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Animacy effects on the processing of intransitive verbs: an eye-tracking study

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Abstract

This paper tested an assumption of the gradient model of split intransitivity put forward by Sorace ('Split Intransitivity Hierarchy' (SIH), 2000, 2004), namely that agentivity is a fundamental feature for unergatives but not for unaccusatives. According to this hypothesis, the animacy of the verb's argument should affect the processing of unergative verbs to a greater extent than unaccusative verbs. By using eye-tracking methodology we monitored the on-line processing and integration costs of the animacy of the verb's argument in intransitive verbs. We observed that inanimate subjects caused longer reading times only for unergative verbs, whereas the animacy of the verb's argument did not influence the pattern of results for unaccusatives. In addition, the unergative verb data directly support the existence of gradient effects on the processing of the subject argument.

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The Unaccusative Hypothesis (Burzio, 1986) holds that, across languages, intransitive verbs can be divided into two classes, i.e., unaccusatives (e.g., to arrive) and unergatives (e.g., to work). Much linguistic research has differentiated these two verb classes with respect to their inherent syntactic properties (e.g., Burzio, 1986; Ackema and Sorace, 2017); however, alongside the syntactic distinction, the unaccusative/unergative split is sensitive to the semantic characteristics of the verb and of its argument (cf., Sorace, 2000; 2004). In the current study we tested whether a manipulation of a semantic feature of the verb's argument, namely animacy, affects the processing of Italian intransitive verbs.

A relevant difference between unaccusatives and unergatives relies in their semantic underpinnings. Semantically, unaccusative verbs involve actions that typically involve a change of state (e.g., die, disappear), whereas unergatives typically denote controlled motional processes (i.e., work) (Sorace, 2000). There are crucial semantic implications in terms of the underlying thematic properties of the argument of the verb: unaccusatives require a non-agentive argument, whereas unergatives involve actions that are performed by a proto-typically agentive argument (cf. Dowty, 1991; Van Valin, 1990).

Experimental evidence based on transitive (agentive) events suggests that animate agents are much preferred over inanimate ones because they are more prototypical and thus more accessible (Keenan & Comrie, 1977; see also Bock & Warren, 1985; Bock, 1986; Bock & Loebell, 1990). Additionally, there is a bulk of **experimental** evidence indicating that **under some conditions** animate agents are more likely to be assigned to higher grammatical functions (Comrie, 1989; Dowty, 1991; Hopper and Thompson, 1980; Langacker 1991) with this preference being overcome only when agents are inanimate and patients animate (Bock, 1986; Bock & Loebell, 1990). The

tendency to prefer animate agentive entities (in transitive events) in early sentence positions or in higher grammatical roles has been reported in production (e.g., Prat-Sala & Branigan, 2000), and in comprehension too (Kuperberg et al. 2007; Townsend and Bever, 2001). For instance, Weckerly & Kutas (1999) found that sentence-initial inanimate entities occurring in the grammatical role of subject caused significant processing costs and a specific N400-P600 ERP pattern in relative clauses comprehension. In an EEG study, Malaia et al. (2015) tested the processing of the subject noun animacy in the comprehension of relative clauses. Again, inanimate subjects elicited an anterior negative shift and caused a slowdown in sentence comprehension. In the above mentioned cases, animate agents are preferred when they occur in subject/first position. **However, note that this preference is far from being deterministic: it is important to consider a number of additional constraints such as, for instance, the pragmatic function the argument plays in the discourse (whether it is the most emphasised element in a sentence; cf. Gordon, Grosz, & Gilliom, 1993), or the thematic fit of the argument with respect to the verb (McRae, Ferretti & Amyote, 1997; McRae, Spivey-Knowlton and Tanenhaus, 1998; Ferretti et al., 2001). Therefore one might conclude that, under some constraints, an inanimate agent might well be placed as the subject of an active sentence.**

To our knowledge, only few studies have focused on the processing of the subject of intransitive verbs and its effects on split intransitivity. By means of a cross-modal lexical priming technique, Friedmann et al. (2008) tested whether the subject was reactivated more often during the online processing of a sentence involving an unergative or an unaccusative verb. The study revealed that only subjects of unaccusatives were reactivated after the verb, whereas subjects of unergatives were not. One possible explanation for such finding is that, as the argument of unergatives is syntactically a subject, participants did not need to reactivate its trace; in contrast, in unaccusatives, the subject's trace was less salient, and therefore had to be reactivated. All in all, this finding offers support to the view that the single argument of unaccusative and unergative verbs might involve differential processing strategies for the speaker.

According to the literature, however, semantic differences are strictly intertwined with the syntactic distinctions between these verbs classes, suggesting that a more exhaustive explanation of the phenomena at stake here has to be found at the syntax-semantics interface (Levin and Rappaport Hovav, 1995). For this reason, let us briefly summarize the classic syntactic explanation of split intransitivity. According to the Unaccusative Hypothesis (e.g., Burzio, 1986), single arguments of unaccusative verbs are derived by an operation that eliminates the subject of a transitive verb (Reinhart, 2002), leaving the direct object as the only argument of the verb, in the canonical object (post-verbal) position; in contrast, the subject of unergative verbs is equivalent to (and behaves like) the subject of a transitive verb. Thus, the single argument of an unaccusative verb is syntactically comparable to the object of a transitive verb, while the single argument of an unergative verb is comparable to a subject.

Further evidence for the object status of the unaccusative argument is provided by the NE-cliticization test in Italian (Sorace, 1995), which works for unaccusatives (1) as it does for the object of transitives (2), but not for unergatives (3).

(1) *Ne arriva uno.*

Of them arrives one.

'One of them is arriving.'

(2) *Ne ho preso uno*.

Of them I took one.

'I took one of them.'

(3)**Ne chiacchiera uno*.

Of them chats one.

'One of them is chatting.'

The choice of perfective auxiliary is also regarded as a syntactic diagnostics of the unaccusativity/unergativity split. For example, in several European languages, among which Italian, unaccusative verbs generally select 'be' as a perfective auxiliary while unergative verbs select 'have'. In our examples below, (4) involves an unaccusative verb, i.e., *arrivare* ('to come'), and thus selects *essere* ('be') as auxiliary, whereas the auxiliary *avere* ('have') is ungrammatical. On the other hand, the unergative verb *chiacchierare* ('to chat') can take only *avere*.

(4) *Il ragazzo è / *ha arrivato in ritardo.*

'The boy is / *has arrived late.'

(5) *Il ragazzo *è / ha chiacchierato con gli amici.*

'The boy *is / has chatted with friends.'

However, as noted by Sorace (2000), the choice of the auxiliary could not be reduced to a categorical choice (cf. Burzio, 1986). In this regard, she observed that auxiliary selection is crucially determined by the lexical-semantic properties of the verb. That is, the choice of the auxiliary appears to be modulated in a gradient fashion by aspectual features (telicity/atelicity) of the verb and of the predicate in which the verb appears, as well as by the degree of agentivity of the argument of the verb. She thus proposed a hierarchy of semantic verb classes, termed 'Auxiliary Selection Hierarchy' (ASH) (reported below in 6), that captures the gradient likelihood of an intransitive verb to select the auxiliary 'to have' or 'to be'.

(6) *Auxiliary Selection Hierarchy (ASH)*

change of location	verbs select BE
change of state	
continuation of state	
existence of state	
uncontrolled process	
controlled process (motional)	
controlled process (non-motional)	verbs select HAVE

According to the ASH, verbs involving change of location or change of state are 'core unaccusatives', lexically denote telic change and categorically select 'be' as auxiliary; verbs involving non-motional controlled processes are 'core unergatives', denote an agentive activity and categorically take 'have'. Thus, at the 'be end' of the ASH one finds unaccusative verbs involving change of location (e.g., *arrivare*; 'to arrive') or state (e.g., *nascere*, 'to be born'), whereas at the 'have end' there are unergative verbs involving agentive non-motional atelic activity (e.g., chiacchierare; 'chat'). Intermediate verbs between the two extremes incorporate telicity and agentivity to a lesser degree, and involve a less complex event structure and are dependent on other characteristics of the predicate for their interpretation. **That is, auxiliary selection for intermediate (non-core) verbs appears to be influenced to a greater extent by compositional factors (i.e., the event structure of the whole predicate), whereas for core verbs it is derived by the inherent semantic features of the verb and is therefore relatively unaffected by compositional aspects of the predicate (Cennamo and Sorace, 2007; Sorace, 2004).**

These verbs, that are named 'peripheral' or 'non-core', are more variable in their choice of auxiliary not only within a language (Levin and Rappaport Hovav, 1995; Sorace, 2000), but also across languages (i.e., they select 'be' in some languages and 'have' in others; Bard et al., 2010).

To sum up, the array of verb classes represented on the ASH can be accounted for with respect to two factors, telicity and agentivity. In particular, telicity lies at the core of unaccusativity whereas agentivity is the primary feature of unergativity. As the ASH was found to explain gradience in other diagnostics of split intransitivity, henceforth we will refer to this hierarchy with the more general term of 'Split Intransitivity Hierarchy' (SIH).

