a fisherman and a worker'). The following sentence described an event between two actors of the story, which was in either SVO (e.g., 'The hunter meets the fisherman…') or OVS (e.g., 'The fisherman him meets the hunter…') order. The third sentence began with one of the two overt anaphoric expressions (*aftós* or *o ídhios*), who performed an action related to the third actor or distractor character. The anaphoric expression was always ambiguous as it shared the same gender with the two antecedent referents (e.g., all masculine). Finally, a comprehension question explicitly asked for the referent of the ambiguous subject expression.

During listening to the text, pictures depicting the three actors of the story were presented on the monitor: the subject antecedent (e.g., 'hunter'), the object antecedent (e.g., 'fisherman'), and a distractor character (e.g., 'worker'). In addition, a picture of the scenery was also included to provide contextual information (see Figure 1). To understand whether the online processing of the anaphoric expression was influenced by word-order, age differences and type of anaphor we registered the sum of all fixation durations in the three pictures representing the actors of the story after the ambiguous subject anaphor was presented. Furthermore, to investigate how young and elderly adults interpreted overt anaphoric expressions in Greek, we recorded participants' response preference for the subject antecedent, object antecedent, and distractor in the comprehension question.

Table 2: Example of text used in the online anaphora resolution task.

Introduction		**Edhó íne énas kinighós, énas psarás ki énas erghátis.** **'Here is a hunter, a fisherman and a worker.'**
Word-order	**SVO**	O kinighós sinantái ton psará káthe apóghevma sto dásos dhípla sto potamáki. 'The hunter.NOM meets the fisherman.ACC every afternoon in the forest by the river.'
	OVS	Ton psará ton sinantái o kinighós káthe apóghevma sto dhásos dhípla sto potamáki. 'The fisherman.ACC him meets the hunter.ACC every afternoon in the forest by the river.'
Anaphoric type	**aftós**	Aftós vríke tichéa ekí, metá apó polí keró, ton erghátí. 'He found accidentally there, after a long time, the worker.'
	o *ídhios*	O ídhios vríke tichéa ekí, metá apó polí keró, ton erghátí. 'The same found accidentally there, after a long time, the worker.'
Question		Pjos sinántise ton erghátí? 'Who bumped into the worker?'

Figure 1: Example of pictures displayed in the visual-world paradigm.

2.1 Hypotheses

A syntactic implication arising from the default status of null subjects in NSLs is that overt pronominal subjects are associated with the interpretable features of topic-shift and focus (e.g. Tsimpli et al. 2004). Accordingly, we expected that participants' gaze data would reflect information relevant to these interpretable features. In line with the properties of the two anaphoric expressions discussed before, we predicted that the subject picture would show longer fixation durations when adults listened to *o ídhios* compared to *aftós* (e.g., Varlokosta & Hornstein 1993). This subject preference should remain in the OVS structure as well, assuming that parallelism drives this expression's processing and resolution. In essence both word-orders should reveal matching the subject grammatical role of *o ídhios* to the subject antecedent's (Stevenson et al. 1995).

On the other hand, since the pronoun *aftós* has shown a preference for the less prominent, non-topic entity (e.g., Papadopoulou et al. 2015), we expected anaphoric type to interact with word-order in gaze data on the subject picture. The sensitivity of *aftós* to the discourse-related feature of topic-shift would trigger more ambiguity than *o ídhios*, particularly in the OVS structure where structural subject prominence competes with the topicalized object. Thus, we predicted that *aftós* should be more ambiguous following the OVS vs. the SVO structure.

Turning to predictions for the object picture, we expected that longer fixation durations should be manifested when adults listened to the pronoun *aftós* coming from the SVO compared to the OVS structure (e.g., Papadopoulou et al. 2015), showing a rapid sensitivity to topic-shift in Greek language (e.g., Tsimpli & Sorace 2006). The more frequent but ambiguous nature of the pronoun (cf. Cunnings et al. 2017) would interact with SVO and OVS word-orders used for the introduction of potential antecedents thus leading participants to invest more processing resources (longer fixation durations) to try to resolve the conflict between antecedents.

Age differences were also expected during online processing of these overt anaphoric expressions. Importantly, the ambiguous nature of the pronoun *aftós* and/or the more complex OVS structure were expected to be sensitive to age differences in both subject and object picture gaze duration, where young adults would show longer fixations compared to the elderly, indicating more processing when linguistic circumstances demand high cognitive resources. Age differences were not expected in the subject picture when adults listened to the pronoun *o ídhios*, especially when its potential referents were presented in the unmarked SVO order.

Overall, the online processing effects predicted during pronoun processing (fixation durations) were expected to pattern similarly with the participants' response preference when answering the comprehension question. That is, a general preference for the subject antecedent was expected when adults listened to the pronoun *o ídhios* whereas the pronoun *aftós* should trigger a preference for the object antecedent. However, we also predicted the presentation of the OVS structure would reduce these differences especially for the pronoun *aftós*, suggesting the interpretation of the pronoun is challenging with the OVS word-order. Finally, because no time constraint was imposed on the comprehension question, age differences were not expected to play a role in response preference.

2.2 Method

2.2.1 Participants

A total of 129 native speakers of Greek participated in the present research. Five participants were excluded from further analyses due to the fact that a high proportion of eye movement data was missing (>60%). Two age groups were formed: 65 young adults (28 men, age: $M = 23.51$, $SD = 4.13$; range: 19–35) and 59 elderly adults (31 men, age: $M = 67.97$, $SD = 6.86$; range: 59–83). Young adults were recruited through advertisement in vocational schools and universities, while elderly adults through advertisement in Open Protection Centres for the Elderly. We also considered participants' educational background in order to keep a balanced sample in this respect: both age groups included people who attended only compulsory education, vocational training schools, or possessed a Bachelor degree, a postgraduate diploma (MSc, MA) or a PhD from one of the five disciplinary fields available (humanities, science, health sciences, technological sciences, economy and administration). All participants had normal or corrected-to-normal vision, no health issues and did not suffer general cognitive impairment, as measured by the Mini Mental State Examination (Fountoulakis, Tsolaki, Chantzi & Kazis 2000) in which they scored with high accuracy (range: 28–30).

