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Animacy and Intransitivity in Sentence Processing

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ANIMACY AND INTRANSITIVITY IN SENTENCE PROCESSING

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Abstract

The distinction between animate and inanimate objects is essential to many cognitive tasks. Research has shown distinct patterns of memory, attention, and language response to animate and inanimate objects. This dissertation examines the effects of noun animacy on sentence processing. I report three psycholinguistic experiments on intransitive constructions, testing how animate and inanimate nouns influence expectations for an intransitive clause. Intransitive verbs fall into types based on thematic role. Unergative verbs assign an Agent role. Unaccusative verbs assign a Theme/Patient role, although a subclass of unaccusative verbs can alternate between intransitive constructions with a Theme/Patient subject and transitive constructions with an Agent subject and Theme/Patient object. Agent roles are active and intentional, corresponding to animate nouns, and Theme/Patient roles are nonvolitional and passive, corresponding to inanimate nouns. I hypothesized that reading sentences with an unexpected intransitive clause (i.e., garden-path sentences) would be easier when animacy and thematic roles matched. Our findings suggest that animacy-thematic associations influence readers' expectations for an intransitive clause structure. A corpus-based analysis suggests that individual verb biases for inanimate or animate subject nouns modulate these expectations.

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Chapter 1: Introduction

In this dissertation, we examine the effects of noun animacy on early closure garden-path sentences. Early closure garden-path sentences result when, during the incremental reading of a sentence, new words are encountered that cannot fit into the current clause. These constructions are associated with disruption at the word that follows the finished clause. Conversely, there are late closure garden-path sentences, where a structurally ambiguous word could plausibly be part of an ongoing clause during reading and is interpreted as such. Later in the sentence, the readers are forced to revise their interpretation, as in the famous garden-path sentence, "The horse raced past the barn fell over" (Bever, 1970). Both types of garden-path sentences have been theorized to result from pressure on language processing to be parsimonious. Therefore, readers always initially attempt an interpretation containing the smallest number of clauses, leading to disruption for early closure garden-path sentences and disruption and revision for late closure garden-path sentences. To meet the speed and automaticity requirements of language processing, researchers have argued readers ignore semantic features of words beyond their syntactic category, leading to these two patterns of disruption (e.g., van Gompel & Pickering, 2001).

One well-known type of garden-path sentence relies on an expectation of transitivity (1a, 1b). For example, at the phrase "was sitting" in 1a below, reading is disrupted due to a late closure garden-path effect. "The baby" is initially taken as an object of the verb "bathe," and the revision must occur at the following verb, or readers

will abandon parsing the sentence. In 1b below, there is disruption at the phrase "the baby," as a result of an early closure garden-path effect (Clifton, 1993; van Gompel & Pickering, 2001). Therefore, optionally transitive verbs lead to late closure garden-path effects, and intransitive verbs lead to early closure garden-path effects.

1a. *As the nurse bathed the baby was sitting in the front room.*

1b. *As the nurse arrived the baby was sitting in the front room.*

Two issues with this garden-path framework arise. First, the lack of a comma may be responsible for both late and early closure garden-path effects. Our focus here is early closure garden-path sentences, and some research has been done that suggests early closure effects are, in fact, due to the anomalousness of a clause ending without a comma (Staub, 2007). In line with this finding, we look at early closure garden-path effects as readers failing to expect and rapidly identify the end of one clause and the beginning of a new clause in the absence of punctuation. The second issue that arises is the fact that intransitive verbs are not a unitary group. Intransitive verbs are typically divided into unaccusative verbs and unergative verbs (Levin, Rappaport-Hovav, & Keyser, 1995). They differ in terms of the thematic role they assign their subject.

Thematic roles are the semantic role that a noun plays in the event/argument structure of a verb, which is frequently broadly limited to Agent, Theme, Recipient, Experiencer, Location, and Goal (e.g., Jackendoff, 1987). Other approaches reduce thematic roles to individual proto-features of Agent (the "doer") and Theme (the "done to"; Dowty, 1991). Thematic roles denote the interactional or spatial positions of the referents of nouns involved in the event structure that a verb describes.

Unergative verbs, like “smile,” “laugh,” and “jump,” assign their subject an Agent role. Through its own internal capability or force, the subject can perform the action involved by the verb. Unergative verbs sometimes have a potential transitive form with a cognate object like, for example, “laugh a laugh” or “smile a smile.” Unergative verbs generally prefer an animate subject or can only be interpreted with inanimate subjects through a metaphorical agentive sense (e.g., “the engine growled” or “the echoes laughed”).

Unaccusative verbs, like “fall,” “appear,” and “arrive,” denote an event where the referent of the subject noun is a Theme, the thing to which something happened. Unaccusative verbs can have either animate or inanimate nouns as their subject. However, individual verbs vary in how selective they are about subject nouns. For example, some unaccusative verbs such as “glow” or “exist” are more likely to appear with inanimate subjects, while others such as “arrive” or “die” more frequently appear with animate subjects. Becker (2013) theorized that unaccusative verbs, like “tough”-constructions and raising verbs, are associated with inanimate subject nouns in language acquisition because Theme-assigning constructions are conceptually more consonant with inanimacy. Nonetheless, some unaccusative verbs can appear in transitive clauses, in which the subject noun now acts as an Agent and the object noun as a Theme. Garden-path sentences with these verbs have been shown to be sensitive to subject animacy (e.g., Clifton, 1993).

It has been argued that unaccusative verbs are more syntactically complex than unergative verbs. Because the Theme of a verb originates in the verb phrase and the Agent of a verb originates external to the verb phrase, syntactic theories have argued that

there is additional movement in unaccusative sentences over unergative (Perlmutter, 1980). Some typological evidence supports this, as, for example, languages like Spanish allow unaccusative subjects to either follow or precede the verb, but unergative subjects must precede the verb (Bever & Sanz, 1997). A good deal of experimental evidence also supports this claim, as unaccusative verbs have been shown to lead to greater activity in EEG studies (Shetreet, Freidmann, & Hadar, 2010), as well as fMRI studies (Meltzer-Asscher, Mack, Barbieri, & Thompson, 2015). Cross-modal lexical priming studies have shown unaccusative verbs trigger a delayed reactivation of the semantic content of the subject noun, while unergatives verbs do not trigger reactivation (Friedmann, Taranto, Shapiro, & Swinney, 2008). Importantly, early closure garden-path sentences with unaccusative verbs also show greater disruption than with unergative verbs (Staub, 2007; Dekydtspotter & Seo, 2017).

However, many of the studies demonstrating greater processing cost for unaccusative verbs used animate nouns as subjects. Some studies exclusively used animate subject nouns (e.g., van Gompel & Pickering, 2001; Dekydtspotter & Seo, 2017), while others used a mix of animate and inanimate nouns (e.g., Friedmann, Taranto, Shapiro, & Swinney, 2008; Koring, Max, & Reuland, 2012). Since there is a thematic-animacy match between unergative verbs and animate subjects, but a thematic mismatch between unaccusative verbs and animate subjects, it's possible that some of the findings demonstrating higher processing cost for unaccusative verbs are a result of a preference inanimate (rather than animate) nouns in a Theme role. A good deal of research already suggests that inanimate first nouns lead to disruption with action verbs (Lowder & Gordon, 2012) and unergative verbs (Vernice & Sorace, 2018) – i.e., when they are

assigned an Agent role. We ask whether there is also disruption when an animate first noun must be assigned a Theme/Patient role.

The effect of animacy on unaccusative verbs has not been tested thoroughly. In Italian, Vernice & Sorace (2018) found that unergative verb sentences were influenced by animacy-thematic mismatch, but unaccusative verbs were not. On the other hand, Koring, Max & Reuland (2012) found that a subtype of unaccusative verbs is processed like unergatives (i.e., with no additional reactivation of subject noun semantic material) in Dutch – but this subtype of unaccusatives a) has a strong bias to appear with inanimate subjects (e.g., "glow") and b) did only appear with inanimate subjects in their experiment. Thus, while it is fairly clear that inanimate initial nouns create reading difficulty when they must be assigned a Causative or Agentive role, it is still unclear whether animacy-thematic mismatch has the same effect on animate initial nouns that must be assigned a Theme role. Similarly, we might ask whether sentences where an initial noun is inanimate and then assigned a Theme role show facilitation through an animacy-thematic match effect.

In order to address this gap in the existing research, we performed two experiments using moving-window self-paced reading and a further experiment using corpus data. These experiments manipulated the animacy of the subject noun in early closure garden-path sentences, asking whether animacy-thematic mismatch may account for some of the disruption typically seen at the post-verbal noun in this garden-path framework. If so, animacy-thematic effects may also account for some of the apparent asymmetries in unaccusative and unergative sentence processing. Furthermore, we tested whether the animacy of the second noun in these constructions also influences garden-

path sentence processing, as animacy may be a cue that the noun is the subject of a new clause rather than a potential object noun. Chapters 2 through 4 of this dissertation present the methodology and results for each of these experiments in turn.

Chapter 2 reports an experiment comparing the effect of animacy-thematic mismatch on non-alternating unaccusative verbs, which only (or nearly only) appear in intransitive constructions, and on alternating unaccusative verbs, which can appear alternately in intransitive constructions (with a Theme subject) and transitive constructions (with an Agent subject and Theme object). Clifton (1993) showed that these alternating unaccusative verbs are influenced by subject noun animacy and that inanimate subjects led to an early closure garden-path effect, unlike animate subjects, which led to a late closure garden-path effect. We found that non-alternating unaccusative verb garden-path sentences did show animacy-thematic mismatch effects, with greater post-verbal disruption after animate subjects. Alternating unaccusative verbs showed a sensitivity to subject animacy that replicated the findings in Clifton (1993). Furthermore, inanimate subject noun sentences showed significantly less disruption when the second noun was animate, i.e., not only an implausible object noun but a plausible new-clause subject noun.

Chapter 3 reanalyzes the results of the experiment in Chapter 2 using corpus-derived probabilities for the animacy of the subject noun for each verb, and the probability, given the animacy of the subject noun, of a transitive construction. We extracted these probabilities from the *Penn Treebank Project* (Taylor, Marcus, & Santorini, 2003), tagging sentences individually for the probability of an animate or inanimate subject. The probability-based regression models fit the data from the

experiments better than the category-based regression models for early closure garden-path effects (i.e., immediately after the verb), but the category-based model fit the data better for late closure garden-path effects (i.e., at the disambiguating verb region). This finding suggests that early closure garden-path effects are influenced by verb-specific associations with noun animacy, while late closure garden-path effects are influenced by a categorical association between thematic role and animacy. Additionally, early closure garden-path effects (i.e., non-alternating unaccusative sentences) were not affected by animacy-thematic mismatch when probabilistic variables were controlled for. Instead, individual verbs with a high likelihood for an inanimate subject were influenced by animacy-thematic mismatch, but other verbs were not.

In Chapter 4, we report the effects of subject noun animacy on non-alternating unaccusative verbs and on unergative verbs in the same moving window self-paced reading design as Chapter 2. Though, rather than performing the experiment in-lab, as in Chapter 2, here, as a result of COVID-19 restrictions, the experiment was performed remotely through an online platform. Participants were recruited from the same university-based platform as in Chapter 2, from *Amazon Mechanical Turk*, and from two other sources. The university students showed the same pattern of results with animacy-thematic mismatch and non-alternating unaccusative verbs as was found in Chapter 2. Unergative verb sentences showed a similar pattern of animacy-thematic mismatch, although the effect appeared somewhat stronger and earlier. In the *Amazon Mechanical Turk* group, the results bore the same pattern for unaccusative and unergative sentences – although one region later than in the student group.

These experiments also had meaningful results for second noun animacy. In Chapter 2, we compared early and late closure garden-path sentences – with alternating unaccusative verbs, second noun animacy should influence reading by virtue of its plausibility as a transitive object, but with non-alternating unaccusative verbs, second noun animacy should influence reading by virtue of its plausibility as a new clause subject. In Chapter 4, the interpretation of second noun animacy is narrowed to the latter on the assumption that readers are responsive to the prototypical intransitivity of the verb. We found that animate nouns did appear to ease processing in early closure garden-path sentences, potentially through acting as a cue for a new clause subject.

Overall, these experiments support the view that animacy and syntactic structure are closely intertwined, such that inanimacy may be a good cue during acquisition and language processing for the occurrence of a non-agentive clause. Readers use punctuation to determine expectations about clause structure, but in the absence of punctuation, the animacy of both nouns in this garden-path structure, as well as the transitivity of verbs, guide readers' expectations about the sentence. This dissertation shows that questions about animacy and unaccusativity in sentence processing call for further investigation.

Chapter 2: Alternating and Non-alternating Unaccusative Verbs

Introduction

In this chapter, I review an experiment on animacy and two types of unaccusative intransitive verbs: alternating unaccusative verbs and non-alternating unaccusative verbs. Previous research has established that alternating unaccusatives – which can appear in intransitive or transitive constructions – are sensitive to noun animacy in garden-path sentences. Noun animacy influences both the potential interpretation of the subject noun as a good or bad fit for an Agent or Theme argument and of a post-verbal noun as a good or bad fit for a Theme/grammatical object. The novel question in our research is whether or not non-alternating unaccusative verbs are also sensitive to animacy-thematic mismatch; in other words, do inanimate subject nouns influence readers to expect a Theme role and therefore an intransitive interpretation of the clause? The experiment also tests whether the animacy of post-verbal nouns eases sentence processing and revision when that noun is a good candidate for a new clause subject, i.e., is animate. To foreshadow our results, our research confirmed that sentence processing is sensitive to garden-path sentences containing alternating unaccusative verbs depending on first and second noun animacy. Our research also supported the hypothesis that animacy-thematic mismatch effects take place with unaccusative verbs depending on subject noun animacy, i.e., inanimate first nouns lead to less or no disruption in early closure garden-path sentences.

Literature Review

During sentence processing, subtle pieces of information cued by syntactic, semantic, and probabilistic knowledge are rapidly recognized and integrated into a predicted whole-sentence meaning as each word is encountered (Altmann & Mirković, 2009). The opportunistic nature of processing facilitates comprehension in most cases but can sometimes lead to erroneous interpretations or "garden-paths" that must be repaired once the reader reaches a disambiguating point in the sentence. Two types of garden-path sentences are premised on a tendency for readers to expect an object noun after the verb in sentences like 1a ("examined") and 2a ("read") (Trueswell, Tanenhaus, & Garnsey, 1994). When this expectation is flouted, readers react with surprise, and reading times increase at the disambiguating region ("by the judge" in 1a and "had turned" in 2a). This effect is sometimes called "late closure" because the clause stays "open" to erroneously include the post-verbal noun.