Sorace and her colleagues have demonstrated that speakers of several languages, when asked to judge the acceptability of auxiliary selection, are sensitive not only to split intransitivity, but also to the gradience represented by the SIH. Studies employing an offline magnitude estimation task (Bard et al. 1996) indicate a clear preference for the correct auxiliary over the incorrect in core

verbs in comparison with non-core verbs in judgments of native speakers of Italian (Bard et al. 1996; Sorace, 1993a, 1993b, 1995), Dutch (Sorace and Vonk, 1998), German (Keller and Sorace, 2003), Paduan (Cennamo and Sorace, 2007) and French (Legendre and Sorace, 2003).

Additional evidence for the existence of gradient variation in the SIH was obtained in studies using online measures such as eye movements in sentence reading. Bard, Frenck-Mestre and Sorace's (2010) eye-tracking study investigated the processing of Italian sentences involving unaccusative (7) and unergative (8) core (a) vs. non-core (b) verbs.

(7) a. *Alla festa il miliardario ha entrato / è entrato da solo nella sala*

b. *Alla festa il miliardario ha rimasto / è rimasto da solo nella sala*

'At the party the millionaire entered/remained alone in the room'

(8) a. *A quella vista il codardo ha urlato / è urlato per lo spavento*

b. *A quella vista il codardo ha trasalito / è trasalito per lo spavento*

'At that sight the coward shouted/jumped in fright'

The authors observed that the incorrect auxiliary (i.e., *avere* in 8a and *essere* in 9a) caused longer total reading times in sentences with core unaccusative or unergative verbs in comparison with non-core ones (as in 8b and 9b). The authors account for such findings proposing that for non-core verbs the choice of the auxiliary depends on compositional factors beyond the auxiliary-verb combination (Bard et al., 2010), namely on the integration of other characteristics of the predicate such as the subject of the verb.

Further evidence for the cognitive reality of SIH was provided by means of a series of event-related brain potentials (ERPs) experiments. Note that this methodology allows not only to distinguish the time course of processing, but crucially to differentiate the on-line integration of different types of information (i.e., semantic vs. syntactic) as they are encountered in the sentence. The ERP correlates of German auxiliary selection were studied by Roehm and Sorace (2008) and by Roehm, Bornkessel-Schlesewsky and Sorace (2010, 2013). Overall, these studies indicate that auxiliary selection violations with core verbs caused a biphasic N400-P600 pattern.

Regarding the N400, although in the literature a negativity with a peak latency of approximately 400 ms post-stimulus onset was initially regarded as a reaction to anomalies at the lexical-semantic level (Kutas and Hillyard, 1980), later work showed that this negativity is associated with predictive processing in a broader sense. That is, the N400 is often reported to be sensitive to unexpected sentence continuations in terms of both form and content (Ito et al., 2016). Therefore, N400 effects might signal whether the incoming words do not fit the expectations of what comes next (Frisch & Schlesewsky, 2005). In other words, the amplitude of the N400 response varies inversely to the cloze probability of the following word (Lau, Phillips and Poeppel, 2008). Interesting evidence of the fact that the N400 could be associated with semantic processing costs along with syntactic elaboration can be found in Nieuwland et al. (2013). In their study the N400 was engendered by a semantic incongruence due to a syntactically-induced thematic problem (e.g., incorrect case-marking with animate objects).

As for the P600 - a late positivity expressed by a peak latency of approximately 600 ms after stimulus onset - this electrophysiological response has long been associated with the resolution of syntactic anomalies (e.g., garden path effects; Osterhout and Holcomb, 1992), reflecting processes of reanalysis and repair. However, more recently the P600 has been interpreted as a signal of syntactically unexpected continuations (Van Berkum et al., 2007) or semantic reversal anomalies (Nieuwland and Van Berkum, 2005; Kuperberg et al., 2005; Hoeks et al., 2004). Additionally, recent research suggests that this late positivity could further indicate an incongruence in well-formedness categorization (Frenzel, Schlesewsky, and Bornkessel-Schlesewsky, 2011; Bornkessel-Schlesewsky et al., 2011).

Roehm et al. (2013) offer an exhaustive explanation for the N400-P600 pattern found in their study. First, when participants read HAVE and BE auxiliaries, they pre-activate verbs with compatible semantic/aspectual properties (atelic vs. telic). However, an auxiliary violation with core verbs might result in an incompatible auxiliary-verb combination, causing lower lexical preactivation of the verb, and therefore leading to an N400. According to the authors, the N400

could be explained in terms of the (incongruent) anticipation of particular verb classes (i.e. based on their specific aspectual properties) rather than to the preactivation of an individual word. Second, the authors discuss two competing interpretations to account for the P600 effect. While they favor the hypothesis according to which this late positivity could reflect a categorisation process that classifies as ill-formed sentences with a dispreferred auxiliary (Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky et al., 2011), they do not rule out a re-analysis explanation. Under this view, when the semantic ambiguity (telic vs. atelic), set up by the auxiliary-verb combination, is resolved towards the dispreferred reading, a reanalysis process is required.

The bulk of these previous studies allows us to draw a simple but clear-cut conclusion: violations in auxiliary selection are more taxing in verbs fully specified for telicity than in verbs underspecified with respect to this semantic feature. However, recall that intransitive verbs on the SIH are differentiated not only with respect to telicity, but also for their inherent agentivity: in core unergatives, the action denoted by the event is agentive, whereas in core unaccusatives the action may be agentive or non-agentive without affecting auxiliary choice. As a consequence the verb's subject, an agent in unergatives and a patient or a theme in unaccusatives, should be processed in a different way across verb classes (see Belletti, 1988, for an overview).

According to the literature on language acquisition, since a very early age children process differently the internal argument of the two verb classes (Friedmann, 2007; 2011). A first strong evidence derives from a syntactic perspective: post-verbal subjects are more numerous with unaccusatives as early as age 2 (Lorusso, Caprin, and Guasti, 2005), while, at the same age, only preverbal subject are reported in unergatives, suggesting that children process the subject of an unaccusative verb as an internal object argument, and the subject of an unergative verb as a real subject (Friedmann & Costa, 2011; Lorusso, Caprin, and Guasti, 2005).

A second, relevant piece of evidence speaks about the ability of children to differentially represent the inherent properties of the argument of intransitive verbs (Vernice and Guasti, 2015). The authors moved from the assumption that unaccusatives assign partitive case to the (postverbal)

verb argument, such that it would be felicitously expressed only by means of an indefinite NP (Milsark, 1974; Belletti, 1988). They then asked Italian 4- and 5-year-olds to repeat a series of sentences involving unaccusative/unergative verbs with indefinite/definite NP subjects that occurred in pre/post verbal position (Esce/passeggia un/l'orsetto con i suoi amici vs. Un/l'orsetto esce/passeggia con i suoi amici; 'goes out/walks a/the little bear with its friends' vs. 'a/the little bear goes out/walks with its friends'). In their (non-verbatim; cf. Friedmann, 2007) sentence repetitions, children were more likely to produce post-verbal subjects with unaccusative verbs only when the argument was indefinite. The presence of a definite NP increased the preference for preverbal subject repetitions even in unaccusatives. In unergatives, children transformed postverbal sentences into preverbal ones regardless of the definite or indefinite nature of the subject NP. The crucial finding at stake here is that children appeared to process an inherent property of the status of object, indefiniteness, only with respect to the verb's argument of unaccusatives, but not for unergatives, that do not involve an object argument. Therefore, such finding is an indication that a child's parser can access the internal representation (i.e., the inherent features) of different intransitive verbs and match it with the compositional features of the verb's argument.

According to the above mentioned evidence, one might claim that it should be possible to differentiate intransitive verb classes with respect to the way the subject is processed. **One could predict therefore that unergative verbs, which typically denote agentive processes, will elicit a strong preference for animate agents. It would likely follow that a violation of animacy expectations (i.e., an inanimate argument) could result in higher processing costs for the sentence. As for unaccusatives, we may predict that the animacy of the argument will not contribute to processing costs.**

In the current study we address this question by monitoring eye-movement of Italian participants while processing sentences involving unaccusative vs. unergative verbs with animate vs. inanimate subject arguments. On the assumption that prototypical agents tend to be animate (Comrie, 1989; Dowty, 1991; Hopper and Thompson, 1980; Langacker, 1991), we predict that in

verbs that denote agentive events (i.e., unergatives) the animacy of the verb's argument should affect the processing of the predicate more strongly than for typically non-agentive verbs such as unaccusatives. In particular, as a consequence of the strong association between agency and animacy (Aissen, 1999; Dowty, 1991), we expect animate subjects in unergatives to be preferred over inanimate subjects, whereas for unaccusatives we do not predict such a preference.

Our predictions could be therefore summarized as follows: (a) unergative verbs, as opposed to unaccusative ones, should be sensitive to the agentivity of the subject argument, and this should be reflected in the online processing of the verb's argument across verb classes; (b) the subject of unergative verbs should be more acceptable, and thus more easily processed, when animate; (c) the processing of unaccusatives should not be sensitive to subject agentivity. Additionally, the effects should be modulated by the position of the verb along the SIH, with maximally agentive core verbs showing a stronger preference for animate subjects in comparison with less agentive verbs that lie at the **non-core** end of the SIH continuum. Note that, as for the processing of the predicate itself, we expect to find differences across verb classes in late measures of eye movements (such as total reading times or regressions), that is those measures reflecting a late processing of the sentence after the verb has been encountered.

