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Unaccusativity in Sentence Production

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Linguistic analyses suggest that there are two types of intransitive verbs: unaccusatives, whose sole argument is a patient or theme (e.g., *fall*), and unergatives, whose sole argument is an agent (e.g., *jump*).[1] Past psycholinguistic experiments suggest that this distinction affects how sentences are processed: for example, it modulates both comprehension processes (Bever and Sanz 1997, Friedmann et al. 2008) and production processes (Kegl 1995, Kim 2006, J. Lee and Thompson 2004, M. Lee and Thompson 2011, McAllister et al. 2009). Given this body of evidence, it is reasonable to assume, as we do here, that this distinction is directly relevant to psycholinguistic theorizing. However, especially in production, exactly *how* this distinction affects processing is unknown, beyond the suggestion that unaccusatives somehow involve more complex processing than unergatives (see M. Lee and Thompson 2011). Here we examine how real-time planning processes in production differ for unaccusatives and unergatives. We build on previous studies on lookahead effects in sentence planning that show that verbs are planned before a deep object is uttered but not before a deep subject is uttered (Momma, Slevc, and Phillips 2015, 2016). (We use terms like *deep subject* in a theory-neutral fashion, with no intended commitment to a specific syntactic encoding.) This line of research sheds light on the broader issue of how the theory of argument structure relates to sentence production.

1 Unaccusativity and the Timing of Verb Planning in Sentence Production

The Unaccusative Hypothesis claims that the subject of an unaccusative verb originates as the object of the verb (e.g., Burzio 1986, Perlmutter 1978). Supporting this hypothesis, a range of linguistic phenomena, including *ne*-cliticization and auxiliary selection in Italian (Burzio 1986), English resultatives (Levin and Rappaport Hovav 1995), and possessor datives in Hebrew (Borer and Grodzinsky 1986), suggest that the subjects of unaccusative verbs behave like objects. Reflecting this object-like nature of unaccusative subjects, in transformational theories such as Government-Binding Theory (Chomsky 1981) unaccusative subjects are considered to be base-generated in the object position and moved to the subject position (e.g., Burzio 1986).

Recent studies on the time course of sentence planning suggest that speakers plan verbs (specifically, verbs' lemma representations; Kempen and Huijbers 1983; see Levelt, Roelofs, and Meyer 1999 for a detailed review) before they articulate a deep object, but not before they articulate a deep subject.[2] These studies support an intermediate position between production models that assume that verbs must be planned before all arguments (e.g., Bock and Levelt 1994) and models that assume

that no advance verb planning is needed (e.g., Schriefers, Teruel, and Meinshausen 1998). Specifically, we have shown (Momma, Slevc, and Phillips 2016) that verbs are planned before the object noun is uttered but not before the subject noun is uttered in Japanese active sentences. Similarly, we have shown that verbs are planned before subject nouns are uttered in passive but not in active sentences in English (Momma, Slevc, and Phillips 2015). These studies together suggest that verbs are planned before a deep object, regardless of case marking/grammatical function or whether a noncanonical word order is involved. This finding makes an interesting prediction about the production of intransitive sentences. If unaccusative subjects are deep objects, unlike unergative subjects, then unaccusative sentences but not unergative sentences should require advance planning of the verb before the subject noun is articulated. If this prediction is correct, it would show that the subject of unaccusative sentences is processed like a deep object in sentence production, and that split intransitivity directly affects the time course of speaking.

One way to study the timing of verb planning in sentence production is to use the extended picture-word interference paradigm (Meyer 1996, Momma, Slevc, and Phillips 2015, 2016, Schriefers, Teruel, and Meinshausen 1998). In an extended picture-word interference experiment on verb planning, participants describe pictures depicting an action/event in sentential form. At the same time as they see each picture, or slightly before/after, they also see or hear a distractor word. This distractor word is sometimes semantically related to the target verb, which could cause interference in verb processing.[3] This interference can delay verb-related computation, specifically lemma retrieval, which surfaces as a delay in production. (Interference is always measured by comparison with an unrelated distractor word.) The critical question is when this interference effect is observed. If it delays the onset of the subject noun, one can infer that the verb's lemma is planned (i.e., retrieved in advance) before the subject noun is uttered. This pattern would demonstrate that some computation involving the verb's lexical representation is performed before the subject noun is uttered. On the other hand, if an interference effect is observed after the onset of the subject noun, one can infer that the verb is planned after the subject noun is sent for articulation, suggesting that no computation involving the verb's lexical representation is performed before the subject noun is uttered. Therefore, the timing of verb-related interference is informative about what kinds of computations are involved in the production of verbs' arguments. In the current study, we used extended picture-word interference to specifically examine the timing of verb planning in unaccusative and unergative sentences.