1a) *The lawyer examined by the judge was found to be lying.*

1b) *The lawyer who was examined by the judge was found to be lying.*

2a) *The doctor read the study had turned out to be wrong.*

2b) *The doctor read that the study had turned out to be wrong.*

Early theories explained the above examples through parsimony of processing: choosing the structurally simplest way to integrate a new word into the current incremental interpretation of the sentence. In other words, new words are taken to be hierarchically dependent syntactic structures of the preceding clause, rather than part of a new clause, because this spares the parser from the processing burden of composing and inserting a new syntactic node (e.g., Frazier, 1987).

However, such proposals imply that the human parser is at least initially blind to semantic, probabilistic, discourse, and lexical features in the content preceding the disambiguating point of the sentence. This implication has been challenged by subsequent research. For example, verb bias – the frequency of co-occurrence in the usage of a specific verb with one of the argument structures available to it – has been shown to influence sentence processing. In sentences like 2a above, reading time slows down at the phrase "had turned" because the verb "read" is more likely to take a direct object than a clause complement (Garnsey, Pearlmutter, Myers, & Lotocky, 1997). Verbs that occur more frequently with clause complements, like "know" or "decide," behave differently – usually without reading disruption with either continuation (Boland, Tanenhaus, Garnsey, & Carlson, 1995; Pickering & Traxler, 2003). Similarly, knowledge of events and their typical locations, participants, instruments, and contexts seems to immediately influence lexical and sentence processing (McRae & Matsuki, 2009; Bicknell, Elman, Hare, McRae, & Kutas, 2010). For example, verb-naming tasks are accomplished significantly faster when primed by nouns whose referents are associated with the events represented by the verb, suggesting that verbs can be predicted by the thematic relations of their argument structure (McRae, Hare, Elman, & Ferretti, 2005), and the reverse is also true: noun-naming tasks are sped up when primed by verbs associated with events involving the nouns referents (Hare, Elman, Tabaczynski, & McRae, 2009).

3a) *As the nurse bathed the child was sitting in the front room.*

3b) *As the nurse bathed the novel was sitting in the front room.*

3c) *As the nurse arrived the novel was sitting in the front room.*

Research with sentences like 3a-3c, however, does seem to support a version of parsing that prefers new material to be treated as syntactically dependent on existing structures regardless of meaning (Adams et al. 1998; van Gompel & Pickering, 2001; Dekydtspotter & Seo, 2017; Staub, 2007). In sentences like 3b, where the second noun is clearly implausible as an object for the dependent clause verb, and even in sentences like 3c, where the verb itself is unambiguously intransitive, studies have nevertheless found a disruption in self-paced reading at the second noun, "the novel*",* but not at the later disambiguating phrase, "was sitting". Pickering and colleagues have argued this early reading disruption indicates that neither the implausibility of an object noun phrase nor the argument structure of the verb are able to deter the initial construction, during parsing, of a direct object analysis (van Gompel & Pickering, 2001). In other words, consistent with serial parsimony-based processing models, parsing initially ignores subcategorical (i.e., semantic) information. This effect is sometimes called "early closure" since the disruption is attributed to the immediate "closing" of the clause.

Staub (2007) replicated these findings but attributed the post-verbal effect to the cost of starting a new clause without clear prosodic or punctuation cues – rather than a reaction to an initial implausible direct object interpretation. His second experiment supported this by manipulating the appearance of commas and post-verbal preposition phrases and showing that introducing a comma removes the processing difficulty, while a lack of comma induces reading difficulty even when the clause could not possibly continue grammatically.

A possible limitation of the studies above is that they used stimuli sentences with animate dependent-clause subject nouns (i.e., "the nurse" in 3a-3c). Animacy is a

prototypical property of thematic Agents, the "doer" of an action, but not of Themes/Patients, the ones undergoing the action (e.g., Dowty, 1991). Inanimate nouns are generally incompatible with an Agent role. The link between agentivity and animacy has long been noted, such that inanimate nouns are difficult to incorporate even as causal instrumental subjects (Lowder & Gordon, 2012). A bias for animate transitive constructions also seems to be borne out in corpora studies of the frequency of use, as animate nouns are more frequently transitive subjects and inanimate nouns more frequently transitive objects (e.g., Dahl & Fraurud, 1996; Gennari & MacDonald, 2009; Merlo & Stevenson, 2001).

Stowe (1989) tested the effects of animacy in early closure garden-path sentences using self-paced reading and a version of the stop-making-sense task, in which participants are asked to note at each word whether the sentence makes sense or not. She found an effect of disambiguation at the second verb with animate subjects, but not with inanimate ones – showing that prototypical thematic roles did affect garden-path effects. However, she also found reading disruption for both animate and inanimate subject nouns post-verbally if the second noun was an implausible object for the verb (i.e., at "the moon" below in sentence 4a). Because Stowe's judgment task might have given readers more time to access animacy-thematic information, Clifton (1993) recreated the same studies using eye-tracking without a secondary task.

4a) *Before the police/the truck stopped the moon had risen over the ocean.*

4b) *Before the police/the truck stopped the Datsun disappeared into the night.*

Clifton (1993) likewise found that there was post-verbal reading disruption regardless of subject animacy when the second noun was an implausible object (i.e., 4a

above), but that only inanimate subject sentences showed post-verbal disruption when the second noun was plausible (i.e., 4b above). In 4a above, animate subject sentences also showed reading disruption at the disambiguating region. In other words, his first experiment showed that the implausibility of the second noun as an object of the verb leads to immediate disruption (early closure effects) for both animate and inanimate subjects. Only animate subjects led readers to difficulty at the disambiguating region, and thus to experience both early and late closure effects. Clifton's second experiment (like 4b above) found that animate subjects avoided early closure effects at the cost of greater late closure effects; in this case, inanimate subjects led to immediate post-verbal difficulty and also difficulty at the disambiguating region, although only in measures of later processing, like gaze duration and regressive eye movements.

The findings discussed above may reflect a processing expectation that animate subject nouns will take an agentive thematic role. Inanimate initial nouns are inconsistent with an agentive thematic role, counter to readers' expectation, and when the verb typically assigns an Agent role to the subject, like unergative verbs (e.g., "smile," "sleep;" Vernice & Sorace, 2018) and action verbs (e.g., "shoot," "chase;" Lowder & Gordon, 2012), reading disruption occurs because inanimate nouns are difficult to incorporate as a subject to these verbs. However, there is evidence of increased processing difficulty at and after the verb with verbs that assign a non-agentive, Theme/Patient role to animate noun subjects (e.g., unaccusative verbs, see below). However, these studies have not manipulated subject animacy. If readers' expectations about local argument structure are influenced by animacy and inanimacy of the subject (e.g., Becker, 2014), then encountering a non-agentive verb (i.e., where the subject is a

Theme) following an animate subject noun would require the revision of an agentive interpretation to a non-agentive interpretation. In contrast, encountering a non-agentive verb following an inanimate subject noun would not require any revision.

Intransitive verbs fall into two types: unergative verbs, which have an agentive subject, and unaccusatives verbs (e.g., "fall," "die"), which assign a Patient/Theme role to their subject nouns (discussed further in Chapter 4). Furthermore, unaccusative verbs are often categorized in terms of whether they partake in the transitive alternation, such as "break," "choke," "decrease," "sink," "roll," or if they do not alternate, like "arrive," "fall," "die" (Levin, 1993; Levin, Rappaport-Hovav, & Keyser, 1995). We refer to these as alternating unaccusative and non-alternating unaccusative verbs, respectively. The availability of a transitive interpretation for alternating unaccusative verbs is related to whether the subject is animate or not. Animate subject nouns typically result in transitive constructions, while inanimate subjects typically result in intransitive constructions.

In contrast to alternating unaccusative verbs, for non-alternating unaccusative verbs, the animacy of the subject does not alter what role is assigned to it. Multiple studies have shown a difference between unergative intransitive verbs and non-alternating unaccusative verbs, suggesting that non-alternating unaccusative have more difficult post-verbal processing than unergative verb sentences (e.g., Staub, 2007; Friedmann, Taranto, Shapiro, & Swinney, 2008; Koring, Mak, & Reuland, 2012; Dekydtspotter & Seo, 2017). Vernice & Sorace (2018) found, in Italian, that unergatives led to difficulty with inanimate subjects but that non-alternating unaccusatives were not sensitive to subject animacy, i.e., animacy-thematic mismatch. However, no research has tested whether expectations for transitive constructions are modulated by subject animacy

with non-alternating unaccusative verbs – in other words, whether inanimate subjects reduce post-verbal processing difficulty. Such a finding would suggest that the stronger early closure garden-path effects for unaccusative verbs may actually represent animacy-thematic mismatch effects.

The current study examined whether thematic role and argument structure predictions are made on the basis of first noun animacy and thematic roles assigned by unaccusative verbs. Specifically, the study asked 1) whether previously observed effects of animacy-transitivity bias with alternating unaccusatives would be present in a recreation of experiments like Stowe (1998) and Clifton (1993) that exclusively used alternating unaccusatives, rather than optionally transitive verbs, and 2) whether animacy may be responsible for early closure garden-path effects observed in previous research with non-alternating unaccusative verbs (e.g., Staub, 2007; Dekydtspotter & Seo, 2017) – if so, these effects may be a result of animacy-thematic mismatch, rather than of early closure garden-paths. Finally, this study also tested 3) whether the animacy of the second noun (i.e., "the child/novel" in 3a-3c) in early closure garden-path sentences would influence reading times.

Previous research has manipulated the plausibility of the second noun as an object of an optionally transitive verb (e.g., "As the band played the beer/the song was entertaining the crowd," Clifton, 1993; Traxler, Williams, Blozis, & Morris, 2005), finding, as discussed above, an effect on reading speed, even if effects are weak or subject to individual variation. In listening studies, the effect of prosody and thematic fit is demonstrable, as shown in a recent ERP study manipulating both factors (Sheppard, Midgley, Love, Shapiro, & Holcomb, 2018). However, if the animacy of the second noun

is not only a cue of its likelihood as an object of the verb but also of its likelihood to be a new grammatical subject, then its animacy should influence how easily that noun is interpreted as the jumping-off point to start a new clause. This should especially be considered for non-alternating unaccusative verbs, which already cannot participate in transitive constructions.

Methods

Participants

University of South Carolina undergraduate students (N = 123) were recruited through the Department of Psychology participant pool in exchange for course credit.

Design

Fourteen sentences with alternating unaccusative verbs and 14 sentences with non-alternating unaccusative verbs were assembled into two lists of 28 sentences each. Two versions of each sentence were created; one contained animate subjects and the other inanimate subjects – in all other ways, the stimuli on the lists were identical. Each participant saw 7 items in each verb type-animacy condition, and each verb appeared exactly once for each participant. Participants were randomly assigned to one of the two lists. Additionally, 14 distractor filler sentences were created, which mirrored the construction of the garden-path stimuli but differed in that transitive verbs were used, and a subsequent object was included after the verb, after which the subject of a new clause appeared. The study also included 42 unrelated filler items so that for each experimental stimulus, there were two filler/distractor items. In accordance with the grammaticality judgment task that participants performed at the end of each sentence, half of the filler and distractor items were grammatical, and the other half were not. Overall, each

participant saw 84 sentences (28 experimental, 14 filler-distracter, and 42 filler-unrelated). Items were presented in a random order for each participant, using the E-Prime software (Psychology Software Tools, 2016), with the only restriction that experimental items alternated between the animate and inanimate subject conditions with half of the participants seeing a sentence with an animate subject first, and the other half seeing a sentence with an inanimate subject first. Four experimental sentences in the alternating unaccusative condition ("break," "close," "shut," and "open") were also, by the author's intuitions, ungrammatical with an animate subject – which means that there were 30 ungrammatical and 54 grammatical sentences in each run of the experiment. Each sentence had a prepositional phrase at the end to counter potential sentence wrap-up effects (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Each of these sentences had an inanimate second noun. Data was collected for this experimental design from 60 participants.

The entire process was then repeated for the 28 verbs and first nouns, but the second clause of the sentence was manipulated so that the second noun was always animate. Stimuli sentences were kept as close as possible to those in Experiment 1, excepting the alteration of the animacy of the second noun, and consequently, also the main clause (i.e., the second) verb. Two sentences also had the subject noun replaced; one involved substituting "dancer" for "dentist", and the other "cart" for "chair," since combination with their respective verbs, "roll" and "turn," resulted in more sensible sentences. Data were collected from a different group of 63 participants for this version of the study.

Table 2.1: Sample items in all conditions

	Inanimate second noun		Animate second noun	
	Non-alternating unaccusative	Alternating unaccusative	Non-alternating unaccusative	Alternating unaccusative
Animate first noun	As the lawyer fell the sign was being displayed on the busy highway.	As the warrior swung the armor was being hidden in the distant city.	As the lawyer fell the journalist was being insulted on the busy highway.	As the warrior swung the enemy was being defeated in the distant city.
Inanimate first noun	As the apple fell the sign was being displayed on the busy highway.	As the hammer swung the armor was being hidden in the distant city.	As the apple fell the journalist was being insulted on the busy highway.	As the hammer swung the enemy was being defeated in the distant city.

Procedure

Participants were seated at a comfortable distance from a computer monitor in a quiet room with no people or other distractions. Sentences were presented using a word-by-word moving-window paradigm in which all the letters in the sentence were replaced with dashes except for the current word the participant was reading. Sentences lacked punctuation marks, except for a final period which was not replaced by dashes and remained on the screen for the duration of the trial (Just et al. 1982). Participants were instructed to read the sentences as quickly and naturally as possible and to try to understand each word before pressing the space bar to move on to the next word. These instructions were intended to ensure that participants read as naturally as possible to maintain ecological validity. After receiving the instructions and completing four practice sentences, participants began the actual 84-item experiment, which took around 20 minutes to complete. Participants completed a grammaticality judgment task at the end of each trial to maintain their engagement and examine their comprehension of the sentence. The task consisted of a prompt following each sentence asking participants to press the SPACE key if they considered the sentence that they just read to be grammatical and to press the left SHIFT key if they assessed the sentence to be ungrammatical. These judgments and their response times were recorded.

Analysis

Reading times per word lower than 100 ms or longer than 2000 ms were considered outliers as they likely reflected measures that violated the instructions of the experiment to read quickly and naturally. The response times were put through a log transformation and subsequently into a regression model that included the log of word

length (in the number of characters) as a fixed effect with the random effect of subject and the slope for word length. The residuals from this model were then taken as a measure of reading time minus the effect of word length, as is sometimes seen as a standard data preparation for reading experiments (e.g., Linzen & Jaeger, 2016; Trueswell, Tanenhaus, & Garnsey, 1994). Filler items were then removed from the data, and individual word residualized reading times within each region of interest were averaged for Region 1 (the intransitive verb), Region 2 (the determiner "the" and the second noun), Region 3 (the auxiliary verbs "was" and "being") and Region 4 (the second verb and the following preposition).