In addition to the predictions regarding animacy, in our experimental items we orthogonally manipulated the core vs. **non-core** position of the verb on the SIH, and whether it was presented with the correct vs. incorrect auxiliary. Our aim was to replicate the previous finding that an incorrect auxiliary should cause slower reading times as compared to a correct one, and that processing an incorrect auxiliary would be more taxing for core than for **non-core** verbs of both types.

Method

Participants

Thirty-six Italian native speakers aged 22;3 to 25;8 years (3 M) voluntarily participated in the experiment. All participants had normal and corrected-to-normal vision. Each participant responded accurately to more than 85% of the comprehension questions. Four participants were excluded due to lack of reliable eye-tracking data (e.g., poor calibration or lack of accurate eye-tracking). The final analysis was run on thirty-two participants.

Materials and Design

We created 36 sets of sentences: half (18) involved unaccusative verbs (e.g., 11a-d), half involved unergative verbs (e.g., 12a-d). In each intransitive type set of sentences (18 sets each), 9 presented an inanimate subject (e.g., 'the moped' in 12a-d) and 9 an animate subject (e.g., 'the rebel' in 11a-d). 72 Italian intransitive verbs were evenly divided by Intransitive Type (36 unaccusatives and 36 unergatives) and by SIH Type: half of each Intransitive Type verbs were core, half non-core. Verbs were classified as core or non-core on the basis of their semantic properties: core unaccusatives were telic verbs of change of location or change of state; non-core unaccusatives were stative verbs; unergative verbs denoted a controlled non-motional activity, while non-core unergatives denoted atelic, uncontrolled activities (thus, less agentive).

Each core verb was matched with a non-core verb of the same intransitive type and appeared as main verb of one of the 18 sets of sentences (each for intransitive type). Thus, each set of sentences included 4 sentences, which were structurally identical, except for the verb, which was either core (11a-b; 12a-b) or non-core (11c-d; 12c-d), and for the auxiliary, which was *essere* (11a, 11c; 12b, 12d) or *avere* (11b, 11d; 12a, 12c). Below we provide examples of the experimental sets involving an unaccusative (11a-d) and an unergative verb (12a-d), respectively. The full list of experimental sentences is reported in Appendix A.

Unaccusative:

(11) a. Subj-Animate, Core, Correct Auxiliary (*essere)*:

Stando ai compagni il ribelle {*è*} scappato per giorni sulle montagne.
According to the companions the rebel is escaped for days on the mountains.

b. Subj-Animate, Core, Incorrect Auxiliary (*avere)*:

Stando ai compagni il ribelle {**ha*} scappato per giorni sulle montagne.
According to the companions the rebel has escaped for days on the mountains.

'According to his companions the rebel escaped for many days on the mountains'.

c. Subj-Animate, Non-core, Correct Auxiliary (*essere)*:

Stando ai compagni il ribelle {*è*} resistito per giorni sulle montagne.
According to the companions the rebel is withstood for days on the mountains.

d. Subj-Animate, Non-core, Incorrect auxiliary (*avere)*:

Stando ai compagni il ribelle {**ha*} resistito per giorni sulle montagne.
According to the companions the rebel has withstood for days on the mountains.

'According to his companions the rebel withstood for many days on the mountains'.

Unergative:

(12) a Subj-Inanimate, Core, Correct Auxiliary (*avere)*:

Durante il collaudo il motorino {*ha*} viaggiato a velocità sostenuta.
During the test run the moped has traveled at speed significant.

b. Subj-Inanimate, Core, Incorrect Auxiliary (*essere)*:

Durante il collaudo il motorino {**è*} viaggiato a velocità sostenuta.
During the test run the moped is traveled at speed significant.

' During the test run the moped traveled at high speed'.

c. Subj-Inanimate, Non-core, Correct Auxiliary (*avere)*:

Durante il collaudo	il motorino	{*ha*}	sgommato	a velocità	sostenuta.
During the test run	the moped	has	spun	at speed	significant.

d. Subj-Inanimate, Non-core, Incorrect Auxiliary (*essere)*:

Durante il collaudo	il motorino	{**è*}	sgommato	a velocità	sostenuta.
During the test run	the moped	is	spun	at speed	significant.

‘ During the test run the moped tires spun at high speed’.

We normed verbs and sentences for frequency (Bertinetto et al., 2005), familiarity and plausibility. As for frequency, in unaccusatives, core verbs (Mean (M) = 80.01, Standard Deviation (SD) = 106.93) were slightly less frequent than non-core ones (M = 88.55, SD= 98.40), whereas core unergatives (M = 18.82, SD = 20.80) were more frequent than non-core unergatives (M = 3.08, SD= 4.54). The mixed effects model on the log-transformed frequency data, revealed an effect of Intransitive Type (Log-lik = -57.77, number of observations =72; b: -.52, $p < .003$) and a significant interaction between Intransitive Type and SIH Type (b = -.48, $p < .05$). SIH Type factor contributed to the fit of the model, but did not result significant ($\chi_2(1) = 3.55$, $p < .05$; b: .006, $p = .96$).

As for familiarity, we asked 27 native Italian speakers (age range 21-24 years, 11 M) who did not take part in the experiment, to rate the familiarity of the verbs on a 1 to 5 Likert scale. Participants had to read a list of verbs in the infinitive form and rate their familiarity. The analysis revealed that there was only a marginal effect of SIH Type (Log-lik = -39.21, number of observations =72; b = -.11, $p = .06$) with core verbs being perceived as more familiar (M = 4.35, SD = .55) than non-core ones (M = 4.25, SD = .56).

We further normed the plausibility of the events described in the sentences. We asked 44 Italian native speakers (age range: 19-23, 7 M), who did not take part in the experiment or in the familiarity norming study, to rate on a 1 to 5 Likert scale the plausibility of the events involved in

the sentences. Participants were presented with a list of 36 sentences where the verb was presented only with the correct auxiliary (i.e., *essere* for unaccusatives and *avere* for unergatives). As there were only two versions for each item (e.g., core vs. non-core verb), we created two latin square lists to which participants were randomly assigned. Results were fit to a series of mixed effects models. The analysis revealed a marginal effect of SIH type (Log-lik = -62.73, number of observations =72; b: .15, p = .06), with sentences involving a core verb (M = 3.46, SD= .78) being rated as less plausible than sentences involving a non-core verb (M = 3.61, SD= .61).

Finally, core and non-core pairs were not controlled for length of participle in number of letters. However, as we analysed the data with mixed effects models, in every model we tested whether region's length, that is, the number of characters in each region, exerted an effect on the dependent variables.

To sum up, the independent variables animacy (animate vs. inanimate) and intransitive type (unaccusative vs. unergative) were manipulated between items, whereas SIH type (core vs. non-core) and auxiliary (correct vs. incorrect) were manipulated within items. **Following the suggestions of an anonymous reviewer, we created an additional set of experimental stimuli that manipulated animacy (animate vs. inanimate) within items and conducted a plausibility norming study on 24 native Italian speakers with the same age range and background as the participants in the main experiment. The stimuli are available for view at this URL (https://docs.google.com/document/d/1ujgGlXqfaBoaWOuLuCWOWbqMYwJ1s92zne0sefPg-NY/edit?usp=sharing). The analysis revealed a number of significant differences in the acceptability of sentences across conditions. Results indicated that: i) sentences with an inanimate subject (M = 3.35, SD = 1.33) were rated as less acceptable as compared to items involving an animate argument (M = 3.48, SD = 1.42; b = .58, SE = .23, t = 2.478, p< .013); ii) sentences involving an inanimate subjects and an unergative verb (M = 2.65, SD = 1.19) were significantly less acceptable than sentences with inanimate subjects and unaccusative verbs**

(M = 4.05, SD = 1.08), as indicated by the Verb by Animacy interaction (b = -1.42; SE = .33, t = -4.288,p< .001); iii) sentences involving an unergative non-core verb (M = 3.018; SD = 1.48) were marginally less acceptable than sentence with an unaccusative non-core one (M = 3.96; SD = 1.25) as confirmed by the Verb by SIH Type interaction (b = -.56; SE = .33, t = -1.706,p= .08); iv) only in unergatives, sentences with inanimate subjects (M = 2.65; SD = 1.19) were rated as significantly less plausible than those with an animate argument (M = 3.50; SD = 1.39; b = -1.13; SE = .32, t = -3.493,p< .001). The results of the norming study therefore confirmed that a within items manipulation of animacy could not be easily obtained without seriously compromising the plausibility and naturalness of the sentences. For this reason, in the current study, we opted for a set of more plausible and acceptable sentences, although not fully balanced with respect to animacy (see further comments in the General Discussion session).

We created four lists, such that each list contained an equal number of different versions of the items, and such that each item appeared an equal number of times in all the versions of the experimental set. In addition, 4 warm-up sentences preceded the list and 60 filler sentences were presented in random order within the list. Filler sentences included a structure involving a main and a subordinate clause (e.g., *Maria gioca a tennis con Lucia quando è libera dagli impegni*. 'Maria plays tennis with Lucia when she is not busy'). We further included 24 comprehension questions requiring a yes-no response. For example, after the set of sentences 11a–d, the Italian equivalent of the following question appeared: 'Is the preceding sentence about a rebel on the run?'. Half of the comprehension questions followed experimental sentences (half for each intransitive type), half followed filler sentences.