2 Experiment

2.1 Participants

Twenty-four native speakers of English participated for either class credit or monetary compensation.

2.2 Materials and Design

Twenty-four pictures of events were selected. Half corresponded to unergative verbs (e.g., *sleep*), and half corresponded to unaccusative verbs (e.g., *float*); see the example in figure 1. The participants of the events corresponding to the unergative verbs were all animate, but half of the participants of the events corresponding to the unaccusative sentences were inanimate. This imbalance in the number of animate subjects in unergative vs. unaccusative conditions was due to the practical difficulty of drawing a picture in which animate participants undergo the action denoted by certain unaccusative verbs (e.g., *melt*). The six animate participants in the unaccusative pictures were exactly matched to the six animate participants in the unergative pictures.

This identical subset of nouns was used to test whether any difference between unaccusative and unergative conditions could be attributed solely to the difference in verbs. A full list of target sentences and distractors can be found in appendix 1 (available online at http://www.mitpressjournals.org/doi/suppl/10.1162/ling_a_00271). Also, for each verb, we applied five different tests for unaccusativity, and the results of these tests are reported in appendix 2 (available online at the same address).

For each picture, a semantically related distractor verb was selected from the set of target verbs for the other pictures. These distractors always corresponded to one of the other target verbs to maximize the chance of obtaining an interference effect (Roelofs 1992). Semantic relatedness was estimated on the basis of the cosine distance measure from latent semantic analysis (Landauer and Dumais 1997). This measure reflects how close two words are in a multidimensional semantic space with values ranging from 0 to 1. As a point of reference, the clearly related pair *cat* and *dog* receives a value of .36, while the pair *cat* and *desk* receives a value of .01. The average cosine distance between each target verb and its related distractor verb was .31 for the unergative verbs and .35 for the unaccusative verbs, values that did not differ significantly ($p > .5$). Each related distractor word was re-paired with a picture from the same verb type to create the unrelated picture-distractor pairs. The average cosine distance between each target verb and its unrelated distractor verb was .08 for the unergative verbs and .14 for the unaccusative verbs. Unsurprisingly, there was a significant difference in the cosine distance between related and unrelated pairs, both with unergative verb pairs ($p < .001$) and with unaccusative verb pairs ($p < .001$). Importantly, the mean cosine distance between the related and unrelated pairs differed by .23 for unergative verbs and by .21 for unaccusative verbs, so the relatedness manipulation was comparable for the two verb types.

In sum, the current study had a 2×2 within-subjects design, with Verb Type (unergative vs. unaccusative) as a between-items factor and Relatedness (related vs. unrelated) as a within-items factor. There were 24 filler trials where distractors were replaced with ''xxxx''. In total, there were 72 trials, and participants saw each picture three times: once with a related distractor, once with an unrelated distractor, and once as a filler with xxxx. Note that this number of repetitions is many fewer than in some previous picture-word interference studies (e.g., Schriefers, Meyer, and Levelt 1990).

2.3 Procedure

Participants were first familiarized with the pictures and the target sentences corresponding to each picture, until they felt comfortable with each picture and sentence. This familiarization session was used in order to increase the accuracy and reaction time stability of their production, and it is a standard procedure in picture-naming studies (e.g., Schriefers, Teruel, and Meinshausen 1998).