2.2.2 Materials

Our materials are divided in two sections: control measures and the online anaphora resolution task. First, independent measures of educational background and WM Capacity were employed to control for confounding variables. Secondly, processing and interpretation of overt anaphoric expressions in Greek were assessed by means of a visual-world paradigm.

2.2.2.1 Control measures

Educational background. Information about participants' education was based on the total number of years receiving formal education up to the highest educational degree they possessed. Participants reported (questionnaire) on the level of education they attended and the field, their profession (years of practice) and their current occupation. The two age groups did not significantly differ in educational background, $t(122) = .61$, $p = .54$ ($Ms = 14.86$ and 14.54, for young and elderly adults, respectively).

Working Memory. A backward digit span task was assessed to measure WMC. Immediately after the presentation of a list of digits, participants had to recall the sequence in reverse order. There were six levels increasing in difficulty from 2 (Level 1) to 7 (Level 6) digits, with five trials per block. Participants continued with the next block if they successfully recalled three out of the five trials. In contrast, when participants failed at three trials of the same block, the task was terminated. The final score was the total number of trials correctly recalled. A *t*-test comparison on working memory scores demonstrated significant differences between age groups, $t(122) = 4.87$, $p < .001$, with higher WMC in young adults ($M = 21.35$, $SD = 5.30$) than in the elderly ($M = 16.71$, $SD = 5.29$). Taking into account the literature suggesting that WMC (Hendriks et al. 2014) can affect AR, we decided to include this measure in the analyses (see Data analysis) to control for error variability.

2.2.2.2 Online anaphora resolution task

As mentioned, we monitored eye movements using a visual-word paradigm in which participants listened to three-sentence-long narratives presented in Greek (see Table 2), while simultaneously looking at four pictures, three of characters mentioned in the story and one visualizing the scenery (see Figure 1). There were a total of 10 experimental narrative-picture items: 5 with male actors and 5 with female actors, using common nouns (i.e., professions). We used ten experimental items and ten fillers in order to reduce the length of the experimental session and to avoid fatigue and loss of attention among our older participants. Each narrative began with a sentence introducing three actors by using indefinite NPs (e.g., 'Here is a hunter, a fisherman and a worker'). Then, the second sentence narrated an event with two of the actors, introduced now with definite NPs. This second sentence could be presented either in the unmarked SVO (e.g., 'The hunter.NOM meets the fisherman.ACC every afternoon in the forest by the river') or the marked OVS (e.g., 'The fisherman.ACC him meets the hunter.NOM every afternoon in the forest by the river') structure. The second sentence always included familiar and pragmatically neutral transitive verbs (e.g., 'meet' or 'wave at') describing an event between the two actors. The third and final sentence started by one of the two ambiguous overt subject expressions: *aftós* ('s/he') or *o ídhios* ('the same'/'himself'), who performed an action related to the third actor of the story (e.g., '**He**/**The same** found accidentally there, after a long time, the worker').[11] The three actors of a story always had the same (grammatical and biological) gender,

[11] Nouns and verbs used in the second and third sentence of each narrative were controlled for frequency of occurrence (according to data derived from the Institute for Language and Speech Processing, http://hnc.ilsp.gr/).

which caused ambiguity in the anaphoric pronoun. That is, both *aftós* and *o ídhios* could be co-referential with either the subject or the object of the preceding sentence, since no contextual cues helped to resolve the ambiguity. At the end of each narrative, there was a comprehension question (e.g., 'Who bumped into the worker?') probing participants' interpretation of the ambiguous pronominal subject presented in the third sentence.

Pictures depicted the three actors of the story: the subject antecedent (e.g., 'the hunter'), the object antecedent (e.g., 'the fisherman') and the distractor (e.g., 'the worker'). Additionally, we also included the picture of the scenery (e.g., 'the forest') that was used to help participants to visualize the stories but did not depict events to prevent any thematic role assignment and structural disambiguation of the clauses. Fixation durations (by means of eye movements) were recorded for the three actors of the story from the time the critical subject expression was presented to the onset of the *object of the anaphoric clause* (distractor picture in our analysis), before the definite article ('**He/The same** found accidentally there, after a long time'). This was used as an online measure for early processing effects as soon as the subject expression was encountered (and before the mention of the third participant of the story, which would divert looks towards his/her picture). Pictures remained on the screen until participants answered the comprehension question (i.e., no time constraint) by mouse clicking on one of the three story actors. Participants' preference for the subject, object, or distractor picture (object of the clause starting with the ambiguous subject expression) gave us a measure to explore how adults arrive at an *interpretation* of these anaphoric expressions.

Auditory items and instructions were recorded by a female native Greek speaker. For the experimental and filler items we recorded the stories several times and chose the ones that had low variation of amplitude, pitch and pauses (analysed with Praat (Boersma & Weenink 2012) in order to minimize biasing referent attribution. In addition, pictures were hand-painted to ensure human figures were symmetrical and had no facial features in order to control for potential bias fixations triggered by specific traits (e.g., Sæther, Van Belle, Laeng, Brennen & Øvervoll 2009).

The four crossed conditions (*aftós*-SVO, *aftós*-OVS, *o ídhios*-SVO and *o ídhios*-OVS) were counterbalanced across participants, who never encountered the same experimental item more than once. Lists were created following a Latin square design such that each item appeared in a different condition across lists. In addition, the position of the pictures was also counterbalanced across items. The 10 experimental items for each of the four crossed conditions were intermixed with another 10 filler items. Filler items also included narratives of three sentences followed by a comprehension question (e.g., 'Here is a waiter, a (female) teacher and a (female) student. The waiter meets the teacher often in the coffee shop. SHE was speaking to her student. Who spoke with the student?') while pictures depicted the actors participating in the narrative (and the scenery). Fillers were different from the experimental items in that the use of *aftós* or *o ídhios* was unambiguous (e.g., due to gender cues).