Eye Movement Recordings

Participants' eye movements were recorded by means of an EyeLink 1000 eye-tracker. Eye movements were recorded for the right eye and view was binocular. The sentences were presented

on a computer screen located about 50 cm from the participants' eye. Experimental sentences were presented one at time and each sentence fitted in one line. All the letters were presented in the lower case (except for the first letter) and in Courier New typeface. A trial started with a fixation cross in the center of the screen.

Procedure

Participants received written and oral instructions. They sat in front of a computer screen, holding a joystick. On the joystick there were three buttons: one marked with a green sign to move from one sentence to the following one; a button on the left marked with 'S' (*sì*; 'yes') and a button on the right marked with 'N' (i.e., no) to reply to the comprehension questions. After the eye tracker was calibrated, participants were asked to silently read the sentences that appeared on the screen and then press the marked button on the joystick to move to the next one. When comprehension questions occurred, participants were asked to reply by pressing the appropriate button on the joystick. Immediately afterwards a new sentence appeared on the screen. Participants were free to interrupt the experimental procedure any time between items.

Results

Analyses

Sentences were divided into five regions, corresponding to 1) the sentence onset (usually, a prepositional phrase), 2) the subject, 3) the critical region including the auxiliary and the participle, 4) a region of varying length (3 to 14 characters) following the critical region, 5) the sentence ending. An example is provided below (13).

(13) /$_1$Stando ai compagni$_1$/$_2$il ribelle$_2$/$_3$è scappato$_3$/$_4$per giorni$_4$/$_5$sulle montagne$_5$/.

As the auxiliary *è,* consisting of a single letter, was unreliable as a region, because short regions are more likely to be skipped, we considered as critical region the auxiliary plus the verb

participle (i.e., region 3). The material following the critical region (4) was included in the analysis as it could reveal spill-over effects. In addition we analyzed the region preceding the critical region (2).

We examined five dependent variables: 1) log-transformed total reading time, i.e. the sum of the durations across all fixations within a region (in milliseconds); 2) log-transformed first pass reading time, i.e. the sum of the durations of the first run within a region (in millisecond); 3) (first pass) regression out probability, i.e. whether a regression was made (coded as '1') or not ('0') from a region to an earlier one, prior to leaving that region in a forward direction; 4) regression out full probability, i.e. whether a regression was made ('1') or not ('0') from a region to an earlier one (note that first pass regression out probability only considers first-pass regressions whereas regression out full probability considers all regressions, regardless of whether later regions were visited or not); 5) regression out full count, i.e. the number of times a region was exited towards an earlier region.

The different eye-movement measures collected here signal both early and late processing costs. For instance, first pass and (first pass) regression out probability are known to reflect the early stages of the reading comprehension process. According to the literature, first pass should be more affected by lexical factors as well as other variables, i.e., word frequency and morphological complexity (Pollatsek, Reichle, and Rayner, 2003). Regression out probability is regarded as a difficulty in integrating a word when it is fixated during the first pass of the sentence; thus it might be arguably accounted as an early effect. We recorded also measures assumed to reflect later processing: total reading time, regression out full probability, and regression out full count. Total Reading time may reveal the cost to integrate a word within the sentence context, which may occur late in processing. Similarly, regressions that occur during the second pass of the sentence are likely to reflect later-stage processes (Pickering et al., 2004). In particular, research suggests that both

syntactic and semantic anomalies may cause regressive movements rather than directly affecting fixation (see Boland, 2004).

All dependent variables were fitted to a series of mixed effect models. In each model, we first tested which fixed effects (e.g., animacy: animate vs. inanimate, intransitive type: unaccusative vs. unergative, SIH type: core vs. non-core, auxiliary: correct vs. wrong, (log-transformed) number of characters, (log-transformed) frequency, (log-transformed) plausibility and (log-transformed) familiarity) had to be included in the regression analysis, contributing to the model's fit. To assess the contribution of a predictor or an interaction between predictors in a model, we compared a full model against another that contained one fewer predictor (e.g., Jaeger, 2008). For simplicity, we do not report the χ^2 values and the corresponding p values when the predictor contributed to the fit of the model (and thus had to be included).

As for random effects, as recommended by Barr, Levy, Scheepers and Tily (2013), we started by including the maximal structure of by-participant and by-item random intercepts and slopes that allowed both compared models to converge. When models with fully-specified random slopes did not converge, our final model only included an intercept effect of the random factors. We report the coefficients in the final models thus identified, with p values approximated by the normal distribution (Barr et al., 2013). Additionally, we report only the models in case at least one of the relevant fixed factors (animacy, verb, auxiliary, SIH type), except for length, log-frequency, log-plausibility and log-familiarity, were significant.

All the models were run on three sets of data: 1) on the full set of unaccusatives and unergatives; 2) on the unaccusative sub-set; 3) on the unergative sub-set. Analyses were conducted separately for regions 2, 3 and 4. In all the models we considered reading time per region, and not per character, as the dependent variable; figures graphically represent the data which was submitted to analysis, i.e., reading time per region. All models were implemented in R.

Region 2 – Collapsed unaccusative and unergative data

In total reading time, when the subject argument was an inanimate entity, unergative verbs (Mean total reading time per character (henceforth M) = 44.34, DS = 22.36) required longer reading times as compared to unaccusatives (M = 40.84, DS = 43.25); in contrast, when the subject argument was animate there were slower reading times for unergative verbs (M = 34.80, DS = 19.54) than for unaccusatives (M = 48.65, DS = 37.25). Thus, an animate subject caused shorter reading times in unergatives, and longer in unaccusatives, but when the subject was inanimate we observed the opposite pattern. The mixed effects model on the total reading time data revealed a first level effect of intransitive type and a significant interaction of Animacy x Intransitive Type. No other predictor contributed to the fit of the model. The interaction of Animacy x Intransitive Type at region 2 is graphically represented in Figure 1. As for first pass and regressions, we did not find any significant effect.

INSERT TABLE 1 AND FIGURE 1 ABOUT HERE

Region 3 – Collapsed unaccusative and unergative data

As for total reading time, there was no effect of animacy. There was overall longer total reading time for non-core verbs when the auxiliary was correct (Mean total reading time per character (M) = 46.35; SD = 29.14) as compared to core ones (M = 41.29; SD = 25.37). As expected, we found an opposite pattern when the auxiliary was incorrect (core: M = 60.86; SD = 35.61; non-core: M = 52.72; SD = 33.21): an auxiliary violation caused longer reading times for core verbs as compared to non-core ones and this was true for both verb classes as indicated in Figure 2. The statistical analysis, reported on Table 1, confirmed the pattern found in the descriptive data: there was a first level effect of auxiliary, SIH type, and a significant interaction of Auxiliary x SIH Type. No other variable, including length, contributed to the fit of the model.

INSERT FIGURE 2 ABOUT HERE

The analysis of first pass (see Table 1) revealed a first level effect of animacy and frequency (i.e., the log-transformed frequency of each verb), with shorter first pass for more frequent verbs. As for the animacy effect, inanimate subjects led to longer first pass.

Note that in a mixed-effects model, the coefficients (or estimates) offer an insight into the ability of a predictor to model an outcome variable, but they do not provide us with information about the proportion of variance explained by each specific fixed factor (Baayen, 2008). Therefore, obtaining a significant effect of frequency does not imply that this variable is *statistically subtracted out* from the model. To clarify, the values of the regression coefficient represent, roughly, the change in the outcome score associated with a unit change in the predictor. If a factor has an impact on the ability of the model to predict the outcome, such coefficient should be different from 0. Therefore what the t (or Z) tells us is whether the coefficient is significantly different from 0 (Baayen, 2008). As for the variance explained, in a mixed-effects model, there a number of sources of variance that are modeled together: the variance explained by the fixed factors and the one explained by random effects. Thus, in order to get an insight into the amount of variance explained by frequency, and how much of this is independent of the other variables, one possibility is to residualise responses for the factor one intends to partial out (Fine et al., 2013; Marelli and Baroni, 2015). Note that this metholodogy is (to some extent; cf. García-Berthou, 2001) similar to a standard ANCOVA, in that it provides a way of statistically controlling for the independent contribution of a variable. To do so, we ran an additional analysis on the residual first pass of the statistical model employing frequency as fixed factor. These latter data capture the variance in first pass that is not explained when including frequency as predictor. A significant effect of animacy emerges in this follow up test ($t = 1.942, p = .052$), indicating that animacy explains a portion of variance in first pass that is not accounted for when including frequency as a predictor.

Returning to the analysis, as the animacy manipulation occurred at region 2 and first pass reflects a very early stage of processing, it is possible to account for such effect as a spillover of the already mentioned animacy effect found in region 2, rather than an effect due to integration costs. Regarding regressions, we did not find any other significant effect.