The experimental session directly followed this familiarization session. Participants were instructed to ignore the written distractor word (in red font) on top of the picture and to describe the picture in sentential form (in present progressive) as soon as they could, except when they saw xxxx as a distractor. When they saw xxxx, they were instructed to not describe the picture and instead press the spacebar. This prevented them from visually ignoring the distractor, thereby ensuring that the distractor words were processed at least to the extent that they could be distinguished from xxxx. On each experimental trial, the participant saw a fixation cross at the center of the screen for 750 ms. Then, a distractor verb (equally often related or unrelated to the target verb) or xxxx appeared at the center of the screen in red font for 500 ms. A short time (150 ms) following the appearance of the distractor, a picture from the studied set appeared on the screen for 1,500 ms. A blank screen, shown for 2,000 ms, separated the

trials. Two values were measured manually using Praat (Boersma and Weenink 2015): the time from picture onset to utterance onset, and the duration of the subject noun head and following auxiliary verb *is*. These measures were log-transformed and submitted to statistical analysis.

2.4 Results

The results for onset latencies are summarized in table 1 and figure 2 (left) and the results for duration in table 2 and figure 2 (right). A mixed-effects model with maximal random effects structure in the sense of Barr et al. 2013 was constructed. For the model of subject noun duration, the number of syllables of the noun was included as a predictor.

The model of onset latency revealed a main effect of Relatedness ($\beta = -0.07$, $SE = 0.02$, $|t| = 3.42$, $p < .01$), but no main effect of Verb Type. The interaction between Verb Type and Relatedness was significant ($\beta = 0.06$, $SE = 0.03$, $|t| = 2.08$, $p < .05$). Following planned comparisons revealed that distractor relatedness affected onset latency in unaccusative sentences ($t1(23) = 4.56$, adj. $p < .001$; $t2(11) = 2.92$, adj. $p < .05$) but not in unergative sentences ($t1(23) = 0.11$; adj. $p = .9$; $t2(11) = 0.71$, adj. $p > .9$).

In contrast, the duration measure showed a significant interaction in the opposite direction ($\beta = -0.05$, $SE = 0.02$, $|t| = 2.58$, $p < .01$), with no main effect of Verb Type or Relatedness. The number of syllables in the preverbal noun was also significantly related to duration ($\beta = 0.12$, $SE = 0.03$, $|t| = 4.24$, $p < .001$), but did not interact with Verb Type. Planned comparisons revealed that participants lengthened the utterance of the subject in unergative sentences ($t1(23) = 2.85$, adj. $p < .01$; $t2(11) = 3.18$, adj. $p < .05$) but not in unaccusative sentences ($t1(23) = -0.6$, adj. $p > .9$; $t2(11) = -0.88$, adj. $p > .8$).

To ensure that these effects were not due to idiosyncratic differences between items,[4] a secondary analysis examined the subset of 12 items that elicited exactly the same set of animate subject nouns in the unergative and unaccusative conditions. This yielded the same qualitative pattern of results: a greater onset interference effect for unaccusatives than unergatives (60 ms vs. 21 ms), and a greater duration interference effect for unergatives than unaccusatives (23 ms vs. -14 ms).

A potential concern is that any difference in semantic relatedness between the target nouns and distractor verbs across conditions might have confounded the results. For instance, if the target noun *doctor* and the related verb distractor *drown* (unaccusative) are more closely related than the target noun *doctor* and the unrelated verb distractor *burn* (unergative), the effects reported above could reflect an interference effect on noun retrieval rather than on verb retrieval. To address this concern, we conducted a post-hoc analysis on relatedness measures between target nouns and distractor verbs, using cosine distance values derived from latent semantic analysis (Landauer and Dumais 1997). In the unaccusative conditions, the mean cosine distance (*SEM*) was 0.14 (0.03) in the related condition and 0.10 (0.05) in the unrelated condition ($p > .5$). In the unergative conditions, the mean cosine distance was 0.13 (0.03) in the related condition and 0.09 (0.03) in the unrelated condition ($p > .3$). Thus, in both cases, cosine similarity between verb distractors and nouns was 0.04 higher in the related than the unrelated condition. This small difference in relatedness was not statistically reliable ($p > .3$) and, more importantly, was identical for the unaccusative and unergative verb conditions. Furthermore, when these cosine distance values were incorporated into the mixed-effects models for the onset data reported above, semantic relatedness did not interact with Relatedness, Verb Type, or the Relatedness by Verb Type interaction (all ps $> .35$). Thus, lexical relatedness between the target

nouns and distractor verbs, at least as reflected in latent semantic analysis, cannot account for the key finding of our study.