A mixed model linear regression was performed individually on each region of interest with the fixed factors: first noun animacy, second noun animacy, and verb type. Mixed effect regression analysis was performed using lmerTest R package version 3.0 (Kuznetsova, Brockhoff, & Christensen, 2017) and lme4 version 1.1.17 (Bates, Mächler, Bolker, & Walker, 2015). Random effects of the intercept for subjects and items were included in the model, and the maximal model of random effects was attempted; if the model didn't converge, then only the intercepts were included (Barr, 2013; Vernice & Sorace, 2018).

Estimated means and confidence intervals were calculated for the residualized reading time of each of the eight conditions. Because of the residualization, these confidence intervals are important since differing from zero implies a difference in processing beyond the effect of word length. Therefore, if the confidence interval is higher or lower than zero, it suggests there is disruption or facilitation, respectively. Confidence intervals were adjusted with the Bonferroni method for eight measures.

Contrasts were performed by subtracting the residualized reading times for animate first nouns from the residualized reading times for inanimate first nouns for each verb type and second noun animacy permutation. This results in four tests: inanimate first noun minus animate first noun (alternating unaccusative, animate second noun), inanimate first noun minus animate first noun (alternating unaccusative, inanimate second noun), inanimate first noun minus animate first noun (non-alternating unaccusative, animate second noun), inanimate first noun minus animate first noun (non-alternating unaccusative, inanimate second noun). The same was done for inanimate second nouns minus animate second nouns, resulting in four more tests: inanimate second noun minus animate second noun (alternating unaccusative, animate first noun), inanimate second noun minus animate second noun (alternating unaccusative, inanimate first noun), inanimate second noun minus animate second noun (non-alternating unaccusative, animate first noun), inanimate second noun minus animate second noun (non-alternating unaccusative, inanimate first noun). The Holm correction was used for eight contrasts to adjust for family-wise error. These contrasts are intended to test the hypotheses about first and second noun animacy discussed below.

For analysis of the grammaticality judgment task, results were analyzed in a logistic regression with a dependent variable of whether the answer given was ***YES*** or ***NO***. Accuracy was not used as the dependent variable because in some cases the line between ungrammatical and anomalous was blurred. The independent variables were first noun animacy, second noun animacy, verb type, and all interactions. Secondly, tokens receiving ***YES*** and ***NO*** judgments were separated into two groups, and these groups were put into a mixed-effects regression with question response time as the dependent variable

and, again, first and second noun animacy, verb type, and all possible interactions as independent factors. Question response times underwent data preparation, with responses shorter than 250 ms and longer than 6 seconds removed. Following this, a Box-Cox power transformation was applied with first noun animacy and verb type for each participant to ensure the data met assumptions for ANOVA and regression (lambda = -0.3026). For both, the logistic regression of grammaticality judgments, confidence intervals for an estimate of each condition, and the planned contrasts were also performed. Response time for the grammaticality judgments was subjected to planned contrasts, but no confidence intervals were performed because, with no residualization, there was no clear test of including or not excluding zero to interpret as disruptive or facilitative.

Hypotheses

1. Alternating unaccusative sensitivity to first noun animacy: First noun animacy should influence reading for alternating unaccusatives at the second noun phrase (Region 2) and at the auxiliary verb phrase (Region 3). Readers should be expecting a transitive clause when the first noun is animate and expecting an intransitive clause when the first noun is inanimate. Therefore, when the first noun is animate and the second noun is inanimate, alternating unaccusatives should be read faster at Region 2 and slower at Region 3 – a classical late closure garden-path effect. When the second noun is animate, there should be disruption at both regions because animate nouns are implausible, or even ungrammatical, as object nouns. When the subject is inanimate, however, results should show an

early closure garden-path effect, i.e., disruption at Region 2 and no effect at Region 3.

2. Non-alternating unaccusative sensitivity to first noun animacy: Non-alternating unaccusatives are expected to show an early closure garden-path effect that is influenced by animacy-thematic mismatch, such that animate first nouns should show disruption at Region 2. Inanimate first noun sentences, on the other hand, have an animacy-thematic match and are expected to show no disruption or less disruption relative to animate first noun sentences.
3. Sensitivity to second noun animacy: There are two hypotheses for how animacy of the second noun influences processing. The weaker view of the effect of second noun animacy is that animate second nouns should preclude a transitive interpretation of the first clause with alternating unaccusative verbs. Likewise, inanimate second nouns are potential objects for alternating unaccusative verbs. Thus, with animate first noun alternating unaccusative verb sentences, animate second nouns should result in immediate disruption, whereas inanimate second nouns should result only in later disruption at the disambiguating auxiliary verb phrase. In alternating unaccusative sentences with an inanimate first noun, animate second nouns should facilitate an intransitive interpretation, and disruption should only occur with inanimate second nouns since they allow a potential, though not plausible, transitive interpretation of the initial clause. Thus, this weaker version of the hypothesis is directly related to Hypothesis 1.

   The stronger hypothesis for the influence of second noun animacy is that, with non-alternating unaccusative verbs, animate second nouns should facilitate

reading since they are a better fit for the subject of a new clause than inanimate second nouns. The stronger hypothesis reflects not whether second noun animacy precludes the completion of a transitive clause but whether it influences the recognition of a new clause. This effect is predicted regardless of the animacy of the first noun with non-alternating unaccusative verbs and so is distinct from Hypothesis 2.

Results

We review the residualized reading times first as they are the focus of our hypotheses. Following reading times results, we will review how verb type and first and second noun animacy influenced grammaticality judgments and the response times for those grammaticality judgments. Figure 2.1 below shows the residualized reading times for all regions in all conditions.

Region 1

There were no significant effects found in the mixed-effects linear regression nor in the planned contrasts or confidence intervals[1].

Region 2

There was a marginally significant main effect of first noun animacy ($\chi^2(1) = 3.576$, $p = 0.059$), suggesting longer reading times for animate first nouns. There were significant two-way interactions between first noun animacy and verb type ($\chi^2(1) =$

[1] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results followed the same pattern as here.

15.925, $p < 0.001$), and between first noun animacy and second noun animacy ($\chi^2(1) = 8.93$, $p = 0.003$). The three-way interaction between first and second noun animacy and verb type was significant ($\chi^2(1) = 3.994$, $p = 0.046$).

Reading Time Results

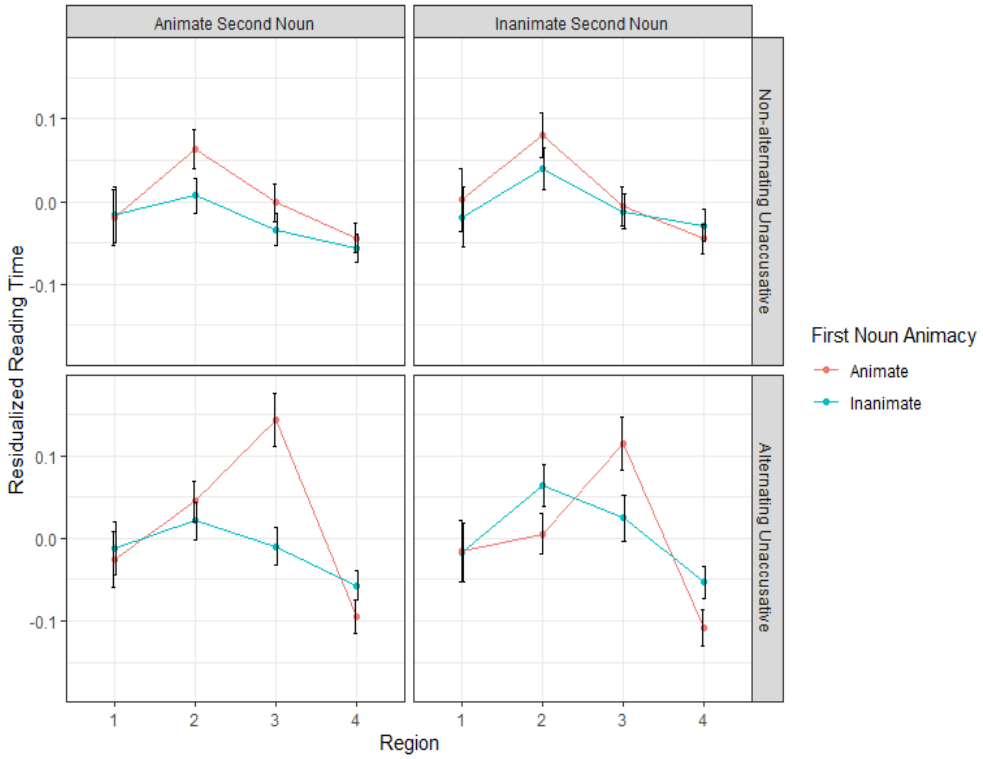

Figure 2.1: Residualized reading times across all regions. Residualized reading times for the eight conditions in each region of the experiment are shown. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale and taken from the data directly, not from the regression model. On the x-axis, 1, 2, 3, and 4 represent Region 1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

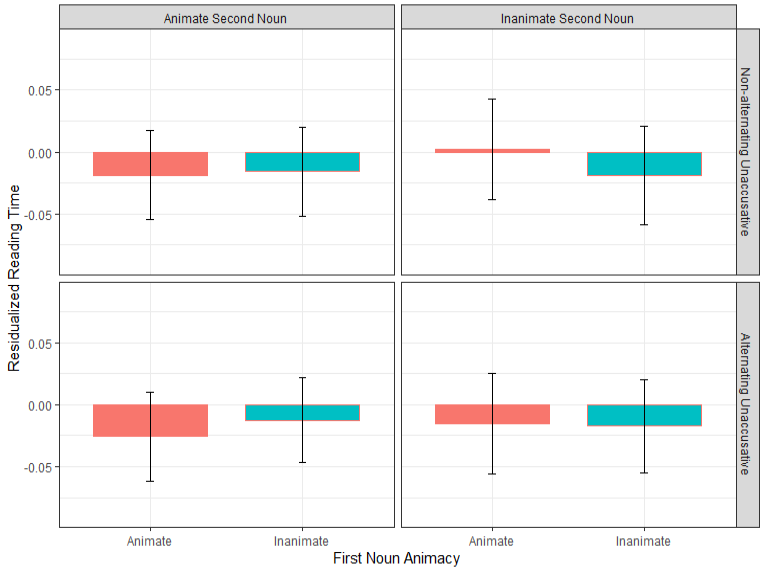

Figure 2.2: Residualized reading times for R1. Residualized reading times for the eight conditions of the experiment are shown. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale and taken from the data directly, not from the regression model.

The planned contrasts found that inanimate first nouns were associated with faster reading times for non-alternating unaccusatives than animate first nouns when there was an animate second noun (M = -0.057, SE = 0.016, z = -3.483, p = 0.004)[2] and the same effect was marginally significant when the second noun was inanimate (M = -0.041, SE = 0.017, z = -2.421, p = 0.093). These results appear to support Hypothesis 2, that there are animacy-thematic mismatch effects with non-alternating unaccusative verbs. With alternating unaccusative verbs, inanimate first noun sentences were read slower than animate first noun sentences when there was an inanimate second noun (M = 0.059, SE =

[2] For all planned contrasts and confidence intervals, we have used set degrees of freedom to infinite because, with as many data points as these studies have, running full calculations of these tests would take a prohibitive amount of additional time with my current computer system.

0.017, $z = 3.5$, $p = 0.004$), though this effect was not significant when the second noun was animate. This supports Hypotheses 1. The faster reading times for animate first noun sentences when the second noun was inanimate suggests that a transitive parse is attempted when the animacy of both nouns supports it. Similarly, this effect is only present when the second noun is inanimate and not when it is animate since neither an animate nor an inanimate first noun would create a plausible transitive clause.

Confidence intervals showed disruption for non-alternating unaccusative sentences with animate first nouns, both when the second noun was inanimate (*M* = 0.081, *SE* =0.018, *95% CI*: 0.032, 0.129) and when it was animate (*M* = 0.064, *SE* = 0.018, *95% CI:* 0.016, 0.112). This supports Hypothesis 2, that animate nouns in non-agentive thematic roles lead to disruption in reading. Inanimate first noun sentences with alternating unaccusative verbs showed disruption when the second noun was inanimate (*M* = 0.065, *SE* = 0.018, *95% CI*: 0.016, 0.114) but showed neither facilitation nor disruption when it was animate. This supports Hypothesis 1 and lends some support to the weaker form of Hypothesis 3, that the animacy of the second noun is influential during reading with alternating unaccusatives[3].

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[3] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results showed differences in results. In this analysis confidence intervals showed disruption for all conditions except inanimate first noun, animate second noun sentences with a non-alternating unaccusative verb (M = 0.014, SE = 0.02, 95% CI: -0.026, 0.051), animate first noun, inanimate second noun sentences with an alternating unaccusative verb (M = 0.03, SE = 0.021, 95% CI: -0.01, 0.071), and inanimate first noun, animate second noun sentences with an alternating unaccusative verb (M = 0.032, SE = 0.02, 95% CI: -0.008, 0.072). Inanimate first noun, inanimate second noun

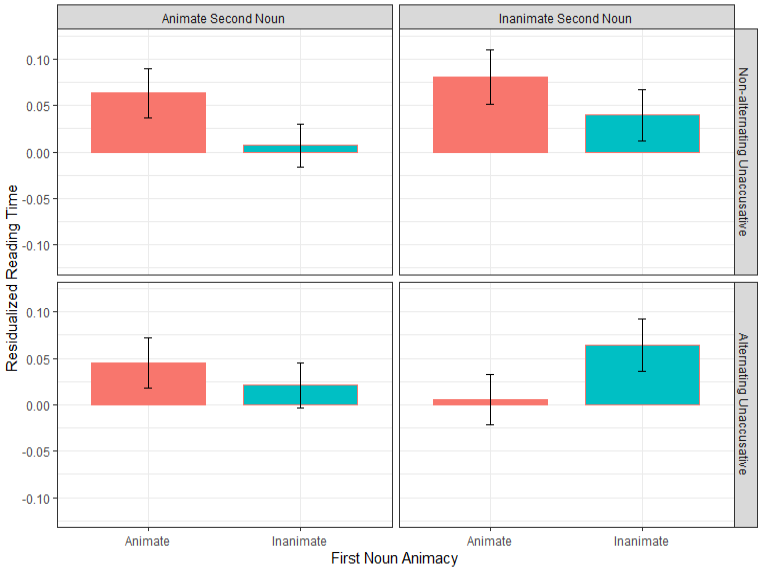

Figure 2.3: Residualized reading times for R2. Residualized reading times for the eight conditions of the experiment are shown. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale and taken from the data directly, not from the regression model.