Region 4 – Collapsed unaccusative and unergative data

The analysis of total reading time indicated a first level effect of auxiliary, SIH type, a significant interaction of Auxiliary x SIH Type and length (i.e., log-transformed number of characters) (cf. Table 1). Again, the effect found in this region basically replicate the one found in the previous one. It could thus be regarded as a spillover effect of the Auxiliary by SIH Type interaction found at region 3, indicating that core verbs caused longer reading times when the auxiliary was incorrect (auxiliary correct: Mean total reading time per character (M) = 48.65; SD = 36.48; auxiliary incorrect: M= 59.73; SD = 36.70), not only in the verb region, but also in the following region. In non-core verbs, in contrast, the difference in reading times with correct vs. incorrect auxiliary was negligible (auxiliary correct: M= 53.70; SD = 41.58; auxiliary incorrect: M= 54.51; SD = 35.14). Figure 3 below graphically represents the effects of auxiliary (correct vs. incorrect) and SIH type (core vs. non-core) on mean total reading time per character in the unaccusative-unergative collapsed data for regions 2, 3 and 4.

Considering (first pass) regression out probability, data showed that, during the first pass of region 4, participants were more likely to regress to a prior region when the auxiliary was incorrect and when the region involved more characters. A similar pattern of results was also found in regression out full probability (see Table 1). Regression out full counts revealed only an effect of length and frequency; however, as stated above, we did not report the summary of the model based on regression out full counts as none of the relevant variables were significant.

INSERT FIGURE 3 ABOUT HERE

Unaccusative data

At region 2, of all the variables considered we observed only a consistent effect of length. That is, longer regions (in terms of number of characters) caused longer reading times and a higher likelihood to regress to a previous region. There was no effect of animacy.

At region 3, total reading time exhibited a first level effect of auxiliary, SIH type and an interaction of Auxiliary x SIH Type (see Table 2). The interaction basically replicates the pattern of results found at region 3 in the unaccusative-unergative collapsed data-set: core verbs were read faster than non-core ones with correct auxiliary, but when the auxiliary was incorrect there were longer reading times in core verbs in comparison with non-core ones. Again, we did not find any effect of animacy.

At region 4, in (first pass) regression out probability data there were first level effects of auxiliary, indicating that participants were more likely to regress to a prior region when the auxiliary was incorrect. A similar pattern of results was found also in regression out full probability and in regression out full count (see Table 2). For all other variables there were only length effects. Figure 4 graphically represents the effects of auxiliary (correct vs. incorrect) and SIH type (core vs. non-core) on total reading time in the unaccusative sub-set of data for regions 2, 3 and 4.

INSERT FIGURE 4 ABOUT HERE

Unergative data

At region 2, total reading time was significantly longer in sentences that involved inanimate subjects (M = 44.35; SD = 22.36) as compared to sentences with animate subjects (M = 34.08; SD = 19.46) and this difference was significant (see Table 3). A similar pattern was found in first pass: when the subject was inanimate there was longer reading time during the first pass of the sentence (Mean total reading time per character (M) = 24.39; SD = 18.86) than when it was animate (M = 19.83; SD = 14.74). Note that first pass variable refers to the reading times of the subject region (i.e., 2) before the eyes entered in the verb region (i.e., 3), where unaccusative and unergative verbs

are disambiguated. It is therefore possible to claim that such effect could be purely accidental or at least, not due to our experimental manipulation. However, one cannot totally exclude the possibility of parafoveal preview from region 2 to 3 (Kliegl and Engbert, 2005; Rayner, 1998). If this is the case, the longer first pass reading time could be due to a more costly early processing of the predicate region when the subject is inanimate. We will return to this issue in the General Discussion. It is interesting to note that the effect of animacy observed in region 2 signaled by early and late measures, indicated that the argument's animacy significantly influenced the processing of the subject region in unergative verbs. For all other variables there was only an effect of length.

At region 3, total reading time exhibited a first level effect of auxiliary, i.e., longer reading times with incorrect auxiliary and an interaction of Auxiliary x SIH Type (see Table 3 and Figure 5). The interaction indicates again that when the auxiliary was correct reading times of non-core verbs did not differ from core ones, but when the auxiliary was incorrect reading times increased significantly for core verbs as compared to non-core ones. Again, the interaction replicates the pattern of results found at region 3 for collapsed data, with the only difference that reading times for core and non-core unergative verbs did not differ when the auxiliary was correct. As for first pass data, there was only an effect of frequency.

Regarding animacy, in regression out full probability variable we found a consistent first level effect of SIH type and a significant interaction of Animacy x SIH Type (cf. Table 3). On the one hand, the main effect of SIH type shows that, in non-core verbs, participants tended to regress more than in core verbs. On the other, the presence of the interaction Animacy x SIH Type indicates that in core verbs, participants were more likely to regress when the subject was inanimate than when it was animate. In non-core verbs the opposite pattern was found: participants were more likely to make regressions after an animate in comparison with an inanimate subject. Regarding all other regression variables the two way Animacy x SIH Type (as well as the three way interaction Animacy x SIH Type x Auxiliary in (first pass) regression out probability variable) was only

marginally significant (all ps > .06), suggesting a pattern of results consistent with the one emerged in regression out full probability variable.

At region 4, total reading time data revealed again an effect of auxiliary: there were longer reading times with incorrect auxiliary (see Table 3). As for regression variables, in (first pass) regression out probability, regression out full probability and regression out full count there was an effect of auxiliary, indicating more regressions to a prior region when the auxiliary was incorrect (see Table 3). Figure 5 reports the effects of auxiliary (correct vs. incorrect) and SIH type (core vs. non-core) on total reading time in the unergative data for regions 2, 3 and 4.

INSERT FIGURE 5 ABOUT HERE

General Discussion

This study used an eye-tracking methodology to test whether the animacy of the verb's argument affected the processing of the subject argument in unergative verbs to a greater extent than the processing of the subject argument of unaccusative verbs. Results confirmed our prediction. In the region where the subject occurred (i.e., region 2), we found a clear interaction between animacy of the subject argument and type of verb. That is, for unergatives there was a slower reading of inanimate subjects compared to animate ones, whereas for unaccusatives reading times were not sensitive to the animacy of the subject argument. The interaction clearly confirmed that the subject argument is not processed in the same way across intransitive verb classes in Italian, and specifically that variation in the animacy of the subject affects reading times in unergatives but not in unaccusatives.

The analysis on the unergative sub-set of data provided additional evidence on such effect, showing that inanimate subjects were dispreferred over animate ones, causing longer reading times during early (first pass) and late (total reading time) elaboration of the predicate region. Recall that, whereas total reading time is informative about the late processing stages of a sentence (Pickering et al., 2004), first pass is assumed to reflect the very early stage of the reading comprehension process (Rayner, 1998). That is, the first pass variable refers to the reading time of the subject region *before* the eyes entered the following one, where the type of intransitive verb is disambiguated. Therefore one could possibly claim that participants were not yet aware of the fact that they were reading a sentence involving an unergative or an unaccusative verb. Thus, one possible explanation could be that the animacy effect was not due to the verb type but to sheer chance.

However, an alternative explanation would take into account the possibility that the verb region was in parafoveal pre-view (Hyönä et al., 2004; Rayner, 1998). It is well established in the literature that prior knowledge of the first letters of the words in parafoveal view increases processing efficiency of the targeted word (Kliegl and Engbert, 2005). Evidence indicates that

preview benefits could be obtained for first pass time even when the word in parafoveal view is distanced up to nine character spaces from the targeted word (McDonald et al., 2006). Therefore one might not exclude the option that, while targeting the subject argument, the verb was already in parafoveal view for the participants. The longer first pass would thus indicate a more costly elaboration of the inanimate argument while pre-processing the verb region. If so, the pattern of first pass would corroborate the results of total reading time.

The pattern of results of reading times in the subject region indicates that the processing of the subject predicate in intransitive verbs varies across verb classes: agentivity plays a role in determining a strong preference for animate agents in unergatives, and has no effect on unaccusative verbs.

Our study aimed at answering another question about the intransitivity split, namely whether the position of the verb along the SIH continuum (i.e., core vs. non-core) could affect the processing of the animacy of the subject argument. Recall that maximally agentive verbs are situated at the unergative end of the SIH continuum (Sorace et al., 2011) and are classified as core verbs. Therefore one could predict that verbs that are strongly agentive (i.e., core) would support stronger preferences for animate subjects in contrast to less agentive verbs (i.e., non-core). As a consequence, inanimate subjects would be dispreferred to a greater extent with core unergatives, causing a more costly processing of the subject/verb region in such verbs, as compared to non-core ones.

Regression data in the unergative sub-set confirmed this prediction. At the verb region, we found a reliable interaction of Animacy x SIH Type, supporting the claim that inanimate subjects caused more regressions in core verbs as compared to non-core ones. This finding indicates that with core verbs, participants were more likely to make regressions to previous regions when the verb involved an inanimate subject in comparison with an animate one. In non-core verbs we found the opposite pattern. A first explanation for such finding could be that the comprehension system tries to rapidly establish a link between the animacy of the subject argument and the semantic and

aspectual features of the verb. When the subject's animacy (i.e., inanimate) does not inherently fit the verb's semantic entailments (i.e., agentivity), the comprehension system forces reanalysis, as signaled by regressions, to accommodate the final interpretation of the sentence.