A similar potential concern is that semantic relatedness between target nouns (e.g., *doctor*) and target verbs (e.g., *float*/*sleep*) might create some unintended interference, and, if this differs across verb types, might lead to the contrasting pattern of interference reported above. To address this concern, we measured the relatedness (again via cosine distances using latent semantic analysis) between target nouns and target verbs. Target nouns and verbs were somewhat related: the average cosine distance was 0.25 ($SEM = 0.06$) in the unaccusative conditions and 0.20 ($SEM = 0.06$) in the unergative conditions; however, this difference was far from significant ($p > .5$). Additionally, when target noun/verb relatedness was incorporated into the mixed-effect models reported above, it did not interact with the effect of Relatedness between distractor and target verbs ($p > .5$). Thus, we find no evidence that the pattern of semantic interference reported here is attributable to semantic relationships between target nouns and target verbs or between target nouns and distractor verbs.

3 Discussion

Given past evidence that verbs must be planned before a deep object is uttered but not before a deep subject is uttered, the current study examined the processing consequences of the Unaccusative Hypothesis. As predicted, verb interference was found before subject onset in unaccusative sentences, but during subject articulation in unergative sentences (figure 3). This suggests that verbs are indeed planned before the utterance of subject nouns in unaccusative sentences, but during the utterance of subject nouns in unergative sentences. Thus, we conclude that the unaccusative unergative distinction is realized by the producer, and that this distinction is reflected in the selective advance planning of verbs in unaccusative sentences.

The selective advance verb planning in unaccusative sentences is naturally explained if the subject of unaccusative sentences is like an object at some level of representation. This is because advance verb planning has been selectively found before direct object nouns in Japanese sentences and before the subject in English passive sentences, but not before the subject in Japanese sentences or before the subject in English active sentences (Momma, Slevc, and Phillips 2015, 2016).

3.1 Relation to Previous Production Research on Unaccusativity

Unaccusativity in sentence production has been mainly studied in the context of agrammatic aphasia (Kegl 1995, J. Lee and Thompson 2011, M. Lee and Thompson 2004, McAllister et al. 2009, Thompson 2003). These studies tested whether producing unaccusative as compared to unergative sentences leads to increased difficulty (and hence increased error rates). In general, unaccusative sentences do seem to be more difficult than unergative sentences for people with agrammatic aphasia in both natural speech (Kegl 1995) and elicited speech (M. Lee and Thompson 2004), although results are not entirely consistent across speech elicitation methodologies (J. Lee and Thompson 2011). Notably, however, little work has investigated the production of unaccusative vs. unergative sentences by healthy speakers.[5] One exception is a study by Kim (2006), who found that unaccusative sentences prime passive sentences. This suggests that some representation or process is shared between unaccusative and passive sentences, such as a shared movement operation. The current study goes beyond these earlier findings in that it tells specifically how unaccusative and unergative sentences are processed differently in speaking.

Some might argue that the current results do not necessarily show that verbs *must* be planned before unaccusative subject nouns are uttered. Some studies find that perceptual factors modulate structural

choice (e.g., passives are more likely to be produced when patient entities are visually cued; Gleitman et al. 2007), at least when the depicted events are difficult to name (van de Velde, Meyer, and Konopka 2014). This type of data is often cited as support for *linearly incremental* production (e.g., Bock and Ferreira 2014), in which there is little or no planning beyond the first constituent or word at sentence onset. By this view, verb planning might not be necessary to produce passive and unaccusative sentence subjects. However, evidence that visual cuing affects structural choice does not necessarily imply an absence of advance planning beyond the first noun phrase. Indeed, Gleitman et al. (2007) also showed that passive utterances took longer to initiate than active utterances, even with perceptual priming of the patient/theme entity. This suggests that speakers do not simply start articulating patient nouns when they are perceptually more available. Instead, even if the first word of the sentence is determined on the basis of its perceptual availability, some additional computations are performed before it is articulated. These computations might well involve advance planning of the verb to establish some syntactic/semantic relation for its internal argument, as proposed here. Thus, the existing evidence is compatible with the strong interpretation of the current results and, until it is disproven, we maintain this strong, more readily falsifiable hypothesis that verbs must be planned before internal arguments can be uttered.