Overall, this region supports our hypotheses. Hypothesis 2, that there would be an effect of animacy-thematic mismatch for non-alternating unaccusative verbs, was confirmed. Animate first nouns were associated with longer reading times regardless of second noun animacy, suggesting that animacy-thematic mismatch disrupted reading with these verbs. Likewise, for Hypothesis 1, there was no disruption for alternating

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sentences non-alternating unaccusative sentences were very close to having no facilitation or disruption (M = 0.046, SE = 0.02, 95% CI: 0.007, 0.085). Animate first noun, noun non-alternating unaccusative sentences showed disruption with inanimate second nouns (M = 0.093, SE = 0.02, 95% CI: 0.054, 0.132) and animate second nouns (M = 0.058, SE = 0.02, 95% CI: 0.02, 0.097). Inanimate first noun alternating unaccusative sentences with an inanimate second noun showed disruption (M = 0.071, SE = 0.021, 95% CI: 0.031, 0.112), as well as animate first noun alternating unaccusative sentences with an animate second noun (M = 0.05, SE = 0.021, 95% CI: 0.017, 0.097).

unaccusative verbs when the first noun was animate, but when the first noun was inanimate, there was disruption when the second noun was a good fit for a transitive object (i.e., inanimate), and there was no such disruption when the second noun was animate and therefore ruled out a plausible transitive interpretation. This pattern also supports the weaker version of Hypothesis 3, that second noun animacy will affect reading times as a good/bad fit for a transitive object noun. The stronger version of Hypothesis 3, that animate second nouns reduce reading difficulties because they are a cue that a new clause subject is being encountered, was not supported.

Region 3

There was a significant main effect of first noun animacy ($\chi^2(1) = 63.883$, $p < 0.001$) and of verb type ($\chi^2(1) = 23.623$, $p < 0.001$). There were significant two-way interactions between first noun animacy and verb type ($\chi^2(1) = 33.19$, $p < 0.001$), and between first noun animacy and second noun animacy ($\chi^2(1) = 6.251$, $p = 0.012$).

Planned contrasts showed faster reading times for inanimate first nouns than animate first nouns in alternating unaccusative verb sentences both when the second noun was inanimate ($M = =-0.091$, $SE = 0.0180$, $z = -5.038$, $p < 0.001$) and when it was animate ($M = -0.153$, $SE = 0.018$, $z = -8.73$, $p < 0.001$). This supports Hypothesis 1 as a late closure garden-path effect at the disambiguating verb region.

Confidence intervals around the estimated mean of residualized reading times showed disruption for alternating unaccusative sentences when the first noun was animate and the second noun was inanimate ($M = 0.116$, $SE = 0.016$, *95% CI*: 0.071, 0.16) and also when it was animate ($M =0.143$, $SE =0.016$, *95% CI*: 0.1, 0.187). This

pattern of results supports Hypothesis 1, that a late closure garden-path effect will occur with alternating unaccusative verb sentences[4].

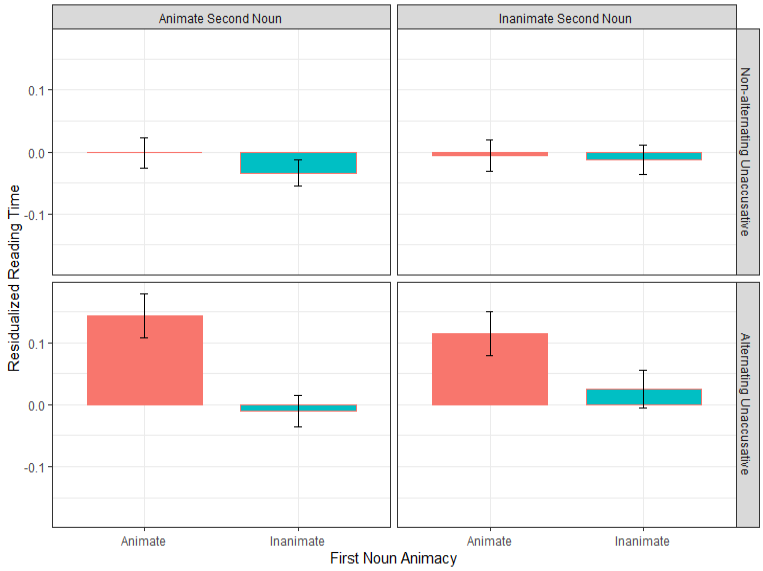

Figure 2.4: Residualized reading times for R3. Residualized reading times for the eight conditions of the experiment are shown. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale and taken from the data directly, not from the regression model.

Overall, in this region, our hypotheses also seem to be supported. Alternating unaccusative sentences showed disruption when the first noun was animate. This disruption begins here, at the auxiliary verb phrase, when the second noun was inanimate (i.e., a prototypical object). When the second noun was animate (i.e., an implausible object), the disruption at Region 3 was instead a continuation from the disruption at the

[4] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results followed the same pattern as here.

second noun phrase. This pattern represents the standard late closure garden-path effect as observed in previous studies.

Region 4

There were significant main effects of first noun animacy ($\chi^2(1) = 5.754$, $p = 0.017$) and of verb type ($\chi^2(1) = 5.383$, $p = 0.02$), such that animate first nouns incurred longer reading times and alternating unaccusative verbs incurred longer reading times. There was also a significant interaction between first noun animacy and verb type ($\chi^2(1) = 4.048$, $p = 0.044$).

Planned contrasts showed that animate first noun sentences were read marginally faster than inanimate in alternating unaccusative sentences with inanimate second nouns ($M = 0.044$, $SE = 0.017$, $z = 2.609$, $p = 0.073$).

Estimated means and confidence intervals showed facilitation for animate first noun, alternating unaccusative sentences with both inanimate ($M = -0.061$, $SE = 0.016$, *95% CI:* -0.103, -0.018) and animate second nouns ($M = -0.046$, $SE = 0.015$, *95% CI:* -0.088, -0.004)[5].

The final region was not central to our hypotheses. However, there appeared to be facilitation for animate first noun sentences with alternating unaccusative verbs. This

[5] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results were slightly different. There were no significant effects in the planned contrasts and, in the confidence intervals, only animate first noun, inanimate second noun alternating unaccusative sentences showed facilitation (M = -0.038, SE = 0.017, 95% CI: -0.071, -0.004), but animate second noun sentences did not (M = -0.017, SE = 0.017, 95% CI: -0.049, 0.016).

facilitation was most apparent when the second noun was inanimate. Because participants were responding to a grammaticality judgment task after each sentence, it is possible that this effect is a result of readers abandoning the task of parsing the sentence after they encountered the auxiliary verb phrase. In this sense, the lower residualized reading times at this region may indicate that readers have abandoned attempting to parse the sentence, rather than that ungrammatical sentences aided readers in parsing.

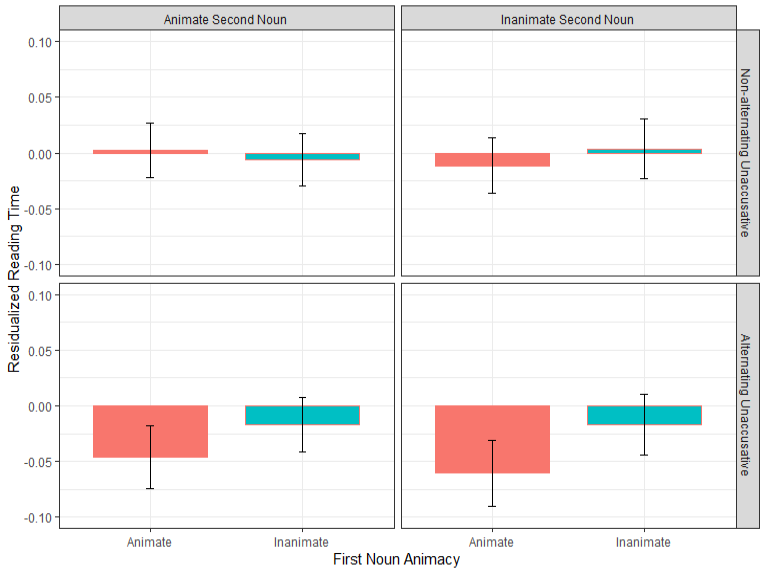

Figure 2.5: Residualized reading times for R4. Residualized reading times for the eight conditions of the experiment are shown. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale and taken from the data directly, not from the regression model.

Grammaticality Judgment Results

Overall, there were numerically more ***YES*** (n = 10,853, 59%) than there were ***NO*** responses (n = 7,511, 41%). A mixed-effects logistic regression of grammaticality judgments found a main effect of first noun animacy ($\chi^2(1) = 1574.7$, $p < 0.001$), suggesting lower accuracy for animate first nouns, and of verb type ($\chi^2(1) = 15.293$, $p < 0.001$), suggesting lower accuracy for alternating unaccusative verbs. There were two-

way interactions between first noun animacy and verb type ($\chi^2(1) = 726.9$, $p < 0.001$), between first noun animacy and second noun animacy ($\chi^2(1) = 115.9$, $p < 0.001$), and between second noun animacy and verb type ($\chi^2(1) = 4.77$, $p = 0.029$). The three-way interaction between all three factors was also significant ($\chi^2(1) = 9.239$, $p = 0.002$).

Confidence intervals showed a higher rate of ***NO*** answers for alternating unaccusative sentences with animate first nouns and inanimate second nouns (*M* = -1.047, *SE* = 0.234, *95% CI:* -0.408, -1.687). There was no difference from zero for alternating unaccusative sentences with animate first nouns and animate second nouns (*M* = -0.474, *SE* = 0.231, *95% CI:* -1.105, 0.158). There were higher rates of ***YES*** answers for all other sentence types: inanimate first noun, inanimate second noun non-alternating unaccusative sentences (*M* = 1.154, *SE* = 0.234, *95% CI:* 1.793, 0.515), inanimate first noun, animate second noun non-alternating unaccusatives sentences (*M* = 1.309, *SE* = 0.232, *95% CI:* 1.943, 0.68), animate first noun, inanimate second noun non-alternating unaccusative sentences (*M* = 0.658, *SE* = 0.233, *95% CI:* 1.296, 0.019), animate first noun, animate second noun non-alternating unaccusative sentences (*M* = 1.191, *SE* = 0.232, *95% CI*: 1.824, 0.558), inanimate first noun, animate second noun alternating unaccusative sentences (*M* = 0.792, *SE* = 0.231, *95% CI:* 1.424, 0.16), and inanimate first noun, inanimate second alternating unaccusative sentences (*M* =-0.889, *SE* = 0.234, *95% CI:* 1.529, 0.25).

Planned contrasts showed inanimate first noun sentences were assigned a ***YES*** response more often than animate first noun sentences when the verb was non-alternating unaccusative and the second noun was inanimate (*M* = -0.496, *SE* = 0.048, *z* = -10.356, *p* < 0.001), and a marginal difference in the same direction when the second noun was

animate (M = -0.118, SE = 0.05, z = -2.368, p = 0.072). There were more ***YES*** answers for inanimate first noun sentences than for animate first noun sentences with alternating unaccusative verbs when the second noun was inanimate (M = -1.937, SE = 0.049, z = -39.536, $p < 0.001$) and when it was animate (M = -1.266, SE = 0.047, z = -26.72, $p <$ 0.001). Inanimate second nouns had more ***NO*** responses than animate second nouns in animate first noun, alternating unaccusative sentences (M = 0.574, SE = 0.237, z = 2.427, p = 0.076) and in animate first noun, non-alternating unaccusative sentences (M = 0.534, SE = 0.237, z = 2.254, p = 0.073) [6]. Animacy of the second noun had no effect on grammaticality judgments for inanimate first noun, non-alternating unaccusative sentences or for inanimate first noun, alternating unaccusative sentences. Thus, it appears that animate first noun sentences were more likely to be judged ungrammatical with both verb types. Inanimate second nouns were more likely to be judged ungrammatical with

[6] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results showed differences in results from here. Animate first noun sentences with alternating unaccusatives did not differ from zero with either animate second nouns (M = 0.128, SE = 0.253, 95% CI: -0.564, 0.820) or inanimate second nouns (M = 0.662, SE = 0.256, 95% CI: -0.039, 1.362). Interestingly, animate first noun, non-alternating verb sentences now did not have a higher rate of YES responses, not differing from zero (M = -0.58, SE = 0.25, 95% CI: -1.264, 0.105). All other conditions showed a higher rate of ***YES*** responses.

Planned contrasts showed significantly more ***NO*** responses for non-alternating unaccusative sentences with inanimate first nouns when the second noun was inanimate (M = -0.465, SE = 0.054, z = -8.593, p < 0.001) and when it was animate (M = 0.178, SE = 0.056, z = 3.194, p = 0.007). Likewise, there were significantly more ***NO*** responses with alternating unaccusative sentences when the first noun was animate and the second noun was inanimate (M = -1.83, SE = 0.059, z = -31.082, p < 0.001) and animate (M = -0.901, SE = 0.056, z = -16.23, p < 0.001). There were significantly more **YES** responses with alternating unaccusatives and inanimate first nouns when the second noun was animate (M = 0.722, SE = 0.26, z = 2.773, p = 0.022).

both verb types when the first noun was animate – which may suggest that animate-verb-inanimate sequences interfere with sentence reanalysis.

Response Time for NO Responses

When ***NO*** responses were given, there were differences across noun animacy and verb type in how quickly those responses were made. A regression of these reading times was performed. There was a significant main effect of first noun animacy ($\chi^2(1) = 56.438$, $p < 0.001$) and of verb type ($\chi^2(1) = 7.657$, $p = 0.006$). The two-way interactions between first noun animacy and second noun animacy ($\chi^2(1) = 29.708$, $p < 0.001$), between first noun animacy and verb type ($\chi^2(1) = 112.12$, $p < 0.001$), and between second noun animacy and verb type ($\chi^2(1) = 46.764$, $p < 0.001$). The three-way interaction between first and second noun animacy and verb type was significant ($\chi^2(1) = 15.357$, $p < 0.001$).

Planned contrasts showed significantly faster response times for animate first nouns than for inanimate first nouns in alternating unaccusative sentences with an inanimate second noun ($M = 0.041$, $SE = 0.003$, $z = 14.987$, $p < 0.001$) and with animate second nouns ($M = 0.041$, $SE = 0.003$, $z = 4.873$, $p = < 0.001$). The ***NO*** response time for inanimate second noun sentences was faster than for animate second nouns in animate first noun, alternating unaccusative sentences ($M = -0.035$, $SE = 0.0123$, $z = -2.847$, $p = 0.026$).[7]

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[7] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results differed from the above results. Animate first noun sentences with alternating unaccusative verbs showed the same pattern of results, taking longer to receive a response than inanimate first noun sentences; however, the effect of second

These response times reflect how long it took participants to reject the grammaticality of the sentence[8]. Therefore, longer response times indicate that it was more difficult for participants to reject the grammaticality of sentences in a condition, and faster times indicate that rejection was easier to decide on. Participants were quicker in rejecting the grammaticality of animate first noun sentences with alternating unaccusative verbs, which supports the idea discussed above that once participants have decided a sentence is ungrammatical, they speed up in reading the rest of the sentence and quickly select a ***NO*** response to the grammaticality judgment. Participants were also quicker to reject inanimate second noun sentences than animate second noun sentences with animate first noun, alternating unaccusative verb sentences, suggesting that inanimate second nouns led participants to believe the sentence was ungrammatical and abandon parsing or simply ignore the rest of the sentence.