The current findings provide additional evidence for the role of semantic influences on parsing, that was captured by the 'Semantic (or thematic) fit' accounts (e.g., Trueswell et al., 1994; McRae, Ferretti & Amyote, 1997; McRae, Spivey-Knowlton and Tanenhaus, 1998; Ferretti et al., 2001). According to a well-known eye-tracking study (Trueswell et al., 1994), verb-related semantic knowledge rapidly influences the assignment of thematic role. The authors examined the processing of temporarily ambiguous sentences such as reduced relative clauses by manipulating the animacy of the first noun phrase, that could be animate ('the speaker proposed…') or inanimate (i.e., 'the solution proposed...'). Reading times data showed that, when the first noun phrase was inanimate, participants rapidly assigned the thematic role of a patient despite the strong preference towards a main clause interpretation. When the eyes encountered the 'by-region' ('…by the group, would work perfectly…') the authors observed shorter first pass with inanimate arguments. Such finding supports the claim that the comprehension system rapidly processed whether the predicate's conceptual features fitted the verb semantic entailments (i.e., 'to propose' requires an animate agent) and made use of this information to resolve the temporary syntactic ambiguity.

A series of self-paced reading studies offered further evidence for the thematic fit account (McRae et al., 1997). The authors did not manipulate animacy, but the thematic plausibility of a specific argument to occur in the agent or patient role within a verb frame. For instance, in the study participants read reduced relatives beginning with a good patient (i.e., the customer) or a good agent (i.e., the waitress) for the action of 'serving'. As expected, a sentence such as 'The waitress served by the trainee was displeased with his attitude', where 'waitress' occurs in the patient role, caused a significant slow-down in reading times in comparison with 'The customer served by the trainee…', involving a good patient (i.e., customer) for the same action. The authors suggested that thematic roles cannot be regarded as empty slots to which concepts are assigned at thematic level (Fillmore,

1968; Jackendoff, 1972, 1987), rather as verb specific concepts formed through everyday experience, that are more similar in nature to nominal concepts.

Returning to our data, overall the pattern of results is compatible with a thematic fit explanation, given the fact that the argument of unergatives is an agent, and agents are typically animate entities (Bock and Warren, 1985; Dowty, 1991). However, our findings do not simply indicate that unergatives strongly prefer animate arguments; more importantly, they show that such preference is not discrete in nature, but is modulated in a gradient fashion, according to the position of the verb on the SIH continuum. Therefore, the interplay of the conceptual features of a predicate and their appropriateness with the verb semantic entailments, represented on the SIH, appeared to affect the parsing of the sentence, causing reanalysis when there was a (strong) semantic mismatch between the verb's inherent semantic features and the animacy of the subject argument.

The current study aimed at addressing a third issue, namely whether auxiliary selection in intransitive verbs was modulated by the verb inherent aspectual features as defined by the SIH continuum (i.e., core vs. non-core). Previous studies revealed that the preference for the 'correct' auxiliary with intransitive verbs varies in strength depending on whether the verb lies closer to the core or to the non-core end of the SIH continuum (Keller & Sorace, 2003; Legendre, 2007; Legendre & Sorace, 2003; Sorace, 2000, 2003). Recall that core unaccusatives are associated to a stronger preference for the auxiliary 'essere', while core unergatives tend to show a stronger preference for 'avere'. Non-core verbs, in contrast, are associated to weaker preferences in the choice of auxiliary. As a consequence, our prediction was that auxiliary selection violations would affect to a greater extent sentence processing in core verbs, causing, possibly, a slow-down in reading time.

The results confirmed our prediction, replicating previous findings. At the verb region, there was a significant interaction between Auxiliary and SIH Type: the presence of an incorrect auxiliary caused longer reading times in core verbs, and this effect was consistently found in the collapsed dataset as well as in the unaccusative and unergative sub-set of data. Auxiliary choice

violation affected reading times and regression measures of core verbs also in the region following the verb. In non-core verbs, the effects of auxiliary violation were, as expected, significantly minor. Again, we demonstrated that auxiliary selection is sensitive not only to split intransitivity, but most importantly to the gradience represented by the SIH.

Before concluding, it is important to discuss a potential limitation of the current study. In our experiment we opted for a between verb manipulation of subject identity in order to maintain the plausibility and the naturalness of the sentences. However, we are aware of the fact that an unbalanced design with respect to animacy could represent a flaw in the stimuli. Indeed, we cannot completely exclude on the basis of our data that any difference across animate/inanimate arguments could be due not only to the subject's animacy, but also to the verbs that appear in the sentences. To partly address this limitation, we point out that, although verbs (and subjects) were lexically different across sentences, they were balanced and carefully matched with respect to their underlying semantic properties (i.e., being for instance, core vs. non-core or agentive vs. non-agentive). Therefore current results are compatible with an interpretation under which (lexically diverse) verbs sharing the same semantic entailments show a similar pattern in subject argument processing: namely, verbs expressing an agentive non-motional event entail a preference for animate subjects, as confirmed by a more taxing processing of the inanimate subject argument; verbs denoting a non-agentive action, in contrast, appear to be relatively unaffected by verb argument's animacy.

In order to fully address this limitation in future studies, we advise to use a limited set of carefully controlled sentences built on purpose to maintain subject identity within verbs, but crucially preserving the naturalness and the plausibility of the events described in the sentences. As far as we are aware, none of the previous studies testing the intransitivity split has been able to manipulate subject identity within verbs (except for Vernice et al., 2012, that

however used simplified vocabulary items based on preschoolers' lexicon). Therefore, replicating these results would represent an exceptionally important step for the field.

In summary, our paper aimed at providing empirical evidence of the SIH put forward by Sorace (2000, 2004), not only with respect to the syntactic behavior of unergative and unaccusative verbs (e.g., auxiliary selection), but with regard to the semantic entailments, i.e., agentivity, encoded by these intransitive verb classes. We tested agentivity through animacy manipulation of the verb argument, offering compelling evidence for split intransitivity: only unergatives were sensitive to the animacy manipulation, in contrast to unaccusatives that showed no effect. Additionally, our findings provided further evidence for the gradient nature of the SIH. First, our data showed that the mismatch between the argument's animacy and the semantic features of the verb caused a penalty only in the processing of core unergatives in comparison with non-core ones. Second, present results replicated previous findings according to which auxiliary selection violations affect to a greater extent the processing of core verbs. All in all, current findings suggest that the gradience represented in SIH underpins variations not only in auxiliary choice, but also in the way the verb's single argument is processed.

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Appendix A

A list of 18 sets of sentences involving unaccusative verbs (1-18) and 18 sets of sentences with unergative verbs (19-36) (English translation in brackets).

Unaccusatives:

1. Stando ai compagni il ribelle è/ha scappato/resistito per giorni sulle montagne. [According to his companions the rebel escaped /withstood for many days on the mountains.]
2. Secondo il giornale il politico è/ha fuggito/mancato di fronte al proprio dovere. [According to the newspaper the politician escaped in face of/failed to accomplish his duty.]
3. Come previsto il materiale è/ha arrivato/scarseggiato dopo pochi mesi. [As expected the materials arrived/lacked after a few months.]
4. Nella missione l'obbligo della decisione è/ha ricaduto/gravato sul comandante. [In the mission the duty to take the decision was up to/burdened the commander.]
5. Dopo la rinuncia dell'attrice il ruolo è/ha ritornato/spettato infine a me. [As the actress gave up that role went back/was up to me.]
6. In quella residenza estiva il re è/ha tornato/risieduto regolarmente per anni. [In that summer residence the king regularly came back/resided for years.]
7. Dopo la riunione il neo assunto è/ha partito/convenuto con il capufficio. [After the meeting the new employed left/agreed with the head office.]
8. Quest'anno lo spettacolo è/ha scaduto/costato veramente tanto. [This year the show went down/costed a lot.]

9. Dopo il tradimento il fidanzato è/ha caduto/parso in preda ai sensi di colpa. [After the betrayal the boyfriend fell beside himself with guilt/seemed guilty stricken.]

10. Alla festa il milionario è/ha entrato/restato solo nella sala. [At the party the millionaire entered/stayed alone in the hall.]

11. A quanto dicono il mostro di Lochness è/ha esistito/emerso davvero in Scozia. [As it is said the monster of Lochness really existed/emerged in Scotland.]

12. Alla fine il frate è/ha crollato/risultato impotente di fronte alle tentazioni. [Eventually the friar fell down/resulted powerless in face of temptations.]

13. In cielo il segno celeste è/ha apparso/sembrato accecante agli occhi della folla. [In the sky the sign appeared/looked blinding to the crowd.]

14. Dopo l'assedio l'allarme è/ha rientrato/durato in tutte le zone della città. [After the siege the alarm stopped/lasted in all the areas of the town.]

15. Oggi il prezzo del petrolio è/ha salito/rimasto a sessanta dollari. [Today oil price raised above/stayed above sixty dollars.]

16. Col tempo un sentimento inaspettato è/ha sorto/perdurato nel cuore di Lucia. [In time an unexpected feeling arose/lasted in Lucia's heart.]

17. In cella il prigioniero è/ha sprofondato/vissuto in uno stato di depressione. [In jail the prisoner fell/lived in a state of depression.]

18. Durante la guerra l'uomo è/ha regredito/sopravvissuto ad una condizione di povertà. [During the war the man got back/survived to a poor condition.]

Unergatives:

19. A quella vista il codardo è/ha urlato/trasalito per lo spavento. [At that sight the coward shouted/gave a jump for fear.

20. In carrozza il viaggiatore è/ha dormito/sobbalzato fino a destinazione. [On the carriage the traveler slept/jolted till at destination.]