2.3 Procedure

Two individual sessions were held for each participant. Consent forms were signed at the beginning of these sessions. The first session started with the educational background questionnaire and the Mini Mental State Examination (Fountoulakis et al. 2000), which together took no longer than 15 minutes. After a five minutes' break, we also assessed the backward digit span task, taking less than 10 minutes to complete. In total, the first session lasted about 30 minutes.

Two to three days later, the second session took place. Participants were presented with the online AR task which took approximately 40 minutes. Participants were seated in a comfortable chair at approximately 60 cm from the eye tracking monitor attached to

a DELL laptop and advised to look on the computer screen throughout the experimental procedure to avoid any sudden movements. Light conditions in the environment were carefully controlled. Eye-movements were recorded with a Tobii X2-60[12] eye-tracker upon a 15.6″ screen (adapted to 4:3 format, 800 × 600 resolution). Auditory and visual stimuli were presented using the E-Prime software (Schneider, Eschman & Zuccolotto 2002), while fixation duration and response preference were recorded with the E-Prime extensions for Tobii software. A nine point calibration was followed by the instructions of the task. Three practice items ensured participants understood the whole procedure. They were instructed to listen to the short narratives while viewing the pictures, and subsequently answer the comprehension question by clicking with the mouse on the image illustrating their choice. A fixation cross surrounded by a red square during fixation (see Thaler, Schuütz, Goodale & Gegenfurtner 2013) was presented in the center of the screen for 750 ms before each trial. Then, the fixation cross disappeared and participants were simultaneously exposed to the auditory narrative and the pictures. Both experimental and filler items were randomized, to avoid any error variability due to familiarity and/or fatigue.

2.4 Data analysis

Different statistical analyses were conducted for the two measures of the online AR task. First, Linear Mixed Effects (LME) model analyses were carried out on the sum fixation duration (in milliseconds) for a time window of 1200 ms which began at the onset of the critical anaphoric expression, i.e., the beginning of sentence (3) and lasted until the onset of the *object of the anaphoric clause*, before the definite article introducing it, using the *lmer* function of the lme4 R package (Bates, Maechler, Bolker & Walker 2015). Overall fixation duration was preferred over division in bins to minimise the impact of the one-syllable difference between the duration of the two anaphoric expressions examined. Second, because response preference to the question for each picture was coded as a binomial measure (preferred vs. not preferred), we carried out a Mixed-Effect Logistic Regression (MELR) model analysis by using the *glmer* function of the lme4 R package. Both LME and MELR models are very powerful statistical analyses that account for both random and fixed effects. All models included Participants as the random factor, and Anaphoric type (*aftós* vs. *o ídhios*), Word-order (SVO vs. OVS), and Age (young vs. the elderly) as the fixed factors. Items were not included as a random factor because there were not enough data points (i.e., fixations) for each participant and item in the four types of pictures. The maximum fixed structure was always composed by a three-way interaction (i.e., anaphoric type × word-order × age). To control for working memory differences between young and elderly adults, we included the total score of WMC as a random slope of Participants factor. A minimum and maximum duration of 80–1000 ms. was established for fixation data (Manor & Gordon 2003). Outlier fixation duration data per anaphoric type, word-order and age group was detected by the Box-Whisker plot and replaced with the mean (3.46%).

The best fixed structure was found using stepwise model comparison from the most complex (the three-way interaction) to the simplest (a main effect) model, and selecting the one with lower AIC and BIC, and significant χ^2 test for the Log-likelihood, using the maximum likelihood. The p value of each significant fixed effect was calculated by the *Anova* function of the car package (Fox et al. 2018), and in case post-hoc comparisons were necessary we used the *testInteractions* function of the phia R package (De Rosario-Martínez 2013) with Bonferroni correction. Effect sizes for LME were informed by the explained

[12] To facilitate the procedure with elderly adults we used a Tobii X2-60 portable eye-tracker. The task was developed by using the E-prime Extensions for Tobii (Professional version) which allows the direct communication with Tobii Studio Software (TET and CV packages).

deviance (*dv*) extracted by the pamer.fnc function of the LMERConvenienceFunctions R package (Tremblay & Ransijn 2015). This statistic serves as a generalization of R^2 because it measures the marginal improvement or reduction in unexplained variability in the fixed component after accounting for a given predictor. Effect size for MELR was reported using odds ratio (OR) and the 95% confidence interval (CI), by the lsmeans function of the lsmeans R package (Lenth 2017). OR indicates the constant effect of a specific predictor on the likelihood that one outcome will occur whereas CI estimates the precision of the OR (i.e., small CI signals high precision).

3 Results

Our results are divided in two main sections according to both dependent measures: fixation duration (online AR processing) and response preference (AR interpretation). In fixation duration, we first explored whether age differences were exclusively related to the antecedents (subject and/or object pictures), and not to the third human figure depicting the object of the anaphoric clause, not mentioned in the time window examined (distractor) to subsequently perform main analyses only in the subject and object pictures. In response preference, we first looked at whether both age groups showed a preference for either the subject or the object picture with very low preference proportion for the distractor picture (object of the anaphoric clause), and then analysed only the two antecedents of the story.

3.1 Fixation duration

To understand whether age differences in the processing of the ambiguous pronoun appeared only in the subject and/or object picture but not in the distractor picture, we performed a LME with age (young vs. elderly) and picture (subject, object and distractor) on fixation duration sum. This model showed a significant main effect of age, $F(1) = 10.30$, $p < .01$, $dv = .88$, with longer fixation durations in young ($M = 603$, $SE = 15$) than in elderly ($M = 536$, $SE = 16$) adults. In addition, the two-way interaction between age and picture was also significant $F(2) = 9.28$, $p < .001$, $dv = .79$ (see Figure 2), where post-hoc comparisons revealed longer fixation durations in young compared to elderly adults in the subject, $\chi^2(1) = 8.65$, $p < .001$, and the object picture, $\chi^2(1) = 17.49$, $p < .001$, but not in the distractor picture, $\chi^2(1) = 2.25$, $p = 0.40$.