Response Time for YES Responses

When ***YES*** responses were given, there were differences across noun animacy and verb type in how quickly those responses were made. There was a significant main effect of first noun animacy ($\chi^2(1) = 187.38$, $p < 0.001$). There was a significant interaction between first noun animacy and second noun animacy ($\chi^2(1) = 30.961$, $p < 0.001$), between first noun animacy and verb type ($\chi^2(1) = 54.292$, $p < 0.001$), and second noun animacy and verb type ($\chi^2(1) = 34.867$, $p < 0.001$). The three-way interaction between

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noun animacy with alternating unaccusatives and inanimate first nouns was no longer significant. Also, animate first noun sentences now had significantly quicker responses than inanimate first noun sentences with non-alternating unaccusative sentences and animate second nouns (M = -0.016, SE = 0.004, z = -4.292, p < 0.001).

[8] A better alternative for analyzing response times would have utilized d'-analysis to account for speed-accuracy trade-off effects. See Limitations section, this chapter.

first and second noun animacy and verb type was marginally significant ($\chi^2(1) = 3.206$, $p = 0.073$).

Planned contrasts showed slower ***YES*** response times for animate first noun than for inanimate first noun sentences with alternating unaccusative verbs when the second noun was inanimate ($M = -0.032$, $SE = 0.003$, $z = -10.738$, $p < 0.001$) and also when it was animate ($M = -0.022$, $SE = 0.003$, $z = -8.465$, $p < 0.001$). There were slower ***YES*** response times for animate first noun sentences than inanimate first noun sentences with non-alternating unaccusatives when the second noun was inanimate ($M = -0.017$, $SE = 0.002$, $z = -7.559$, $p < 0.001$).[9]

Interpreting these results, response times reflect how long it took participants to approve of the grammaticality of the sentence. Therefore, longer response times indicate greater difficulty in determining to approve of the grammaticality of a sentence in a condition, and short times indicate greater ease in recognizing grammaticality. Here, we see an inverse effect from the rejection response times. It took longer to approve of sentences with animate first nouns and alternating unaccusative verbs. This suggests that participants were able to revise their parse of the sentences but that the grammaticality of the revised parse took longer to confirm. There is also a similar effect with animate first nouns and non-alternating unaccusative sentences, but only when the second noun was animate. This suggests readers' comprehension is thrown off by the potential for a

[9] Four of the alternating unaccusative verbs led to sentences that were ungrammatical with an animate subject noun. Similarly, three of the non-alternating unaccusatives were found in later analyses (see Chapter 3) to be potentially considered as alternating unaccusatives. In a linear mixed-effects regression with these seven verbs excluded the results showed no difference in the pattern of results from here.

transitive clause even with non-alternating unaccusative sentences when the first noun is animate, leading to premature rejection of the sentence. This finding suggests that patterns of animacy in noun pairings (i.e., animate-verb-inanimate) may create interference by creating a lingering expectation for a transitive construction, even when the verb does not allow it.

Discussion

Hypothesis 1 that late closure garden-path effects would be recreated with alternating unaccusative verbs was confirmed. There was the same pattern of results here as there was in Clifton (1993), where similar verbs were used with first noun animacy manipulated experimentally, along with the second noun's plausibility as an object. When the first noun was inanimate (signaling an intransitive clause) and the second noun was animate (so not a plausible object and also a good new clause subject), there was no disruption at the clause break in the absence of a comma. When the second noun was inanimate, there was disruption even with an inanimate first noun, which suggests there was competition between an intransitive and transitive interpretation of the clause. Animate first noun sentences, on the other hand, followed the pattern for late closure garden-path sentences. When the second noun was inanimate (i.e., a cue for a transitive clause), there was no disruption at the post-verbal noun phrase, but there was disruption at the disambiguating auxiliary verb phrase. When the second noun was animate, there was disruption at both the second noun and the disambiguating verb phrase, suggesting that even implausible objects lead to late closure garden-path effects. These results suggest that the parser uses animacy and verb-thematic information quickly to interpret the syntactic structure of a sentence.

Our novel hypothesis that non-alternating unaccusative verbs would show an animacy-thematic mismatch effect (Hypothesis 2) was also confirmed in this experiment. The reading disruption for animate but not inanimate first nouns suggests that unaccusativity, thematic roles, and noun animacy may be more deeply related than previous research has assumed. Previous sentence processing studies (Friedmann, Taranto, Shapiro, & Swinney, 2008; Koring, Mak, & Reuland, 2012) have treated unaccusativity as a primarily syntactic phenomenon, in which the subject noun undergoes movement from an object to a subject position in terms of syntactic compositionality (e.g., Burzio, 1986). However, our findings suggest that greater processing cost for unaccusatives may reflect an animacy-thematic bias rather than an effect of only syntactic complexity. When non-alternating unaccusative verbs are paired with an inanimate first noun, which leads to an expectation for a non-agentive role, there is no disruption with non-alternating unaccusative verbs. However, an animate first noun leads to an expectation of an agentive thematic role, and when an unaccusative verb assigns it a non-agentive role instead, the non-canonical thematic role incurs additional processing cost.

Although this animacy-thematic effect supports probabilistic, opportunistic use of information during parsing rather than parsimony-based explanations of language comprehension, it also suggests that even in probabilistic approaches to sentences processing, the role of animacy may be underestimated. As described above, Staub (2007) presents a convincing argument that early closure garden-path effects stem from the lack of a comma between two clauses rather than a temporary default transitive interpretation of clause structure. However, our findings suggest that early closure garden-path effects may also be influenced by animacy-thematic mismatch and the

associations between thematic roles, animacy, and syntactic structures. Early closure garden-path effects can be viewed as representing the difficulty of recognizing a new clause without a punctuation cue; this difficulty can be alleviated when other sources of information, like noun animacy, reenforce an intransitive structure for the dependent clause.

This finding also differs from the effect of animacy and non-alternating unaccusatives found in Vernice & Sorace (2018). In their study, the "be/have" auxiliary variation between unaccusative and unergative verbs was tested during reading in Italian. In Italian and other Romance languages, unaccusative verbs are paired with the verb for "to be" as an auxiliary verb, while unergatives are paired with "to have," which means that the unergative/unaccusative divide is morphologically marked in Italian, whereas in English it is unmarked. They found unergative verbs were read with disruption after an inanimate subject (i.e., animacy-thematic mismatch). However, the reading of unaccusative verbs was not modulated by the animacy of the subject noun. In our current study, however, non-alternating unaccusatives did show disruption when there was an animacy-thematic mismatch. The differences between the language being investigated and experimental methods being employed likely influence our different results. Notably, our study includes potential transitivity as a variable, whereas, in Vernice & Sorace (2018), the link between animacy and transitive and intransitive verbs was not explored.

Animacy plays a major role in cognitive processing across various realms (e.g., Paczynski & Kuperberg, 2012; Nairne & VanArsdall, 2013; Tao, Baker, Tang, Xu, & Tenenbaum, 2019). Becker (2014) claims that animacy-thematic role associations are essential in language acquisition, as well as processing. Inanimate nouns are associated

with Theme roles, and animate nouns are associated with Agent roles. Language learners and users use these associations to form expectations about the grammatical and thematic structure of a sentence, from encountering the first words. Our research suggests syntactic constructions, like (in)transitivity, are also associated with noun animacy and thematic roles. Studies that have argued that the greater processing cost for unaccusative verbs is solely due to greater syntactic complexity may be ignoring the role of animacy and thematic structure (e.g., Friedmann, Taranto, Shapiro, & Swinney, 2008).

Finally, the weak form of Hypothesis 3 was confirmed since second noun animacy influenced reading times both when it allowed and when it didn't allow a plausible transitive clause interpretation. In other words, second noun animacy had a significant effect in sentences with alternating unaccusative verbs, in particular when the second noun ruled out a possible instrumental subject transitive clause with an inanimate first noun. The strong form of Hypothesis 3, however, was not confirmed. There was no significant contrast between animate and inanimate second nouns with unaccusative verbs for sentences for either inanimate or animate first nouns. However, animate second nouns did appear to ease processing with inanimate first nouns for both verb types, so the question may require more research.

Limitations

An issue with this experimental design was the inclusion of some verbs that were not ideal for the study. Four alternating unaccusative verbs led to ungrammatical sentences (or sentences that required a wholly different sense in order to be considered grammatical) when the subject noun was animate ("close," "shut," "open," and "break"). It is possible, especially considering that half the filler sentences were ungrammatical,

that readers skipped through these sentences after they reached the seemingly ungrammatical second noun phrase during parsing. The goal of the experiment is not to explore reading patterns while recognizing an ungrammatical sentence but rather to explore reading patterns with sentences that require some revision of the incremental parse. Also, three verbs that were denoted as non-alternating unaccusatives ("settle," "crumble," and "collapse") did take part in the transitivity alternation. Even though these verbs are rarely transitive, they have a tangible transitive sense. This mistake in the design of the experiment was noted after the experiment had been completed. The data was re-analyzed with these seven verbs removed – although this removal negatively affects the power of the study. A comparison of the pattern of results in the full experiment and the experiment without these potentially interfering verbs is shown in the table below in terms of confidence intervals as a measure of disruption or facilitation.

Table 2.2: Differences between analyses

	All verbs	With 7 verbs removed
Region 1	No effects	No effects
Region 2 Non-Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	No effect	Disruption
Animate-Animate	Disruption	Disruption
Animate-Inanimate	Disruption	Disruption
Region 2 Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	Disruption	Disruption

Animate-Animate	No effect	Disruption
Animate-Inanimate	No effect	No effect
Region 3 Non-Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	No effect	No effect
Animate-Animate	No effect	No effect
Animate-Inanimate	No effect	No effect
Region 3 Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	No effect	No effect
Animate-Animate	Disruption	Disruption
Animate-Inanimate	Disruption	Disruption
Region 4 Non-Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	No effect	No effect
Animate-Animate	No effect	No effect
Animate-Inanimate	No effect	No effect
Region 4 Alternating		
Inanimate-Animate	No effect	No effect
Inanimate-Inanimate	No effect	No effect
Animate-Animate	Facilitation	No effect
Animate-Inanimate	Facilitation	Facilitation

With the anomalous verbs removed, the pattern of results primarily changes at Region 2, the second noun. The evidence for animacy-thematic mismatch effects weakens to a degree because there is now disruption with non-alternating unaccusative verbs for sentences where the first and second nouns were both inanimate. This disruption may result from the second noun as a poor cue for a new clause. However, the analysis without the anomalous/ungrammatical verbs may not be wholly reliable, due to the low number of items and potential power issues related to it.

With alternating unaccusatives, there are also some notable differences. When the four verbs that led to ungrammatical sentences with animate first nouns were removed, there was disruption at Region 2 with an animate first noun when the second noun was animate, which didn't occur when those verbs were included. Likewise, at Region 4, animate first and second noun sentences had faster reading times when the ungrammatical-sentence verbs were included but did not when they were removed. This pattern of results suggests that the ungrammatical-sentence verbs led readers to abandon attempting to parse the sentence by the time they reached the final verb. These ungrammatical-sentence verbs also may be more accepting of animate second nouns than other alternating uaccusative verbs, as long as they are followed by a particle such as "broke him down/out/the news" or "shut her in/out/down." With only grammatical alternating unaccusatives included, readers recognize the animate second nouns as anomalous for a transitive interpretation, showing disruption at Region 2. Likewise, readers appear to be less likely to abandon parsing grammatical sentences, since there is no longer facilitation at the final verb with ungrammatical-sentence verbs removed.

With the ungrammatical alternating unaccusative and anomalous non-alternating unaccusative verbs removed, grammaticality judgments also differed slightly. All other conditions had a higher rate of ***YES*** responses for grammaticality, as demonstrated earlier. However, when all verbs were included, animate first noun, inanimate second noun sentences with alternating unaccusative verbs had a higher rate of ***NO*** responses and animate first noun, animate second noun sentences showed no effect; with the ungrammatical sentences removed, neither condition showed any effect. This makes sense because participants are marking more ***NO*** responses for sentences that are, in fact, ungrammatical. Similarly, animate unaccusatives took longer to approve and less time to reject, as expected. With non-alternating unaccusative verbs, the results aligned with our reading time results in both ***YES*** and ***NO*** responses.

Overall, the differences and similarities between the study with ungrammatical alternating unaccusatives excluded support our general hypothesis and refine our understanding of the cause of some of the late closure garden-path effects observed here. With the questionable non-alternating unaccusative verbs excluded, animacy-thematic mismatch effect was only clear when the second noun was animate. Inanimate first noun sentences still showed disruption when the second noun was also inanimate. In this way, the experiment with these seven verbs removed led to some support for the strong version of Hypothesis 3, that animate second nouns should aid parsing of the two-clause structure of the sentence. An improvement on this experiment would be to remove these anomalous verbs and replace them with verbs that better fit the goals of the study to maintain statistical power for our analyses.

Furthermore, this study employed grammaticality judgments after each stimuli sentence. However, this framework may lead to strategic or unnatural reading patterns since participants may focus on accepting or rejecting the grammaticality of the sentence rather than reading it for meaning. The filler sentences, as well, were half ungrammatical, which would further lead to unnatural reading. An experiment only using grammatical sentences and comprehension questions would produce more generalizable results since it is hard to determine what effect grammaticality judgments might have on reading times for non-alternating unaccusative sentences.

A final limitation is that we did not perform a d'-analysis on our filler and experimental sentences for the accuracy of grammaticality judgments (Heitz, 2014; Alday & Kretzschmar, 2019). A d'-analysis takes into account the rate of correct rejection of ungrammatical sentences and the rate of false alarms, or rejection of grammatical sentences, in relation to the speed of response to the grammaticality judgments. This analysis would allow us to better control for individual participants' strategies in confirming or rejecting grammaticality. Furthermore, it would allow us to examine the time-course of decision making, as accuracy increases from chance to an asymptote. In future work, we will utilize this approach for our grammaticality judgment data.

Conclusion

The findings of the current study corroborated previous research exploring the use of alternating unaccusative verbs in late closure garden-path sentences. The animacy of both subject and post-verbal noun influenced reading times in a pattern consistent with Clifton (1993). This finding was expected and is in line with opportunistic, parallel,

incremental sentence processing. The effect of second noun animacy confirmed sensitivity to the plausibility of potential object nouns. Although there was no stark evidence that animacy of the second noun may ease recognition of it as a new subject, the pattern of results did potentially suggest there was less disruption with animate second nouns in early closure garden-path sentences.