21. In classe il supplente è/ha inveito/sbottato spazientito con gli studenti. [In the classroom the substitute teacher railed/burst exasperated against the students.]

22. Durante il collaudo il motorino è/ha viaggiato/sgommato a velocità sostenuta. [During the test run the moped traveled/the moped tires spun at high speed.]

23. Da sempre il territorio è/ha beneficiato/abbondato della presenza di fonti sulfuree. [Since ever the area benefited from/abounded with the presence of sulfur springs.]

24. Dopo l'abbandono il suo animo è/ha reagito/sanguinato sempre di più. [After the abandonment his soul reacted/bled more and more.]

25. Dopo quell'avvenimento il razzismo è/ha trionfato/serpeggiato nella comunità. [After that event the racism triumphed/snaked in the community.]

26. Dopo la carestia il colera è/ha infierito/imperversato per mesi nella regione. [After the famine the cholera raged through/swept through the region for months.]

27. Secondo la tradizione il viso della statua è/ha pianto/lacrimato davanti ai fedeli. [According to the tradition the face of the statue cried/wept in front of the faithful crowd.]

28. Sul palcoscenico il clavicembalo è/ha stonato/tintinnato mentre lo accordavano. [On the stage the harpsichord played out of tune/tinkled while it was tuned.]

29. Il rifornimento idrico è/ha provveduto/sopperito al bisogno della popolazione. [Water provisions supplied/fulfilled to the needs of the population.]

30. A causa di quel guasto il trattore è/ha funzionato/circolato per pochi giorni. [Because of that engine failure the tractor worked/circulated only for few days.]

31. Dopo quell'avvenimento il giovane è/ha riso/tergiversato ancora per giorni. [After that event the boy laughed/beat about the bush for days.]

32. Per ore il fidanzato è/ha passeggiato/tentennato sotto la casa dell'amata. [For hours the boyfriend hung around/tottered outside his girlfriend's house.]

33. Alla polizia il reo è/ha acconsentito/esitato a lasciare le impronte digitali. [At the police department the offender agreed/hesitated in giving his fingerprints.]

34. Alla festa il festeggiato è/ha armeggiato/trepidato prima di stappare lo spumante. [At his party the boy messed about/was anxious before uncorking the sparkling wine.]

35. Vista la situazione il ministro è/ha meditato/titubato prima di dare le dimissioni. [In that state of events the minister pondered/hesitated over before giving his resignation.]

36. Per quell'esame lo studente è/ha sgobbato/sudato per mesi sui libri. [For that exam the student worked hard/sweated for months on books.]

Tables

Table 1. Summary of the best-fitting models in the collapsed data-set.

Region 2:Total Reading Time					
	β	*SE*	*df*	*t*	*p*
Intercept	79.115	3.887	41.830	20.352	0.000 *
Animacy-Inanimate	2.084	5.369	32.000	0.388	0.700
Verb-Unergative	-10.496	5.182	31.570	-2.025	0.051*
Animacy-Inanimate: Verb-Unergative	16.100	7.549	31.680	2.133	0.040 *
Region 3: Total Reading Time					
	β	*SE*	*df*	*t*	*p*
Intercept	54.784	2.825	48.300	19.393	0.000 *
SIH Type-non-core	6.707	2.338	83.900	2.868	0.005*
Auxiliary-Uncorrect	16.050	1.988	1036.200	8.075	0.000*
SIH Type-non-core: Auxiliary-Uncorrect	-11.193	2.814	1037.900	-3.978	0.000 *
Region 3: First Pass Reading Time					
	β	*SE*	*df*	*t*	*p*
Intercept	86.4773	3.048	51.430	28.371	0.000 *
Log-frequency	-0.1238	0.040	87.270	-3.052	0.003*
Animacy-Inanimate	3.880	1.621	33.020	2.393	0.022*
Region 4: Total Reading Time					
	β	*SE*	*df*	*t*	*p*
Intercept	36.036	5.577	115.000	6.461	0.000 *
SIH Type-non-core	4.142	2.096	1079.400	1.976	0.048*
Auxiliary-Uncorrect	10.266	2.101	1078.800	4.885	0.000*
Log-length (characters)	2.434	0.508	90.800	4.784	0.000 *
SIH Type-non-core: Auxiliary-Uncorrect	-7.854	2.964	1077.400	-2.650	0.008
Region 4: (first pass) Regression out probability					

	β	*SE*	*Z*	*p*
Intercept	-2.322	0.372	-6.232	0.000 *
Auxiliary-Uncorrect	0.71391	0.143	4.963	0.000*
Log-length (characters)	0.10403	0.036	2.839	0.004 *
Region 4: Regression out full probability				
	β	*SE*	*Z*	*p*
Intercept	-1.744	0.340	-5.118	0.000 *
Auxiliary-Uncorrect	0.64668	0.133	4.833	0.000*
Log-length (characters)	0.09757	0.033	2.917	0.003 *

Note: Only best fitting models shown. All the factors were coded using treatment coding. The correct auxiliary, core auxiliary, animate argument, and unaccusative verb were used as the reference levels (0) for the auxiliary, SIH type, animacy and verb factors respectively. Significant effects at a $p \leq .05$ level are marked with a *.

Table 2. Summary of the best-fitting models in the unaccusative data-set.

Region 3: Total Reading Time

	β	*SE*	*df*	*t*	*P*
Intercept	44.064	3.189	61.700	13.819	0.000 *
SIH Type-non-core	8.864	2.768	527.200	3.202	0.001*
Auxiliary-Uncorrect	17.043	2.768	527.200	6.158	0.000*
SIH Type-non-core: Auxiliary-Uncorrect	-11.972	3.901	525.800	-3.069	0.002*

Region 4: (first pass) Regression out probability

	β	*SE*	*Z*	*p*
Intercept	-1.1370	0.176	-6.445	0.000 *
Auxiliary-Uncorrect	0.4968	0.206	2.401	0.016*

Region 4: Regression out full probability

	β	*SE*	*Z*	*p*
Intercept	-0.6131	0.173	-3.542	0.000 *
Auxiliary-Uncorrect	0.4433	0.206	2.147	0.031*

Region 4: Regression out full count

	β	*SE*	*df*	*t*	*P*
Intercept	0.4275	0.062	24.606	6.893	0.000 *
Auxiliary-Uncorrect	0.1415	0.062	16.577	2.285	0.036*

Note: Only best fitting models shown. All the factors were coded using treatment coding. The correct auxiliary and core auxiliary were used as the reference levels (0) for the auxiliary and SIH type factors respectively. Significant effects at a $p \leq .05$ level are marked with a *.

Table 3. Summary of the best-fitting models in the unergative data-set.

Region 2: Total Reading Time

	β	*SE*	*df*	*t*	*p*
Intercept	30.489	6.287	17.570	4.849	0.000 *
Animacy-Inanimate	12.990	3.261	14.889	3.983	0.001*
Log-length (characters)	2.1697	0.459	14.731	4.719	0.000*

Region 2: First Pass Reading Time

	β	*SE*	*df*	*t*	*p*
Intercept	71.578	3.978	25.352	17.995	0.000 *
Animacy-Inanimate	10.671	4.884	16.051	2.185	0.044*

Region 3: Total Reading Time

	β	*SE*	*df*	*T*	*P*
Intercept	52.315	3.388	47.300	15.441	0.000 *
SIH Type-non-core	3.957	3.059	41.400	1.293	0.203
Auxiliary-Uncorrect	13.918	2.747	493.900	5.066	0.000*
SIH Type-non-core: Auxiliary-Uncorrect	-9.243	3.882	494.900	-2.381	0.017*

Region 3: Regression out full probability

	β	*SE*	*Z*	*P*
Intercept	-1.1317	0.236	-4.795	0.000 *
Animacy-Inanimate	0.2107	0.280	0.752	0.451
SIH Type-non-core	0.5663	0.273	2.074	0.038*
Animacy-Inanimate:SIH Type-non-core	-0.7893	0.393	-2.005	0.045*

Region 4: Total Reading Time

	β	*SE*	*df*	*T*	*P*
Intercept	50.461	2.887	32.310	17.481	0.000 *
Auxiliary-Uncorrect	9.922	2.612	16.970	3.798	0.001*

Region 4: (first pass) Regression out probability

	β	*SE*	*Z*	*P*
Intercept	-1.5673	0.203	-7.708	0.000 *
Auxiliary-Uncorrect	0.8747	0.230	3.794	0.000*

Region 4: Regression out full probability

	β	*SE*	*Z*	*P*
Intercept	-1.0699	0.165	-6.449	0.000 *
Auxiliary-Uncorrect	0.8024	0.233	3.433	0.000*

Region 4: Regression out full count

	β	*SE*	*df*	*T*	*P*
Intercept	0.2836	0.047	35.630	5.990	0.000 *
Auxiliary-Uncorrect	0.3347	0.062	57.920	5.372	0.000*

Note: Only best fitting models shown. All the factors were coded using treatment coding. The correct auxiliary, core auxiliary and animate argument were used as the reference levels (0) for the auxiliary, SIH type and animacy factors respectively. Significant effects at a $p \leq .05$ level are marked with a *.