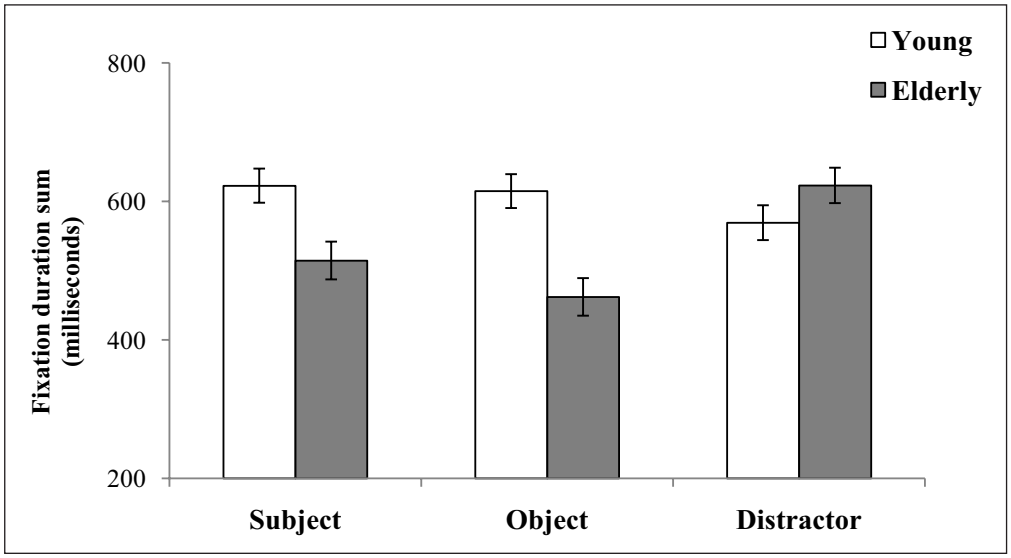

Figure 2: Fixation duration sum (in milliseconds) in the subject and the object pictures of the online AR task, divided by age group and picture.

Table 3: Means (and standard errors) of the fixation duration sum (in milliseconds), divided by anaphoric type, word-order, antecedent type and age group.

		O ídhios		*Aftós*	
		SVO	**OVS**	**SVO**	**OVS**
Subject	**Young**	623 (51)	653 (47)	635 (50)	599 (48)
	Elderly	664 (57)	458 (50)	506 (56)	508 (54)
Object	**Young**	687 (47)	574 (50)	608 (48)	586 (49)
	Elderly	564 (54)	453 (54)	434 (54)	449 (53)

The fact that age differences were found just in the two (subject and object) antecedents discards the possibility that the distractor could be playing a role when explaining individual differences in AR processing. Thus, critical analyses were carried out only in the subject and object pictures (see Table 3 for means and standard errors).

Overall, descriptive measures show that the elderly preferred to link *o ídhios* subject expression to the subject antecedent when its possible referents were introduced in SVO utterances (no preference attested for the OVS word-orders). Young adults looked more to the object (than the subject) antecedent when *o ídhios'* referents were introduced in SVO utterances and preferred the subject (over the object) antecedent when referents were introduced in OVS utterances. On the other hand, a subject preference is attested in all instances of *aftós* subject pronoun, irrespective of the word-order used for the introduction of its possible referents, in both age groups. Next, we present analyses performed for each antecedent picture.

3.1.1 Subject antecedent picture

To explore whether AR processing was explained by the type of overt anaphoric expression, word-order and/or age, we ran a LME with anaphoric type (*aftós* vs. *o ídhios*), word-order (SVO vs. OVS), and age group (young vs. elderly) on the fixation duration sum found in the subject picture. Similar to the previous result, the model manifested a significant main effect of age, $F(1) = 7.43$, $p < .01$, $dv = 1.72$, with longer fixation durations in young ($M = 624$, $SE = 25$) than in elderly ($M = 516$, $SE = 27$) adults. More importantly, the three-way interaction of anaphoric type, word-order and age was also significant, $F(2) = 4.28$, $p < .05$, $dv = 1.05$. No other effect reached significance (all $ps > .05$).

To follow-up on the three-way interaction, we divided the analysis by type of anaphoric expression (see Figure 3). The analysis performed for *o ídhios* trials demonstrated a significant interaction between word-order and age, $F(1) = 7.88$, $p < .01$, where the two age groups did not differ in SVO, $\chi^2(1) = 0.70$, $p = .81$, but they did in OVS, $\chi^2(1) = 10.10$, $p < .01$, where young adults showed longer fixation durations than the older ones. In contrast, the interaction of word-order and age was not significant in the pronoun *aftós*, $F(1) = 0.03$, $p = .86$, where compared to the elderly, young adults had longer fixation durations in both SVO and OVS structures. In other words, young adults spent significantly more time than elderly adults on the subject picture when *o ídhios* was preceded by a OVS word-order with a pre-posed object than an SVO word-order. Similarly, young adults looked at the subject picture more than elderly adults when they encountered the pronoun *aftós* in both word-order structures.

3.1.2 Object antecedent picture

A third LME with anaphoric type (*aftós* vs. *o ídhios*), word-order (SVO vs. OVS), and age group (young vs. the elderly) was performed on the fixation duration sum of the object picture. The model showed a significant main effect of age, $F(1) = 16.41$, $p < .001$, $dv = 1.72$, where, once more, young adults had longer fixation durations than the elderly ($M = 613$, $SE = 26$ and $M = 461$, $SE = 27$, respectively; see Figure 4). No other effect was reached (all $ps > .05$). This effect suggests young adults looked at the object antecedent more than the elderly, regardless of the type of anaphoric expression or word-order used.