3.2 Unaccusativity, Argument Structure, and Sentence Production

The question remains: why is the verb selectively planned before a deep object is uttered? One reasonable explanation is that some computation that is needed to retrieve the lemma of an internal argument noun, or to assign some syntactic/semantic status to deep object nouns after lemma retrieval, depends on the lexical representation of the verb. Although we cannot rule out a contribution from noncanonical thematic-to-syntactic mappings in the current study, we have found advance verb planning before canonical objects in Japanese (Momma, Slevc, and Phillips 2016), which is unlikely to be due to computations involved in establishing a noncanonical mapping between thematic roles and grammatical functions. Also, given that advance verb planning was found in unaccusative sentences in the current study and in English passive sentences (Momma, Slevc, and Phillips 2015), the current effect is not likely due to computations related to accusative case assignment.

The remaining candidates include (a) phrase structure building for the underlying object position and/or (b) assignment of internal argument roles. Both candidates have to do with the role of the argument structure of verbs in sentence production, at either the syntactic or the semantic level. The first possibility relates to the claim that the phrase structure for a VP depends on the lexical properties of the verb (i.e., subcategorization) that are not deducible from the conceptual representation alone (Grimshaw 1990).[6] Under this view, a nonlinguistic message-level representation is sufficient for incorporating external arguments into the sentence structure, but lexical representations of verbs are necessary for incorporating internal arguments into the structure. The second possibility is that the difference in thematic roles between external and internal arguments is the key contrast. This account is in line with Kratzer's (1996) linguistic analysis of argument-predicate relationships, according to which only the internal arguments are true arguments of verbs. Under this view, the assignment of an argument role to the object might selectively require selecting a specific verb, while the assignment of an agent/causer argument role to an external argument might be done independently from the lemma of the verb head. In other words, the nonlinguistic message is sufficient

to assign a thematic role to the external argument without the involvement of the verb lemma. In contrast, the verb lemma is necessary to assign thematic roles to the internal arguments.

Future studies should aim to distinguish between these possibilities. For instance, as a reviewer suggests, there are some classes of unergative verbs—namely, *internally caused verbs*—that take a theme as their sole argument (e.g., *glow* and *sparkle*). To the extent that these verbs are actually unergative syntactically, comparing the verb planning of theme unergative and unaccusative sentences could reveal whether the effects reported here are due to thematic or syntactic differences. More broadly, the current paradigm can be extended to other classes of verbs that have been the center of attention in argument structure research, such as psych verbs (Belletti and Rizzi 1988), verbs that take instrumental subjects, and other types of unaccusative verbs that do not alternate (Levin and Rappaport Hovav 1995). Given these prospects, we hope that the current study opens up opportunities for developing a line of research that will inform how theories of argument structure relate to theories of sentence production.

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[1] Some have claimed that unaccusative verbs that can participate in a transitive alternation are not truly unaccusative verbs, suggesting that the subject of those alternating verbs does not undergo movement and instead is base-generated in the subject position (Haegeman 1994). We acknowledge that some evidence suggests that this distinction may have some processing consequence. However, the evidence is equivocal at best (see Friedmann et al. 2008). Hence, we adopt here the more common view that both alternating and nonalternating verbs are unaccusative verbs (e.g., Perlmutter 1978).

[2] Most prominent models of sentence production (e.g., Garrett 1975, Bock and Levelt 1994, and their more recent variants) divide structure building into two processes: functional (i.e., assignment of grammatical function) and positional (i.e., assignment of hierarchical and/or linear position). Although one might ask which of these processes is responsible for advance verb planning before deep objects, the current findings do not distinguish these alternatives.

[3] By *verb*, we specifically refer to the verb root. We remain agnostic about whether the inflectional component of a verb is planned together with the verb root or not.

[4] We conducted this analysis because animacy is sometimes argued to be used for assigning grammatical functions (e.g., Branigan, Pickering, and Tanaka 2008). To the extent that advance verb planning occurs because of grammatical function assignment, it is possible that animacy might change the time course of verb planning (e.g., subject function assignment might require verbs only when the noun head is inanimate).