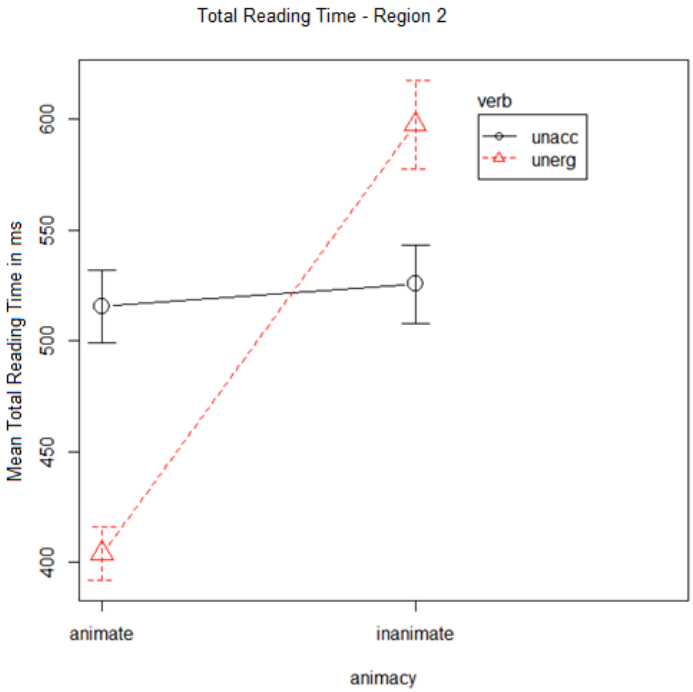

Figure 1. Mean total reading time in region 2 as a function of Animacy x Intransitive Type. Error bars refer to the Standard Error of the Mean.

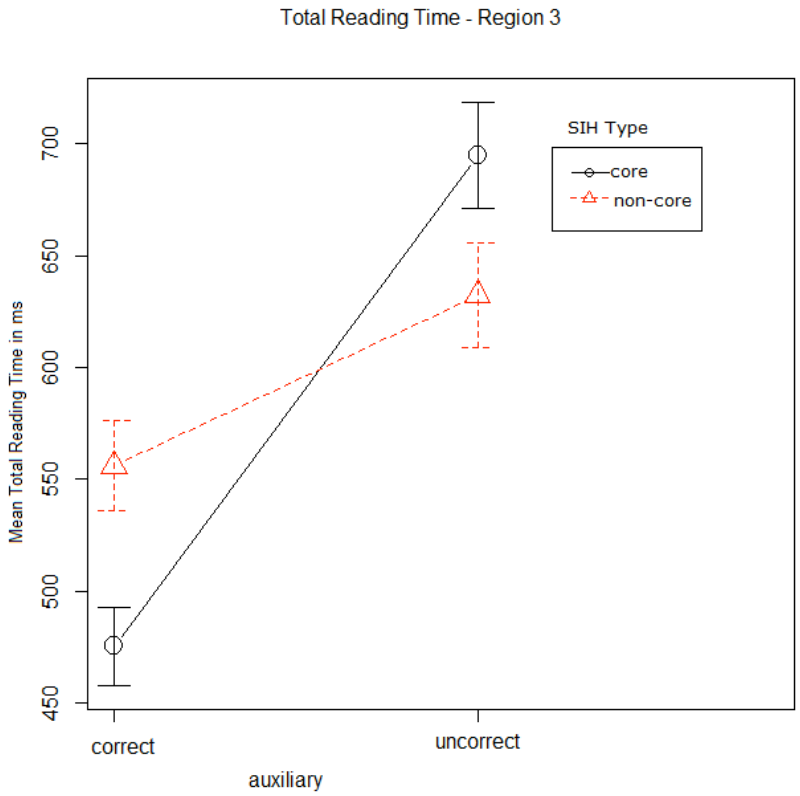

Figure 2. Mean total reading time in region 3 as a function of SIH type and Auxiliary. Error bars refer to the Standard Error of the Mean.

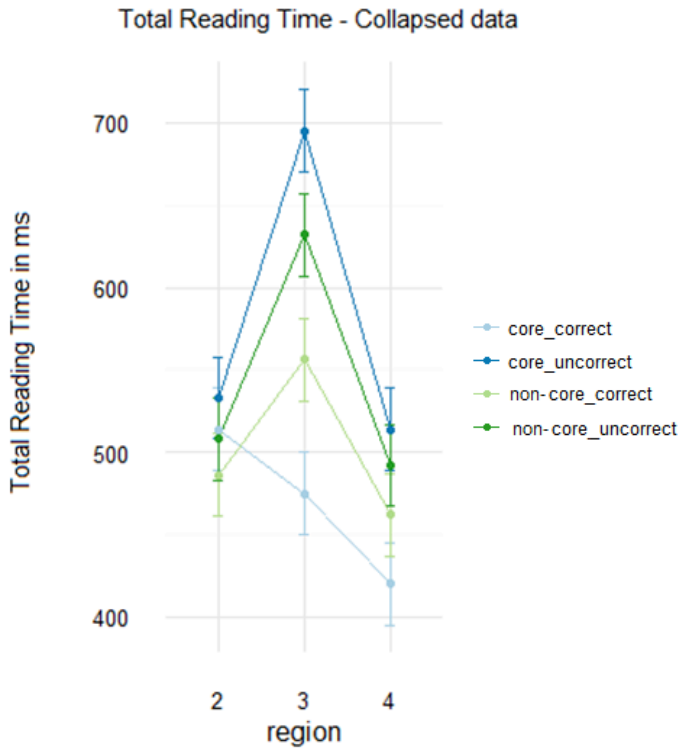

Figure 3. The graph represents the mean total reading time in regions 2, 3 and 4 as a function of SIH type and auxiliary for the collapsed data. Error bars refer to the Standard Error of the Mean.

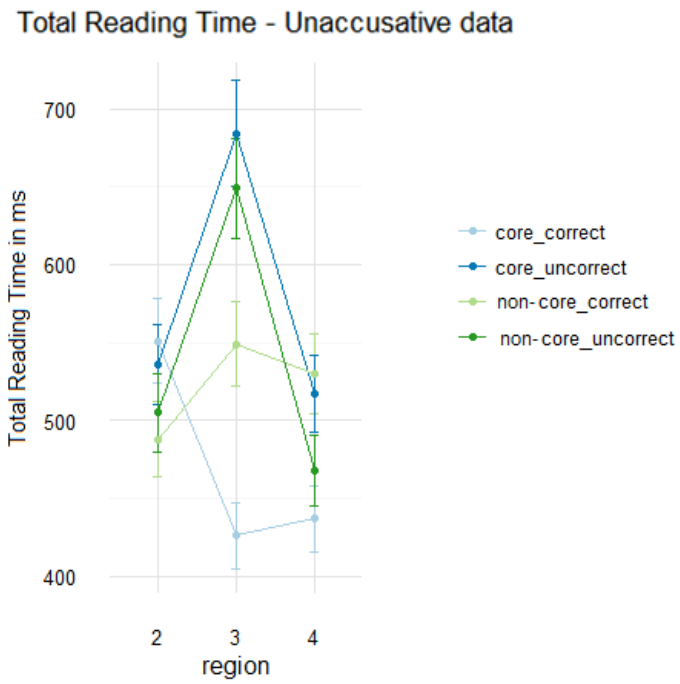

Figure 4. The graph represents the mean total reading time in regions 2, 3 and 4 as a function of SIH type and auxiliary for the unaccusative sub-set of data. Error bars refer to the Standard Error of the Mean.

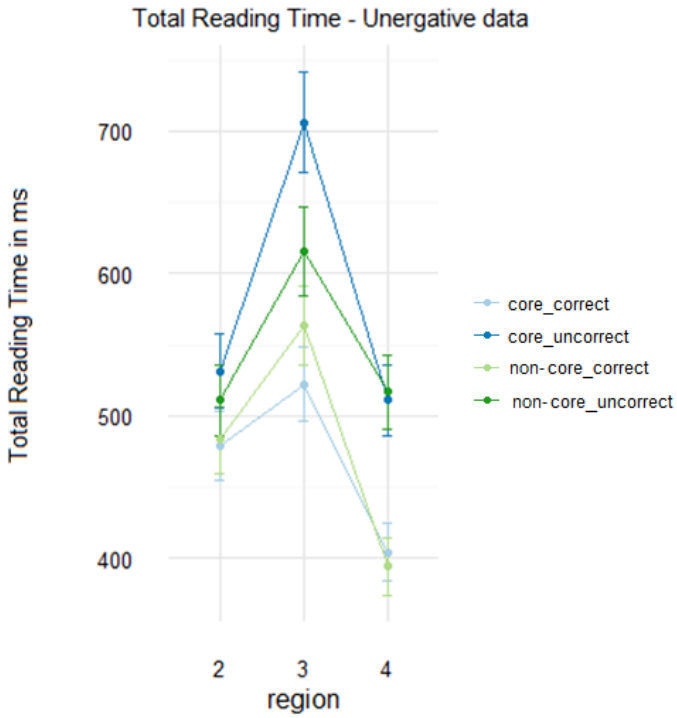

Figure 5. The graph represents the mean total reading time in regions 2, 3 and 4 as a function of SIH type and auxiliary in the unergative sub-set of data. Error bars refer to the Standard Error of the Mean.