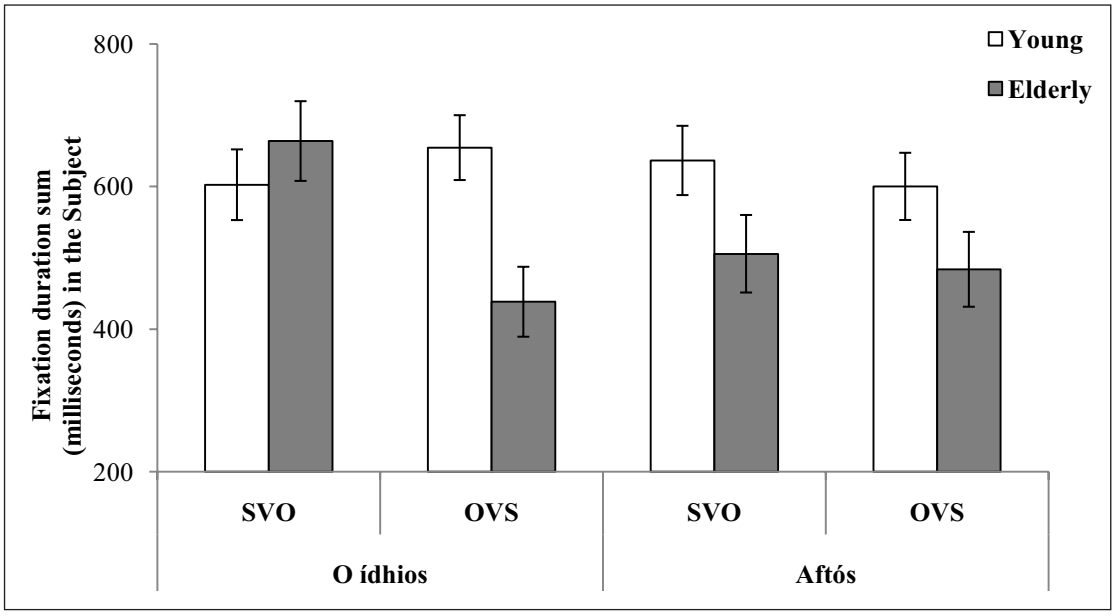

Figure 3: Fixation duration sum (in milliseconds) in the subject picture of the online AR task, divided by anaphoric type, word-order and age group.

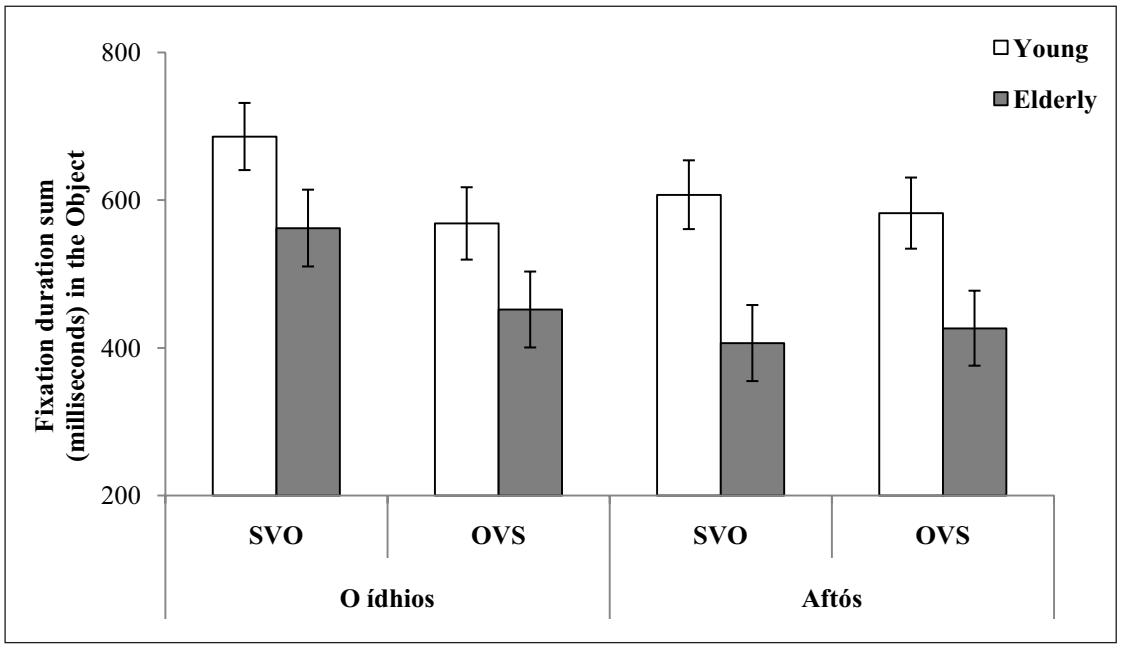

Figure 4: Fixation duration sum (in milliseconds) in the object picture of the online AR task, divided by anaphoric type, word-order and age group.

3.2 Response preference

To understand whether participants had a preference for the subject and/or object antecedents compared to the distractor character when resolving the ambiguity of the anaphoric expression, we examined the proportion of response preference (from 0 to 1) for each picture. Both age groups had a relatively high preference proportion for the subject (0.58 and 0.56 for young and the elderly, respectively) and the object antecedent (0.40 and 0.41), whereas proportion was very small for the distractor picture (0.02 and 0.03). Accordingly, we carried out a MELR analysis with word-order (SVO vs. OVS), anaphoric type (*aftós* vs. *o ídhios*) and age (young vs. elderly) including only preference proportion for the subject or object antecedents (see Table 4 for means and standard errors).