[5] J. Lee and Thompson (2011) also investigated healthy participants' production of unaccusative verbs with a task in which participants produced unergative (*The black dog is barking*) vs. unaccusative (*The black tube is floating*) sentences by rearranging written words on a screen. Using eye-tracking, they found that healthy participants fixated on the noun more than the adjective when producing the noun in unaccusative sentences but not in unergative sentences. They used this finding to argue that unaccusative sentences are processed more sequentially. We do not think, however, that this result is informative about how unaccusative sentences are processed differently from unergative sentences: the observed contrast is not motivated by a model of production, since the unergative sentences showed numerically the same pattern and no interaction analysis was reported, and since the written-word-rearranging task does not engage normal production processes.

[6] We assume that conceptual representation is equivalent to nonlinguistic representation of a message, which is assumed to be the starting point of production in many production models (e.g., Bock and Levelt 1994).

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Figure 1
Example pictures for unergative sentences (left: *The doctor is sleeping*) and unaccusative sentences (middle: *The doctor is floating*), and example picture with superimposed distractor (right: either a related distractor (e.g., *drown*), an unrelated distractor (e.g., *burn*), or (as shown here) xxxx).

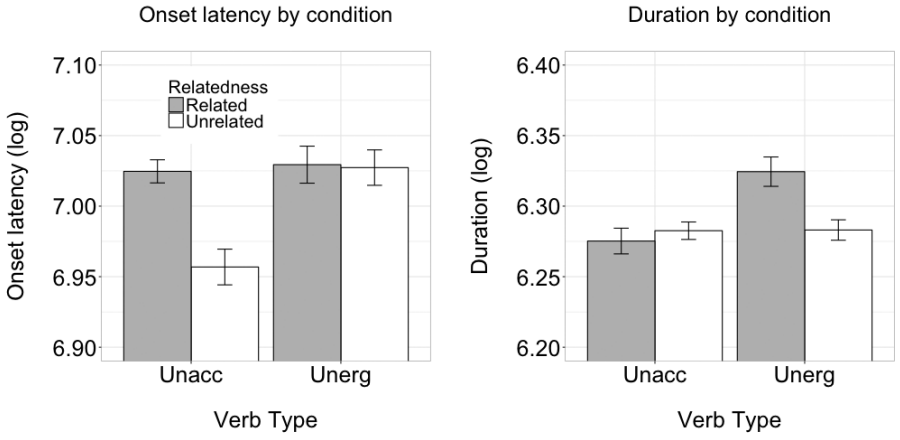

Figure 2
Mean speech onset latency (left) and duration (right) by each condition (log-transformed), with associated within-subject standard errors

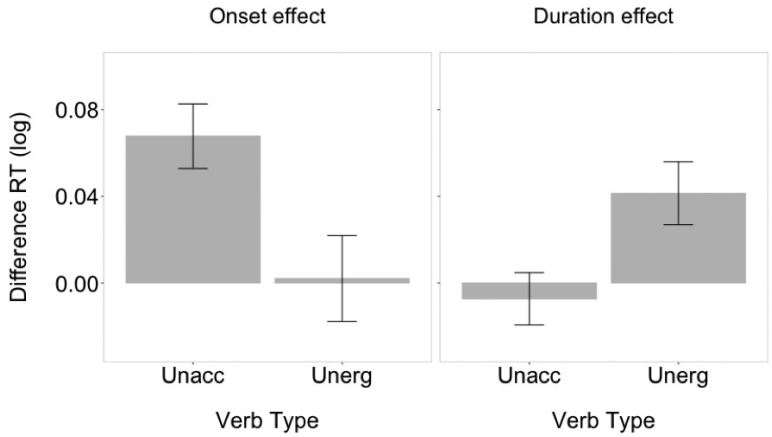

Figure 3
Effect of verb associates (related-unrelated) on subject NP onset latency (left) and duration (right). (RT = response times, in ms)

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Table 1
Mean speech onset latency for each condition, with within-subject standard errors (calculated according to Morey 2008) in square brackets

	Mean latency		Onset interference effect
	Related	Unrelated	(Related-Unrelated)
Unaccusative	1,161 [11]	1,083 [15]	78
Unergative	1,176 [18]	1,171 [16]	5

Table 2
Mean subject noun + auxiliary verb articulation duration for each condition, with within-subject standard errors (calculated according to Morey 2008) in square brackets

	Man duration		Duration interference effect
	Related	Unrelated	(Related-Unrelated)
Unaccusative	548 [6]	551 [4]	−3
Unergative	584 [7]	553 [4]	31