Our findings also suggest that animacy-thematic mismatch effects may play a role in the processing of early closure garden-path sentences with non-alternating unaccusative verbs. Because these verbs always assign a non-agent thematic role to their subject noun, inanimate subjects lead to easier processing, likely because initial inanimate nouns are expected to take on a Theme role in the argument structure of the sentence. Animate subjects were associated with disruption post-verbally because they are likewise expected to take on an Agent role, and this assumption must be revised upon encountering the verb. Questions remain about how the relationship between animacy and thematic roles might interact with or differ from the relationship between animacy and transitivity.

Chapter 3: Corpus-based Animacy and Transitivity Probability

Introduction

In this chapter, we reanalyze the results of Chapter 2 using corpus-derived probabilistic factors based on subject animacy and transitivity. We frame our analyses in terms of domain-specific versus domain-general effects of animacy on sentence processing, with domain-specific effects represented by categorical models and domain-general effects represented by probabilistic models. The number of animate or inanimate subject nouns for each verb were calculated from two corpora from the *Penn Treebank Project* (Taylor, Marcus, & Santorini, 2003). We calculated the probability of an animate or inanimate subject for each verb. We also calculated, for each verb, the conditional probability of a transitive clause, given the animacy of the subject noun. We tested whether categorical or probabilistic models performed better, finding that early closure garden-path effects (at Region 2) are better described by probabilistic models. Late closure garden-path effects (at Region 3) were better fit by categorical models. We also review the regression results for probabilistic models. Here, Region 2 was influenced by simple probability and conditional probabilities, while Region 3 was only affected by conditional probabilities. Finally, we review regression results for models with both probabilistic and categorical variables, which suggest that the animacy-thematic mismatch influence on early closure garden-path sentences found in Chapter 2 may be driven by probabilities associated with inanimate subjects and non-alternating unaccusative verbs.

Literature Review

There is reason to see sensitivity to animacy information as an evolutionarily adapted characteristic. An innate ability to distinguish animacy and to distinctly regulate attentional resources on the basis of animacy has plausible benefits from a historical-biological perspective (Nairne, 2005; Nairne, VanArsdall, Pandeirada, Cogdill, & LeBreton, 2013). Living things may be threats, like wild animals, pests, or disease-infected individuals, and may also represent opportunities for hunting or domestication. Recognizing and devoting additional resources to humans, in particular, is essential for social and communal life, where many events involve coordinated activities and rely on joint attention (e.g., Tomasello, 1995; Pickering & Garrod, 2021). Non-living things, objects without internal force and mobility, are part of a different perceptual experience, being viewed in terms of their functions or in how they may be affected by external forces. For example, inanimate items that have been touched by humans receive more attention and memory resources than items that haven't been (DeScioli, Rosa, & Gutchess, 2015; Cogdill, Nairne, & Pandeirada, 2016). Additionally, this fine-grained sensitivity to animacy information is present from an early age in visual (Gelman & Opfer, 2002; Markson & Spelke, 2006; Di Giorgio, Lunghi, Vallortigara, & Simion, 2021) and linguistic behavior (Dodson & Tomasello, 1998; Becker & Schaeffer, 2013).

If it is given that animacy distinctions play an innate role in cognitive systems, then animate and inanimate types may also be supported by distinct neural mechanisms. Functional MRI studies have shown different neural activity in response to living and non-living objects (Grezes, Funlopt, Bertenthal, et al. 2001; Gobbini, Gentili, Ricciardi, et al. 2011; Scholl & Gao, 2013; Khaligh-Razavi, Pantazis, & Oliva, 2018). Studies have

also found animacy-specific semantic deficits due to brain damage in distinct neural regions – for example, patients have been reported to have difficulty naming or recognizing living entities, like animals (Warrington & Shallice, 1984). There were also patients who showed the reverse pattern, i.e., difficulty naming and recognizing inanimate objects relative to animate (Warrington & McCarthy, 1983). Sentence processing studies also suggest different neural mechanisms for animate and inanimate entities (Weckerly & Kutas, 1999; Kuperberg, Kreher, Sitnikova, Caplan & Holcomb, 2007; Rundle, Coch, Connolly, & Granger, 2018; Lai, Lacadie, Deo, & Pinango, 2020). Recently, research has begun to separate a reaction to animacy per se and a reaction to agency, i.e., a causative/volitional role in an event, in both visual (Gobbini, Gentili, Ricciardi, et al. 2011; Khaligh-Razavi, Pantazis, & Oliva, 2018; Thorat, Proklova, & Peelen, 2019) and linguistic research (de Swart & van Bergen, 2019; Lai, Lacadie, Deo, & Pinango, 2020).

Caramazza and Shelton (1998) argue that evolutionary pressures have resulted in specialized neurological mechanisms for perceptual and conceptual differences in response to animate and inanimate objects. This is the domain-specific hypothesis that distinct attentional and cognitive responses to animate and inanimate concepts are essentially hard-wired into human cognition. Caramazza and Shelton present the alternative position to the domain-specific hypothesis as reductive to a domain-general account: because different mental resources are used in responding to different categories, the observed apparent category-specific advantages and deficits are epiphenomenal to the distinct subsystems deployed in association with animate and inanimate entities (Warrington & McCarthy, 1987; Shallice, 1988; Hillis, Rapp, &

Caramazza, 1995). In other words, the domain-general view of animacy takes the different neural signatures and mnemonic/attentional differences between animate and inanimate objects to be a result of the cumulative and distinct experiences people have with animate and inanimate objects. Thus, in this view, the effects are probabilistic and experiential rather than category-specific and innate.

One way we can explore how much, in garden-path self-paced reading research, the effect of animacy is influenced by probabilistic associations rather than category-specific effects is to employ corpus data about animacy and transitivity. A related concept, verb bias, is frequently used in sentence processing studies. Verb bias refers to the "bias" in the usage of a verb towards appearing in a particular syntactic construction. This measure can be derived from distributional frequencies in textual corpora (e.g., Merlo, 1994; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Gahl et al., 2004), although it is also often derived from production tasks or norming studies (e.g., Trueswell, Tanenhaus, & Kello, 1993). Corpus-based studies on verb bias count the occurrences of specific verbs in different constructional frames, which reflects the probability, or bias, that a specific verb will appear in a given construction. A common example is the contrast between sentential complements and direct objects; verbs like "confirm" have a strong bias for direct object continuations ("He confirmed the date" vs. "He confirmed that he was attending"), while verbs like "suggest" have a bias toward sentence complements ("She suggested the scene" vs. "She suggested they watch the scene"). Numerous studies have found that comprehension occurs more rapidly and more accurately when the experimental sentences match with verb biases (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Gahl,

2002). In this study, rather than standard verb-biases, we would like to examine animacy-verb biases and transitivity-animacy-verb biases.

Effects of verb bias, as well as of probabilistic associations between animacy and grammatical constructions, are in line with theoretical accounts of language like surprisal theory (Levy, 2008; see also, MacDonald, 1994; Jurafsky, 1996) that rely on parallel-access, probabilistic models of word recognition and sentence processing. These probabilistic models often, but not always, frame the human acquisition and use of language as dependent on domain-general capacities for symbolic learning, equating language comprehension to informational processing load, based on likelihoods of a certain continuation in a given context. In this sense, we might take corpus-derived verb biases for animacy and transitivity as estimates of the experiential, contextual influence of animacy-to-verb associations in the language environment. These animacy and transitivity probabilities can be compared to and included in regressions models that use only categorical factors for animacy and verb type.

Two animacy-based probabilities are used in this study. First, the simple probability of animacy of the sentence subject – the animacy-verb bias – is estimated by counting the number of animate/inanimate subject nouns in a corpus sample for each verb and dividing it by the total number of tokens of the verb. This value represents, for non-alternating unaccusative verbs, the likelihood of an animate or inanimate subject. For alternating unaccusatives, this value represents a) the likelihood of the animacy of the subject of the verb and b) an indirect indication of the likelihood of transitivity since most alternating unaccusatives associate subject animacy and transitivity. Second, the conditional probability of transitivity given the animacy of the subject – the transitivity-

animacy-verb bias – can be calculated by dividing the probability of transitivity for each animacy value of each verb by the animacy-verb bias of that verb. This conditional probability encodes not only animacy-transitivity biases but also the unaccusative verb type distinction since alternating unaccusatives will have a value representing the former, while non-alternating unaccusatives will be marked by having zero probability for animate and inanimate subject nouns.

Early closure garden-path effects, where there is slowed reading time immediately after an intransitive verb that ends a dependent clause without a comma, should be affected by both subject animacy probability and the conditional probability of transitivity given subject animacy (CPTA). An increase in subject animacy probability should be linked with reduced reading time for both verb types and both second noun animacy values. CPTA should be linked with reduced reading time with inanimate second nouns but increase it in with animate second nouns.

Late closure garden-path sentences create disruption at the disambiguating phrase, the auxiliary verb. At this point in late closure garden-path sentences, readers are searching for a subject noun for the main clause auxiliary verb, and because they have already assigned an object role to the second noun, they have to revise their interpretation of the clause structure in the sentence. Because this garden-path effect is dependent on accepting the second noun as an object, transitivity-animacy-verb bias (i.e., CPTA) – or the absence of such an effect – is meaningful at the disambiguating region. Subject animacy probability only indirectly relates to transitivity (and represents this only for alternating unaccusatives), and so conditional probability should be more meaningful than subject animacy probability for late closure garden-path effects.

Finally, an important consideration is how well categorical factors and probabilistic factors describe the reading time data in comparison to one another. At all regions, we should expect probabilistic models to fit the data better than categorical models, in line with the idea that processing load is influenced by probability. Especially at Region 2, such a finding would support a probabilistic view of the animacy-thematic mismatch effects that influence early-closure garden-path reading. At Region 3, however, if the categorical variables perform better than probabilistic variables with regard to model fit, this would suggest that late closure garden-path effects – the automatic assumption of a transitive clause – are a category-specific response to an animate subject noun.

Corpus samples

We extracted all tokens for each verb used in the self-paced reading studies, for all grammatical forms of the verb, from the Brown (Francis & Kucera, 1982) and Wall Street Journal Corpora, in the automatically parsed *Penn Treebank Project* (Marcus et al., 1993;). The *Brown Corpus* is a one-million-word collection of fiction, non-fiction, newspapers, and other sources, and *The Wall Street Journal* is a one-million-word corpus from the eponymous economics journal. After collecting the sentences, we tagged the *Brown Corpus* results for whether the subject noun was animate or inanimate. Transitive forms of each verb were also counted for each animacy value. Subject nouns that were not exactly animate but not exactly inanimate, like body parts and vehicles, were tagged as neither animate nor inanimate. Nouns that referred to a class of people, like "the senate," "the bank," or "the company," were considered inanimate. Other continuations, like infinitival and sentential complements and adjective phrases, were kept in the sample

and marked. Likewise, passive and past participial forms of verbs were marked as such and kept in the sample.

The resulting corpus consisted of a total of 4,758 tokens, out of which 1,001 tokens were transitive clauses. There were 2,880 tokens of alternating unaccusative verbs, 859 of which were transitive. There were 1,878 tokens of non-alternating unaccusative verbs, 142 of which transitive. Of alternating unaccusatives, 1,034 had an animate subject, and 552 of these were transitive (53%); there were 1,846 inanimate subject tokens, 307 of which were transitive (17%). Of non-alternating unaccusatives, 507 had an animate subject, 31 of which were transitive (6%); 1,371 had an inanimate subject, 111 of which were transitive (8%). These tokens of transitive constructions with non-alternating unaccusatives were the result of the previously mentioned three mislabeled verbs and of a peculiarity in the corpus sample, which are addressed below.

Subject animacy probability

From the tagged corpora, we calculated the probability of an animate/inanimate subject noun for each verb. Probabilities were arrived at by a) calculating the number of animate subject nouns for a given verb and dividing that number by the total number of appearances of that verb in the corpus; this probability was assigned to the animate version of the experimental sentence for this verb, and b) calculating the number of inanimate subject nouns for a given verb and dividing that number by the total number of appearances of that verb in the corpus; this probability was assigned to the inanimate version of the experimental sentence for this verb.

The average probability of an animate or inanimate subject showed some differences between the two verb types. Non-alternating unaccusatives had an average

probability of occurring with an animate subject of $M = 0.312$, $SE = 0.225$, and an average probability of occurring with an inanimate subject of $M = 0.613$, $SE = 0.205$ in the combined corpora. Alternating unaccusatives had an average probability of occurring with animate subject of $M = 0.395$, $SE = 0.216$, and an average probability of occurring with an inanimate subject of $M = 0.489$, $SE = 0.215$. Both verb types have a higher likelihood of inanimate rather than animate subjects, although non-alternating unaccusatives are more likely on average to have an inanimate subject than alternating unaccusatives.

Table 3.1: Subject animacy probability

Unaccusative type	Verb	Animate prob.	Inanimate prob.
Alternating	freeze	0.333	0.296
Alternating	swung	0.681	0.246
Alternating	grow	0.184	0.79
Alternating	open	0.329	0.571
Alternating	burn	0.222	0.569
Alternating	turn	0.631	0.32
Alternating	break	0.374	0.487
Alternating	close	0.099	0.799
Alternating	twist	0.539	0.269
Alternating	roll	0.425	0.462
Alternating	lean	0.893	0.089
Alternating	drop	0.244	0.728

Alternating	shut	0.35	0.55
Alternating	dry	0.222	0.667
Non-alternating	glow	0.273	0.636
Non-alternating	disappear	0.308	0.615
Non-alternating	decay	0.6	0.4
Non-alternating	settle	0.32	0.655
Non-alternating	die	0.829	0.159
Non-alternating	crumble	0.056	0.778
Non-alternating	appear	0.423	0.557
Non-alternating	emerge	0.247	0.536
Non-alternating	collapse	0.125	0.781
Non-alternating	arrive	0.608	0.329
Non-alternating	vanish	0.174	0.739
Non-alternating	fall	0.092	0.896
Non-alternating	float	0.226	0.613
Non-alternating	exist	0.09	0.883

Individual animacy-verb biases can be seen in Table 3. Among alternating unaccusatives, “swing,” “lean,” and “turn” were more often animate than inanimate, while “close,” “dry,” “grow,” and “open” were much more likely to have an inanimate subject. Animacy with these verbs may be taken as a stand-in for transitivity – animate subjects are more likely in transitive clauses, and inanimate subjects more likely in intransitive clauses. However, in many cases with alternating unaccusatives, verbs with a high likelihood of having an animate subject tend to have an unergative intransitive sense

when the subject is animate. For example, “lean” and “swing” can still be intransitive with an animate subject; in this case, the action is taken to be reflexive (i.e., “She leaned against the wall” or “He swung to face the audience”).