This model showed a significant main effect of anaphoric type, $\chi^2(1) = 23.54, p < .001$, with more preference for the subject in *o ídhios* ($M = 0.66$, $SE = 0.10$) than in *aftós* ($M = 0.52$, $SE = 0.10$; OR = 0.62, CI –0.86, –0.37) and a significant two-way interaction of anaphoric type and word-order, $\chi^2(1) = 9.89, p < .01$ (see Figure 5). No other effects reached significance (all $ps > .05$). Post-hoc comparisons in the two-way interaction showed all participants preferred the subject antecedent with SVO compared to OVS when they listened to *o ídhios*, $\chi^2(1) = 12.25, p < .001$ (OR = 0.62, CI –1.08, –0.17); however, no differences between word-order structures were found with *aftós*, $\chi^2(1) = 0.81, p = .74$ (OR = 0.15, CI –0.28, –0.59).

Table 4: Means (and standard errors) of the preference proportion (from 0 to 1) for the subject and object pictures (notice the reverse pattern between the two), divided by anaphoric type, word-order, age and antecedent type.

		O ídhios		*Aftós*	
		SVO	**OVS**	**SVO**	**OVS**
Subject	**Young**	0.74 (0.24)	0.61 (0.24)	0.47 (0.28)	0.58 (0.23)
	Elderly	0.73 (0.25)	0.59 (0.25)	0.53 (0.29)	0.49 (0.23)
Object	**Young**	0.26 (0.24)	0.39 (0.24)	0.53 (0.28)	0.42 (0.23)
	Elderly	0.27 (0.25)	0.41 (0.25)	0.47 (0.29)	0.51 (0.23)

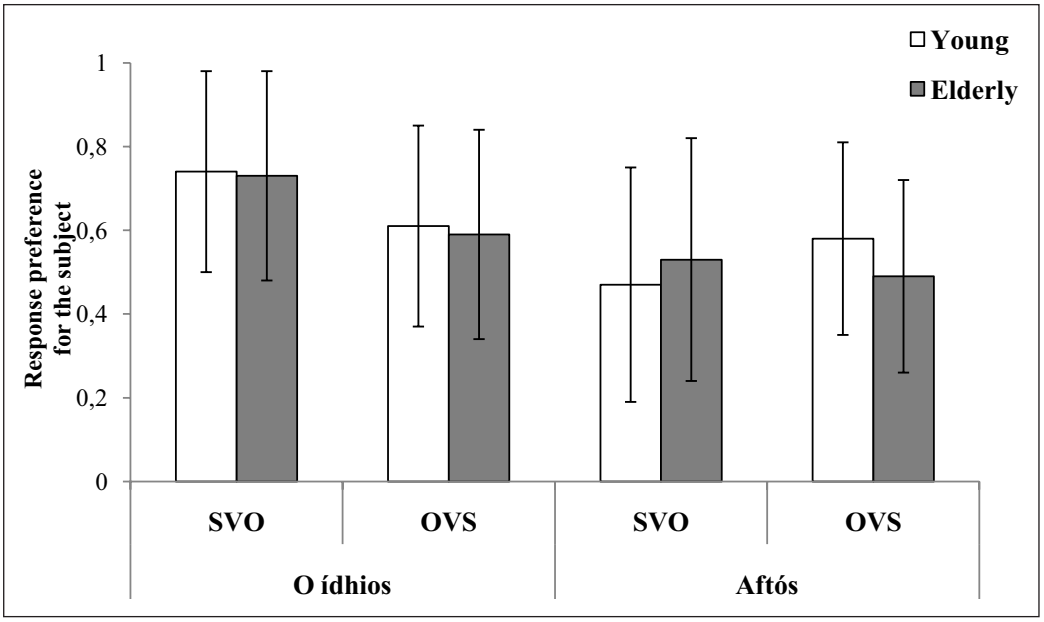

Figure 5: Response preference (from 0 to 1) for the subject antecedent (reverse pattern for the object) in the online AR task, divided by anaphoric type and word-order.

Thus, when the SVO word-order was presented, adults of younger or older age had a preference for the subject antecedent when listening to the subject expression *o ídhios*. Fronting the object in the preceding clause boosted the expression's less preferred object readings. However, no preferences were found with the more ambiguous pronoun *aftós*.

4 Discussion

The aim of the present study was to explore how distinct overt anaphoric expressions are processed and interpreted in relation to linguistic factors (anaphoric type and word-order structure) and age differences. Specifically, we investigated how young and elderly Greek monolingual adults processed the subject expressions *aftós* and *o ídhios* across SVO vs. OVS word-order (syntactic structures introducing the ambiguous subject expressions' potential referents) during online comprehension (fixation duration), and subsequently, how they interpreted the ambiguous anaphoric subject expressions when explicitly asked to do so (response preference). These theoretical questions are discussed below.

4.1 Online anaphora processing: Fixation durations

We first discuss our findings for the online processing of the subject picture and then proceed with a discussion of the fixations on the object picture.

According to our hypotheses, we predicted the online processing of the subject picture to show longer fixation durations when adults listened to *o ídhios* (than *aftós*) irrespective of the word-order used in the clause introducing the possible referents, due to this expression's lexical meaning ('the same') (e.g., Varlokosta & Hornstein 1993) and the associated parallelism preference. In contrast, given that the pronoun *aftós* is suggested to be sensitive to discourse manipulation of topichood (i.e., topic-shift), we expected it would be preferentially linked to the less prominent discourse entity (in line with Papadopoulou et al. 2015 a.o.). However, we expected the online anaphora processing to show an interaction between anaphoric type and word-order. Thus, *aftós* was expected to be more prone to ambiguity in cases where a pre-verbal object was used, since in OVS structures the structural subject and the topicalized object compete for prominence. Age was hypothesized to play an important role during processing of the subject expressions, specifically for the pronoun *aftós*. In this case, we predicted age effects due to (non-structural) ambiguity requiring more cognitive resources for reference interpretation, i.e., the manipulation of linguistic (morpho-syntactic) and extra-linguistic (pragmatic) factors in real time.

Analyses of our gaze data revealed no significant effect of the anaphoric type or the word-order variables, nor of their interaction, suggesting that these linguistic factors alone could not explain online anaphora processing. Nonetheless, anaphoric type and word-order interacted with age. Although we suggested that age differences would be significant for the pronoun *aftós*, gaze data revealed differences in the subject looks for the expression *o ídhios* as well. These differences came from OVS structures: Young adults showed longer fixations than the elderly in the subject picture; no such differences were evinced when the expression's competing referents were presented in an SVO structure (see Figure 3). In other words, when competing referents were presented in a structure marking topic-shift, elderly adults' looks to subject antecedent pictures were significantly less than the younger ones'; young adults did not show this word-order effect. This finding suggests that whereas both groups have preserved ability to process *o ídhios* ('the same'/'himself') when preceded by SVO sentences, young adults outperform older ones when the anaphoric expression is preceded by an OVS sentence, in the sense that their looks to the subject picture do not drop as is the case with the elderly participants.

Turning to data from *aftós*, we found that, on hearing the pronoun, young adults spent more time than the elderly looking at the subject picture, irrespective of the word-order used to introduce the referents. Although we did not have clear predictions for the pronoun *aftós*, these results can be explained by the fact that the more frequent but ambiguous nature of *aftós* caused a conflict between the two types of antecedents (subject and object) requiring more processing time, thus more time spent looking on both potential referents. Young adults were better detecting the conflict than elderly adults by increasing the processing time spent on the subject picture.[13]

Overall, fixation durations in the subject picture suggest that, compared to *aftós*, the online processing of the pronoun *o ídhios* is preserved in elderly adults when structural complexity is lower (i.e., in SVO). This is because *o ídhios* is a less ambiguous pronoun that looks for an antecedent in a parallel (subject) position, due to the focus feature it triggers, as assumed by its lexical meaning.

Results found in the subject picture are also consistent with those studies interpreting lower performance of older adults in AR as a result of cognitive decline in WMC (e.g., Fraundorf et al. 2012; Hendriks et al. 2014), which has been also associated with higher sensitivity to ambiguity (e.g., Dwivedi & Golhawk 2009), and syntactic complexity (e.g., Stine-Morrow et al. 2000). Indeed, Stine-Morrow et al. (2000) found that both younger and older adults performed similarly in subject relative clauses, whereas older adults had problems comprehending object relative clauses. However, in our study, WMC was assessed by an independent task (i.e., the backward digit span task) and the total score of each participant was included as a random slope in all statistical models to control for individual variability possibly due to WMC. Although it is possible that we cannot capture all aspects of WMC with one task, our results suggest that other aspects of cognitive decline (e.g., speed of lexical access) could explain why the elderly experience difficulties during the online processing of *o ídhios* after OVS (but not SVO) sentences, and *aftós* after both SVO and OVS sentences. Overall, however, it seems that elderly adults have fewer processing resources compared to young adults as evinced by the lower overall fixation results in all conditions of the study.

In the object picture, we expected longer fixation durations when participants listened to the pronoun *aftós* coming from the SVO compared to the OVS structure. However, due to the more ambiguous nature of *aftós*, we expected differences between OVS and SVO structures to be attenuated, showing the need to invest more processing in the latter (than the former) condition, due to the conflict between the pronoun's topic-shift feature (favouring object antecedents) and the SVO word-order (pointing to a subject reference). The only significant effect here was age group, where young adults manifested longer fixation durations than the elderly in all conditions, demonstrating a better processing ability.

Although our data cannot clarify whether the lack of a difference between the OVS and SVO structures with the pronoun *aftós* was only due to ambiguity (as the same pattern also appeared in the pronoun *o ídhios*), it seems our online AR task imposed a high cognitive demand. Thus, discrepancies in the preferred reading of *aftós* ('he') found in our study, when compared to previous studies may be explained in terms of methodology. Differently from previous studies investigating AR by using self-paced comprehension (e.g., Papadopoulou et al. 2015), our task was presented through continuous

[13] Alternatively, as suggested by one of the reviewers, the increase of fixation duration on the subject pictures may indicate ambiguity resolution. Our data do not allow us to suggest when processing of the conflict stops and resolution is achieved. Moreover, long fixation durations on the subject antecedent pictures for *aftós* do not align with final interpretation.

speech decreasing the time available for participants to process story content. In addition, instead of assessing AR by providing only one sentence, as in the previous eye-movements study using the visual-world paradigm (Cunnings et al. 2017), we presented stories which were three-sentences-long. Finally, our task involved inter-sentential reference, while prior research focused on intra-sentential reference. Importantly, visual stimuli in previous research depicted events, while we only included pictures of referents. The lack of depicted events meant that moderating processing load or disambiguating the anaphoric expression was not possible using visual cues. The presence vs. absence of contextual information prior to the introduction of the ambiguous pronominal and the differences in methodology (self-paced reading or listening vs. the visual world paradigm) require further research. Still, these differences could have contributed to the lower fixation durations during online anaphora processing in the elderly group of adults.

Interestingly, the pattern of results observed in the object picture contrast with the pattern found in the subject picture. In the subject picture, elderly adults manifested sensitivity to variation in relation to anaphoric type and word-order: they clearly looked at the subject in the *o ídhios*-SVO while their looks in the *o ídhios*-OVS was less than in all other conditions (i.e., *aftós*-SVO and *aftós*-OVS). This differential pattern is easier to understand when we think of it in terms of subject prominence. The subject is by default the most salient entity of the matrix clause, frequently in the first position of a sentence and, therefore, it keeps a grammatical parallel position with that of the pronoun (see Stevenson et al. 1995). In addition, the subject is usually the topic of the sentence and, in Greek it is clearly morphologically marked by nominative, offering many cues to its prominence and interpretation. Finally, our online AR task included only verbs that were thematically neutral between the two antecedents (e.g., 'to meet'), which means that there were no semantic cues that could facilitate either subject or object prominence.