Individual verb biases are visible with non-alternating unaccusative verbs also. “Die” and “arrive” favor animate subject nouns. Verbs like “exist,” “glow,” “vanish,” and “crumble” are much more likely to appear with inanimate subject nouns. Non-alternating unaccusatives are well-suited to the probability of subject animacy as a measure since there is (or should be) no confounding relation between animacy likelihood and transitivity likelihood. Our main question in these experiments has been whether animacy-thematic mismatch effects influence reading times for non-alternating unaccusative verbs. However, animacy-thematic mismatch effects are likely to be tied to subject animacy biases. For non-alternating unaccusatives, including animacy probability in our regression model, along with animacy, allows us to test whether there is truly an animacy-thematic mismatch effect (i.e., a categorical effect), or if the observed effect results more from verb-specific animacy biases (i.e., a probabilistic effect).

Conditional animacy-transitivity probability

Transitivity-animacy-verb biases (i.e., CPTA) were also calculated. Transitive constructions were defined as any syntactic structure that had a determiner and noun following the intransitive verb. CPTA were arrived at by dividing the likelihood of a token being both (in)animate and transitive by the likelihood of the token being (in)animate. For example, the word “roll” had 106 tokens. Forty-nine occurred with an inanimate subject and 45 with an animate – and twelve were passive or other constructions. Of inanimate tokens, ten were transitive; of animate tokens, seventeen

were transitive. The conditional probability of transitivity for inanimate tokens then is 10/106 divided by 49/106, or 0.204. This factor allows us to directly estimate the quality b) above for alternating unaccusative verbs. For non-alternating unaccusatives, this value should be close to zero in all cases.

CPTA differed between the two unaccusative verb types. Alternating unaccusatives with an animate subject had an average conditional probability for transitivity of $M = 0.46$, $SE = 0.287$ and, with an inanimate subject, of $M = 0.224$, $SE = 0.189$ in the combined corpora. Non-alternating unaccusatives with an animate subject had an CPTA of $M = 0.142$, $SE = 0.267$ and, with an inanimate subject, of $M = 0.056$, $SE = 0.108$. Animate subject sentences with alternating unaccusative verbs favored transitive clauses much more so than any other sentence type. With "settle," "crumble," "collapse," and "float" removed, non-alternating unaccusative sentences have an average CPTA of nearly zero for both subject animacy values.

Table 3.2: Conditional probability of transitivity given subject animacy

Unaccusative type	Verb	Animate prob.	Inanimate prob.
Alternating	freeze	0.111	0.625
Alternating	swung	0.489	0.000
Alternating	grow	0.171	0.101
Alternating	open	0.973	0.381
Alternating	burn	0.313	0.049
Alternating	turn	0.48	0.282
Alternating	break	0.628	0.268

Alternating	close	0.894	0.095
Alternating	twist	0.357	0.286
Alternating	roll	0.378	0.204
Alternating	lean	0.06	0.000
Alternating	drop	0.606	0.081
Alternating	shut	0.81	0.545
Alternating	dry	0.167	0.222
Non-alternating	glow	0.000	0.000
Non-alternating	disappear	0.000	0.000
Non-alternating	decay	0.000	0.000
Non-alternating	settle	0.339	0.299
Non-alternating	die	0.000	0.000
Non-alternating	crumble	0 .999	0.000
Non-alternating	appear	0.009	0.007
Non-alternating	emerge	0.000	0.000
Non-alternating	collapse	0.125	0.02
Non-alternating	arrive	0.000	0.000
Non-alternating	vanish	0.25	0.059
Non-alternating	fall	0.04	0.088
Non-alternating	float	0.226	0.316
Non-alternating	exist	0.000	0.000

While most alternating unaccusatives showed a preference for animate subjects in transitive constructions, two verbs, “freeze” and “dry,” had a greater CPTA for inanimate

subjects than animate. This counter-intuitive finding appears to be fueled by the fact that both verbs denote a natural force that humans can only facilitate; people do not dry or freeze items themselves. Instead, natural forces like heat or cold or sun or wind may be utilized by humans to dry or melt or freeze. The animate-esque quality of natural forces in mental representation has been investigated in Lowder & Gordon (2015), which they ascribe to the perception of animacy as a discrete proto-role for agency (Dowty, 1991) or, similarly, as part of the human interpretation of the perceived object's ability to generate internal force (Wolff, Jeon, & Li, 2009). Thus, astronomical or meteorological activities may be semantically inanimate, but they also possess features that human evolution would benefit from monitoring as if they were animate.

Non-alternating unaccusative verbs also showed some anomalous results in the corpus data for CPTA. As mentioned in Chapter 2, three verbs originally classified as non-alternating do take part in the transitive alternation, "settle," "crumble," and "collapse," which was confirmed in the corpus analysis. Each of these verbs has a relatively high rate of transitive constructions when they appear with an animate subject. We saw in Chapter 2 that removing these verbs did influence reading times to an extent. "Float" also appears to take part in the transitive alternation. However, this may be an artificial effect from using the WSJ corpus, where "float" can be used as a synonym of "lend," e.g., "The bank floated a loan to the business." All transitive tokens arose from this use of "float" in the WSJ corpus. Because of this artificial effect, "float" was not removed with the three other misassigned non-alternating unaccusatives in the secondary analysis in Chapter 2.

Methods

Analysis

These analyses used the same residualized reading times as in the previous experiment. To see whether the continuous (i.e., corpus-derived) predictors differed from the categorical predictors, we compared model fit using the corrected AIC (Sakamoto, Ishiguro, & Katagawa, 1986) in the qPCR package in R (Spiess & Spiess, 2018). This method is ideal because models can be compared that are not nested and where the f-test on residual-sum-of-squares is not applicable, meaning we can test the performance of models that do not share nested factors. Additionally, AIC is a good measure of fit, because unlike R^2, where every factor added into a model improves fit, AIC is penalized for each parameter added to the model (Burnham & Anderson, 2002). Smaller AIC values suggest a better balance of fit and parsimony. A difference of 2 or less AIC between models should be taken to mean the models are essentially equally good, a difference of less than 6 means both models should be considered, and a difference of greater than 10 AIC is strong evidence that the higher-AIC model can be rejected (Burnham & Anderson, 2002; Anderson, 2008). Along with the delta of model AIC, we use evidence ratios as means of quantifying the difference between the fit of the two models. For example, if the AIC of Model A has an evidence ratio of four to one to that of Model B, Model A is four times more likely to be a better approximating fit than Model B (Petrossian & Maxfield, 2018). For each region, the corrected AIC was compared for a model with only the probabilistic variables (probability of subject animacy and CPTA) and a model with only the categorical variables (first noun animacy and verb type); both models also included second noun animacy as a categorical factor.

Likewise, both models were compared with a model containing all – both probabilistic and categorical – variables.

We also review the results of the model with only probabilistic variables and second noun animacy. Estimates of the effect of each continuous predictor were compared for the two levels of the single categorical using a single contrast and confidence intervals for the trends of both simple probabilities of animacy and CPTA. The results of regression analysis for the stepwise reduced with both probabilistic and categorical variables are also reviewed for Regions 2 and 3 model (using the step () function in lme4 (Bates, Mächler, Bolker, & Walker, 2015)), as well as the estimates and confidence intervals for the trend of effect for each probabilistic variable in each condition. All confidence intervals are adjusted through the Bonferroni method for eight measures.

Hypotheses

We perform three sets of tests: comparison of model fit for categorical and probabilistic factors, the results of the regression model for the probabilistic factor only model for all regions, and the results of the backward-selection reduced model for both categorical and probabilistic factors for Regions 2 & 3.

1. Comparison of model fit should show lower corrected AIC values for probabilistic models than for categorical models at all regions. At Region 2, if there is better performance of categorical models, this will suggest that early closure garden-path effects are less in line with probability-based associations with animacy but are instead more in line with a categorical effect of animacy and thematic role. At Region 3, if there is better performance for categorical models,

this will suggest that late closure garden-path effects are less in line with probability-based associations with animacy but are instead more in line with a categorical effect of animacy and thematic role.

2. In the probabilistic factor only model, subject animacy probability is expected to be significant at all regions, and CPTA is expected to be significant at Region 3. For the backward-selection reduced models, the factors that remain in the model are important, as well as the results of the model itself. In these models, there may be further support or clarification of Hypothesis 1.

Results

Results for model fit comparison

At Region 1 (AIC: 2,628.034), Region 2 (AIC: 4,995.439), and Region 4 (AIC: 4,857.511), the model with corpus-based probabilities led to a better fit to the dependent variable, residualized reading time, than the model with categorical predictors (Region 1 AIC: 2,650.621, Region 2 AIC: 5,016.24, Region 4 AIC: 4,879.779). The corrected AIC values for each region were compared for the models with corpus-based continuous variables and the categorical factors. For Region 1, the probability-based model was 209.275 times more likely a better fit than the categorical model. For Region 2, the probability-based model was 32,876.51 times more likely a better fit than the categorical model. For Region 4, the probability-based model was 68,448.57 times more likely a better fit than the categorical model. At Region 3, however, a model with only the categorical predictors (AIC: 5,699.085) led to a better fit than the model with probability-based factors (AIC: 5,752.033). Comparison of the two model fits showed that the

categorical model was 14,422,338,464 times more likely a better fit than the probability-based model.

When a model was used that contained all continuous and categorical predictors, a similar pattern of results arose. For Region 1, the full model had a corrected AIC of 2,704.393, which is much higher than either of the simpler models and, therefore, likely a worse balance of parsimony and fit. Region 2 had a full model corrected AIC of 5,048.748, again much higher than either of the simpler models. At Region 4, the corrected AIC for the full model was 4,934.129, likewise much higher than either of the simpler models. The full model of Region 3, on the other hand, showed an improvement over the probability-derived model but not over the categorical model. The full model corrected AIC was 5,747.37, which is better than the probability-derived predictor only model, at 5,752.033. However, the categorical model was much lower than either one; with an AIC of 5,699.085, it was 30,538,234,757 times more likely a better fit than the full model with continuous and categorical variables.

The fact that the model with continuous factors fits the data better than a model with categorical factors suggests that early closure garden-path effects may be better explained by the probabilistic association of animacy and verbally assigned thematic roles. This finding suggests that the relationship between verbs and animate and inanimate subjects are learned over time in conjunction with language, and biases are better explained probabilistically than categorically. In the conception of early closure, garden-path sentencers in Staub (2007) are a lack of ability to detect the end of the initial clause due to a lack of punctuation. In Chapter 2, we showed that animacy-thematic

mismatch effects influence this effect; here, we see that this effect may be more probabilistic rather than categorical.

The results at Region 3 suggest, however, that late closure garden-path effects, may result from domain-specific first noun animacy and verb type effects. The categorical factors better describe the data than the continuous, probability-derived predictors at the disambiguating phrase. This suggests that transitive interpretations may be automatic syntactic processes, as argued in the parsimony-based, serial processing accounts, but that these automatic syntactic processes are sensitive to noun animacy.

In what follows, model comparison results for the continuous models are shown for all regions. After this, we review the results for the backward-selected version of the full continuous and categorical factor models for Regions 2 and 3.

Results for models with corpus-derived probabilities only

Region 1

There were no significant effects found in the mixed-effects linear regression nor in the planned contrasts or confidence intervals.

Region 2

There was a main effect of probability of subject animacy ($\chi^2(1) = 4.604$, $p = 0.032$), suggesting that higher probability of subject animacy correlated with lower reading times. There was also a main effect of second noun animacy ($\chi^2(1) = 4.657$, $p = 0.031$), suggesting that animate second nouns were read faster. The two-way interaction between CPTA and second noun animacy ($\chi^2(1) = 5.5$, $p = 0.019$) was significant. The three-way interaction between second noun animacy, CPTA, and probability ($\chi^2(1) = 3.375$, $p = 0.066$) was marginally significant. There was also a marginally significant

two-way interaction between the effect of subject animacy probability and CPTA ($\chi^2(1) = 3.835$, $p = 0.05$).

Animate and inanimate second noun sentences both showed disruption, with residualized reading time confidence intervals above zero (inanimate second noun: ($M = 0.047$, $SE = 0.013$, *95% CI:* 0.022, 0.071), animate second noun: ($M = 0.029$, $SE = 0.0123$, *95% CI:* 0.004, 0.053). There was no significant difference between animate and inanimate second nouns in the contrast ($M = 0.018$, $SE = 0.015$, $z = 1.240$, $p = 0.215$).

Confidence intervals for the effect of probability of subject animacy showed that greater probability was associated with lower reading times, both with animate second nouns ($M = -0.106$, $SE = 0.028$, *95% CI:* -0.161, -0.05) and inanimate ($M = -0.086$, $SE = 0.029$, *95% CI:* -0.141, -0.029). There was no difference in this trend between animate and inanimate second nouns ($M = 0.021$, $SE = 0.039$, $z = 0.538$, $p = 0.591$).

Confidence intervals for the trend of the effect of CPTA also showed that greater conditional probability of transitivity was correlated with lower reading times both with animate ($M = -0.073$, $SE = 0.035$, *95% CI:* -0.142, -0.005) and inanimate second nouns ($M = -0.156$, $SE = 0.035$, *95% CI:* -0.225, -0.087). A contrast of these trends depending on second noun animacy showed that inanimate second noun sentences had a greater decrease in reading time than animate as the conditional probability of transitivity increased ($M = -0.083$, $SE = 0.039$, $z = -2.109$, $p = 0.035$).

Region 3

There was a significant main effect of subject animacy probability ($\chi^2(1) = 11.221$, $p = 0.001$), suggesting that as probability increased, reading time went down. There was a significant interaction between subject animacy probability and second noun

animacy ($\chi^2(1) = 4.285$, $p = 0.038$) and between CPTA and second noun animacy ($\chi^2(1) = 6.166$, $p = 0.013$). There was a marginal significant three-way interaction between subject animacy probability, CPTA, and second noun animacy ($\chi^2(1) = 3.431$, $p = 0.064$).

Confidence intervals showed significant reading disruption for both inanimate second noun sentences ($M = 0.032$, $SE = 0.012$, *95% CI:* 0.009, 0.055) and animate second noun sentences ($M = 0.031$, $SE = 0.012$, *95% CI:* 0.009, 0.054), but no difference between the two ($M = 0.001$, $SE = 0.013$, $z = 0.07$, $p = 0.944$).

The trend of effect for subject animacy probability showed no disruption or facilitation for either animate or inanimate second nouns, and again there was no difference between the two ($M = 0.027$, $SE = 0.041\ 5$, $z = 0.655$, $p = 0.512$).

Confidence intervals for the trend of effect for CPTA showed disruption for both inanimate ($M = 0.126$, $SE = 0.038$, *95% CI:* 0.052, 0.2) and animate second nouns ($M = 0.228$, $SE = 0.037$, *95% CI:* 0.156, 0.301). The higher the CPTA, the more disruption. This effect of this CPTA-driven disruption was greater for animate second noun sentences ($M = -0.102$, $SE = 0.042$, $z = -2.421$, $p = 0.016$).