Altogether, our findings demonstrate that variation in the type of anaphoric expression and syntactic complexity affects elderly adults' online anaphora processing when related to the subject (but not the object) antecedent.

4.2 Offline anaphora interpretation: Response preference

Our hypotheses for anaphora interpretation in response to the comprehension question were expected to confirm the effects observed in online anaphora processing. More concretely, we predicted a preference for the subject picture when adults listened to the pronoun *o ídhios* (similar to the antecedent reference suggested by the theoretical analysis of Varlokosta & Hornstein 1993), but a preference for the object when listening to the pronoun *aftós* (in line with previous research results for Greek, as in Papadopoulou et al. 2015). In addition, we expected an interaction between anaphor type and word-order, where the presentation of the OVS structure would affect especially the pattern suggested for *aftós*, a pronoun previously suggested being ambiguous in nature (e.g., Cunnings et al. 2017). Age differences were not expected to play a role in response preference, as both young and elderly adults were allowed to take as much time as they needed to answer the comprehension question and in line with previous literature which suggests that comprehension is not affected by age (e.g., Hendriks et al. 2015).

Indeed, according to our results and in line with Varlokosta and Hornstein's (1993) theoretical proposal, the main effect of anaphor type confirmed adults had a preference for the subject picture in the pronoun *o ídhios*, which had not been empirically demonstrated as yet. However, in contrast with previous research demonstrating the pronoun *aftós* showing a preference for the object antecedent (e.g., Papadopoulou et al. 2015),

preference rates for *aftós* were at chance level (about 0.5; see Figure 5), which illustrates the ambiguous nature of this pronoun. This result corroborates the idea that the pronoun *aftós* in Greek is open to either antecedent (subject and object) and does not necessarily mark topic-shift inherently (Cunnings et al. 2017).

Previous research on the relation between reference and word-order of dependent clauses is scarce. However, first mention and recency that have been examined as factors enhancing referent accessibility (e.g., Arnold et al. 2000) are relevant to our discussion. Our results revealed an interaction between anaphor and word-order in response preference. For the subject expression *o ídhios*, our (offline) response results suggest that although there is a clear preference for the subject antecedent referent, OVS structures boosted the less preferred object reading. This finding indicates that the interpretation of the pronoun *o ídhios* was challenging when a syntactically more complex word-order was presented. The finding possibly relates to the idea that the prominence of the element in clause-initial position and the advantage of the first-mentioned referent (the subject in SVO and the object in OVS) reduce preference for the subject antecedent. Interestingly, the preference for the subject picture after listening to the pronoun *o ídhios* coming from SVO sentences is consistent with our fixation duration results on the subject antecedent pictures, where longer fixations were registered for both young and elderly adults (compared to fixations coming from OVS sentences).

In order to investigate whether anaphora processing may in fact predict the subsequent offline interpretation across adulthood, we ran a correlation analysis between fixation duration and offline responses (as suggested by one of the reviewers). The analysis gave no significant results for either group (all $ps > .01$) probably because both the online and offline measurements were distributed close to their means (fixation durations for the two potential antecedents and final interpretations of the subject expressions; see Tables 3 & 4 respectively).[14]

On the other hand, no differences due to word-order used were observed in *aftós*. The pronoun was equally linked to both subject and object antecedent pictures, irrespective of word-order. Thus, locality/recency of specific antecedents did not provide direct resolution of the ambiguous pronoun, traditionally suggested to mark topic-shift. Instead, no change in the preferences of the participants was noted with SVO vs. OVS manipulation. Noticeably, responses in our task illustrated preferences (not categorical judgments) as the ambiguity was never resolved, but interpretation was based in individuals' sensitivity to discourse related cues, world knowledge and processing capacity. Recall that the complexity of the task may partly explain this discrepancy between our data and data from previous research. Alternatively, our results may further support the claim that *aftós* is open to either interpretation and does not necessarily mark topic-shift (in line with Cunnings et al. 2017).

However, the results of the two subject expressions suggest that online anaphora processing may predict the subsequent offline anaphora interpretation in adults, at least in the easy to process and most frequent SVO word-order structures.

Finally, as expected, no age effect was found in response preferences a finding in line with previous literature arguing that language comprehension does not decline due to aging (e.g., Light & Capps 1986; Titone et al. 2000; Hendriks et al. 2014).

[14] A marginal positive correlation was found for the *o ídhios*-SVO condition but only for the elderly group, $r(120) = 141.328$, $p = .089$, $\eta = .588$, Cramer's V = .089, suggesting that they may have been quite rigid in their initial choice for linking *o ídhios* to a subject antecedent when this one occurred in a preverbal (than a postverbal) position.

5 Conclusion

In this study we tried to elucidate how young and elderly adults process and interpret the Greek overt pronouns *o ídhios* and *aftós* in relation to the SVO vs. OVS presentation of potential antecedents. Both the online processing and offline interpretation of *o ídhios* reflected a preference for the subject antecedent, demonstrating the more straightforward interpretation of this pronoun guided by a parallelism effect (i.e., a subject pronoun should refer to an antecedent in subject position). However, although all adults preferred the subject with the easier canonical SVO structure, only young adults had a subject preference in the challenging OVS structure. Importantly, this finding showed that, with low syntactic complexity, elderly adults preserve the ability to process the pronoun *o ídhios* during online comprehension. In addition, the ambiguous nature of *aftós* caused processing difficulties to the elderly and reduced the preference for the object antecedent in both young and elderly adults. This effect indicated that the nature of *aftós* is inherently more ambiguous due to its sensitivity to topichood and discourse-related properties which require the implementation of higher cognitive resources. Overall, our results demonstrate that linguistic factors such as type of anaphoric expression affect AR in Greek on monolingual adults while linguistic factors such as word-order interact more with cognitive resources hence showing age effects in healthy adults.

Abbreviations

ACC = accusative, ART = article, NOM = nominative, 3SG = third person singular

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Competing Interests

The authors have no competing interests to declare.

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