Region 4

There was a significant main effect of CPTA ($\chi^2(1) = 9.729$, $p = 0.002$), such that as CPTA increased, reading time decreased. The interaction between CPTA and second noun animacy was significant ($\chi^2(1) = 4.499$, $p = 0.034$). The three-way interaction between subject animacy probability, CPTA, and second noun animacy was significant ($\chi^2(1) = 10.438$, $p = 0.001$).

Confidence intervals for residualized reading time by second noun animacy showed facilitation with inanimate second nouns ($M = -0.024$, $SE = 0.011$, *95% CI:* -

0.044, -0.003), but not with animate second nouns. There was no difference between the two (M = -0.013, SE = 0.013, z = -1.023, p = 0.306).

The confidence intervals of the trend for the effect of subject animacy probability showed no disruption or facilitation for either animate or inanimate second nouns, and a contrast showed no difference between the two (M = -0.041, SE = 0.038, z = -1.089, p = 0.276).

The confidence intervals of the trend for the effect of CPTA showed facilitation with inanimate second noun sentences (M = -0.114, SE = 0.033, *95% CI:* -0.178, -0.051), but not for animate second noun sentences. There was a greater facilitative effect of CPTA for inanimate second non sentences than for animate (M = -0.101, SE = 0.039, z = -2.602, p = 0.009).

In sum, there are facilitative effects early on (Region 2) for both CPTA and subject animacy probability. Then, at Region 3, there is no effect of subject animacy probability and a disruptive effect of CPTA. Finally, at the post-disambiguating region (Region 4), there is again no effect of subject animacy probability, and now a facilitative effect of CPTA. The effect of CPTA interacted with second noun animacy, such that inanimate second nouns were read faster than animate. This may suggest that participants found particular difficulty revising their transitive interpretation when the animacy of the second noun reenforced such a reading, and the sentence was abandoned by the final region or, alternatively, that participants recognized it would be an ungrammatical sentence and ceased paying attention to the sentence. This latter option is quite possible given there were no comprehension questions following the sentences.

Results for Regions 2 & 3 with model selection

Region 2

The stepwise backward model selection found a reduced model with 17 fixed factors and interactions. As noted above, the corrected AIC for this reduced model was comparable to the categorical-only model but did not perform as well as the probability-only model. The factors and interactions that were in the model are shown in Table 5 below. This model had a corrected AIC of 5,012.03, which is a better fit than the categorical-only model (5,016.24) but still much worse than the probability-only model (4,995.439).

Table 3.3: Variables and significance for Region 2[10]

Variable	χ^2	p-value
First noun animacy	0.768	0.381
Second noun animacy	6.421	0.011*
Verb type	2.796	0.095
Subject animacy probability	0.011	0.917
CPTA	8.02	0.005**
First noun animacy x verb type	11.222	< 0.001***
First noun animacy x CPTA	7.541	0.006**
First noun animacy x subject animacy probability	5.502	0.019*
Verb type x CPTA	10.746	0.001***

[10] For p-values, * indicates significance at 0.05, ** indicates significance at 0.01, and *** indicates significance beyond the 0.01 threshold. With confidence intervals, * indicates that a range that doesn't include zero.

Subject animacy probability x CPTA	10.629	0.001***
Second noun animacy x CPTA	15.67	< 0.001***
First noun animacy x verb type x CPTA	10.178	0.001***
First noun animacy x verb type x subject animacy probability	12.626	< 0.001***
CPTA x subject animacy probability x first noun animacy	5.008	0.025*
CPTA x subject animacy probability x verb type	9.687	0.002**
First noun animacy x verb type x CPTA x subject animacy probability	9.577	0.002**

In the Region 2 regression model, there was a significant main effect for CPTA ($\chi^2(1) = 8.02$, $p = 0.005$), suggesting that the higher the CPTA, the longer it took to read, and second noun animacy ($\chi^2(1) = 6.421$, $p = 0.011$), suggesting that lower reading times were associated with animate second nouns. Verb type showed a marginal effect ($\chi^2(1) = 2.796$, $p = 0.095$). There were significant two-way interactions between CPTA and first noun animacy ($\chi^2(1) = 7.541$, $p = 0.006$), CPTA and second noun animacy ($\chi^2(1) = 15.67$, $p < 0.001$). CPTA and verb type ($\chi^2(1) = 10.746$, $p = 0.001$), CPTA and subject animacy probability ($\chi^2(1) = 10.629$, $p = 0.001$), first noun animacy and subject animacy probability ($\chi^2(1) = 5.502$, $p = 0.019$), and between first noun animacy and verb type ($\chi^2(1) = 11.222$, $p < 0.001$). Three-way interactions were significant between CPTA, subject animacy probability, and first noun animacy ($\chi^2(1) = 5.008$, $p = 0.025$), between CPTA, subject animacy probability, and verb type ($\chi^2(1) = 9.687$, $p = 0.002$), between CPTA, first noun animacy, verb type ($\chi^2(1) = 10.178$, $p = 0.001$), and first noun animacy,

verb type, and subject animacy probability ($\chi^2(1) = 12.626$, $p < 0.001$). The four-way interaction between CPTA, subject animacy probability, first noun animacy, and verb type was significant ($\chi^2(1) = 9.577$, $p = 0.002$).

Confidence intervals for reading times showed disruption for all conditions except for animate first noun, non-alternating unaccusative sentences with both animate and inanimate second nouns (Table 6 below). This is an interesting finding since it differs quite clearly from the results in Chapter 2, where inanimate first noun, non-alternating unaccusative sentences were read faster.

Table 3.4: Condition confidence intervals for reading times at Region 2

First noun	Second noun	Verb type	Estimate	SE	Lower CI	Upper CI
Inan.	Inan.	Non-alt.	0.225	0.071	0.03	0.419*
An.	Inan.	Non-alt.	0.036	0.036	-0.062	0.134
Inan.	Inan.	Alt.	0.056	0.014	0.018	0.095*
An.	Inan.	Alt.	0.073	0.016	0.028	0.118*
Inan.	An.	Non-alt.	0.211	0.071	0.017	0.406*
An.	An.	Non-alt.	0.023	0.036	-0.076	0.121
Inan.	An.	Alt.	0.043	0.014	0.005	0.081*
An.	An.	Alt.	0.06	0.016	0.015	0.10*

Confidence intervals for the effect of subject animacy probability showed that greater probability was associated with facilitation for inanimate first noun, non-alternating unaccusative sentences (Table 7 below). This finding may explain the contradictory nature of the reading time values between Chapter 2 and our current

experiment; not all unaccusatives are highly sensitive to animacy-thematic mismatch, but those unaccusatives that are are easier to process if they have an inanimate first noun.

Note that because there was no first noun x second noun animacy probability interaction in the model, the results are the same for animate and inanimate second nouns, and therefore we do not include second noun animacy in the table below.

Table 3.5: Condition confidence intervals for subject animacy prob. at Region 2

First noun	Verb type	Estimate	SE	Lower CI	Upper CI
Inan.	Non-alt.	-1.035	0.352	-1.997	-0.074*
An.	Non-alt.	-0.161	0.109	-0.46	0.137
Inan.	Alt.	-0.137	0.05	-0.298	0.023
An.	Alt.	0.089	0.053	-0.057	0.234

Confidence intervals for the effect of CPTA showed a trend for facilitation (Table 8 below) with alternating unaccusative verbs regardless of whether the first noun was inanimate or animate as long as the second noun was inanimate. When the second noun was animate, there was also facilitation when the first noun was animate. In other words, the higher the CPTA, the faster the reading time when the second noun didn't contradict a transitive interpretation. When the second noun was animate, there was the same effect for animate first nouns, but not for inanimate first nouns. There was also a disruptive effect for inanimate first noun, animate second noun sentences with non-alternating unaccusatives. Higher CPTA was associated with higher reading time. Notice the same pattern with this unaccusative type: inanimate first noun sentences were read slower than other conditions when the second noun contradicts a transitive reading. This effect appears to reinforce the notion that the mislabeled non-alternating led to interference in

our regression models (i.e., supporting the version of the models in Chapter 2 that didn't include those three verbs).

Overall, the backward-selection reduced model showed highly integrated effects of categorical and probabilistic variables at Region 2. Both verb type and first noun animacy are involved in two-way and three-way interactions, as well as the full four-way interaction with subject animacy probability and CPTA. Alternating unaccusative verb sentences were read faster here when CPTA was higher for all sentence conditions except with an inanimate first and animate second noun. Higher CPTA was associated with slower reading times for inanimate first noun, animate second noun sentences, but this must be an effect of the inclusion of the three non-alternating unaccusative verbs that were better classified as alternating unaccusative verbs. This model also suggests that the influence of animacy on early closure garden-path effects with non-alternating unaccusatives is probabilistic, as in this model there was no animacy-thematic effect. Instead, higher subject animacy probability was associated with faster reading in inanimate first noun sentences with non-alternating unaccusative verbs.

Table 3.6: Condition Confidence Intervals for CPTA at Region 2

First noun	Second noun	Verb type	Estimate	SE	Lower CI	Upper CI
Inan.	Inan.	Non-alt.	0.799	0.321	-0.07	1.676
An.	Inan.	Non-alt.	-0.24	0.168	-0.699	0.22
Inan.	Inan.	Alt.	-0.171	0.058	-0.33	-0.012*
An.	Inan.	Alt.	-0.27	0.046	-0.396	-0.144*
Inan.	An.	Non-alt.	0.923	0.321	0.047	1.8*
An.	An.	Non-alt.	-0.116	0.168	-0.575	0.343

Inan.	An.	Alt.	-0.048	0.058	-0.207	0.112
An.	An.	Alt.	-0.146	0.046	-0.271	-0.021*

Region 3

The stepwise backward model selection found a reduced model with nine fixed factors or interactions. The corrected AIC for this model was 5,697.031, which comparable to the categorical-only model (5,699.085). This reduced model is 2.793 times better than the categorical, which is not enough to conclude that either is truly the better or more likely model. Both this reduced model and the categorical only far outperformed the probability-only model. The variables included in the reduced model are shown in Table 9 below.

Table 3.7: Variables and significance for Region 3

Variable	χ^2	p-value
First noun animacy	4.098	0.043*
Second noun animacy	0.939	0.333
Verb type	22.54	< 0.001***
Subject animacy probability	6.195	0.013*
First noun animacy x verb type	38.407	< 0.001***
First noun animacy x second noun animacy	1.703	0.192
First noun animacy x subject animacy probability	0.002	0.961
Second noun animacy x subject animacy probability	0.983	0.322

First noun animacy x second noun animacy x subject animacy probability	6.114	0.013*

In the regression model, there was a significant main effect for first noun animacy ($\chi^2(1) = 4.098$, $p = 0.043$), suggesting higher reading times for animate subjects, for verb type ($\chi^2(1) = 22.54$, $p < 0.001$), suggesting higher reading times for alternating unaccusatives, and for subject animacy probability ($\chi^2(1) = 6.195$, $p = 0.013$), suggesting that the higher the probability of subject animacy, the longer the reading time. There was a significant two-way interaction for first noun animacy and verb type ($\chi^2(1) = 38.407$, $p < 0.001$). There was significant three-way interaction between first noun animacy, second noun animacy, and subject animacy probability ($\chi^2(1) = 6.114$, $p = 0.013$).

Confidence intervals for reading times (Table 10 below) showed the same pattern as in Chapter 2. The animate first noun sentences with alternating unaccusative verbs had increased reading time regardless of second noun animacy. No other confidence intervals excluded zero. These findings do not substantially differ from those of the categorical model.

Table 3.8: Condition confidence intervals for reading times at Region 3

First noun	Second noun	Verb type	Estimate	SE	Lower CI	Upper CI
Inan.	Inan.	Non-alt.	-0.008	0.017	-0.053	0.037
An.	Inan.	Non-alt.	-0.022	0.017	-0.067	0.022
Inan.	Inan.	Alt.	0.017	0.015	-0.025	0.058
An.	Inan.	Alt.	0.115	0.016	0.073	0.156*
Inan.	An.	Non-alt.	-0.022	0.016	-0.067	0.022
An.	An.	Non-alt.	0.000	0.016	-0.044	0.043

Inan.	An.	Alt.	0.002	0.015	-0.039	0.043
An.	An.	Alt.	0.137	0.015	0.096	0.179*

Confidence intervals for the effect of subject animacy probability showed no disruption or facilitation in any condition (Table 11). The fact that there is no disruption or facilitation from subject animacy probability in any one condition suggests that the categorical factors accounted for late closure garden-path effects adequately. Because verb type was in a four-way interaction with probability and first and second noun animacy, the confidence intervals do not differ across verb types.

Table 3.9: Condition confidence intervals for subject animacy prob. at Region 3

First noun	Second noun	Estimate	SE	Lower CI	Upper CI
Inan.	Inan.	0.02	0.05	-0.116	0.156
An.	Inan.	-0.085	0.048	-0.217	0.046
Inan.	An.	-0.12	0.049	-0.254	0.014
An.	An.	-0.026	0.047	-0.154	0.103

At Region 3, the backward-selection reduced models showed much less integration between effects. Notably, it did not include CPTA in any interactions or as a main effect. Subject animacy probability didn't have a significant effect in any one condition in the confidence intervals, although it was significant in the three-way interaction with first and second noun animacy. The main effect of subject animacy probability indicated that the higher the probability, the longer the reading time. Notably, this effect is the opposite of what we saw in the probability only model, where at Region 3, higher subject animacy probability correlated with lower reading times. In the probabilistic variable only model, CPTA instead had an increase in reading time as it

increased. In other words, with both probabilistic and categorical factors in the model, subject animacy probability ends up playing the role the CPTA played in the probabilistic variable only model.

Discussion

We performed three separate tests. First, we compared the corrected AIC values of models with the two probabilistic variables, CPTA and subject animacy probability, to those of models with the two categorical variables (first noun animacy and verb type), as well to models with both types of variables. We found that models with only probabilistic variables (and one categorical variable: second noun animacy) provided a better fit for the data from Regions 1, 2, and 4[11]. This suggests that early closure garden-path effects may not be different from other, more general effects regarding the likelihood of the structure of the sentence – a dependent clause with an intransitive verb followed by a main clause without a comma in between. In general, when there was more agreement between animacy-based and verb-based expectations, sentences were easier to read. Likewise, at these regions, information about how strongly an animate or inanimate subject influenced the likelihood that the clause would be transitive was more meaningful for describing the results than the categorical variables of first noun animacy and verb type.

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[11] It's interesting that Region 4 patterns with probabilistic models, while Region 3 does not. Region 4 is a likely spill-over region for Region 3, and we might expect to see late closure garden-path effects here. However, this region is late enough in the sentence that there may be wrap-up effects that influence reading, so Region 4 is difficult to interpret. It is a post-disambiguating area.

However, the results at Region 3 were better described by the categorical only model. This model included first noun animacy and verb type, as well as second noun animacy. The better performance of a categorical variable model reflects the fact that alternating unaccusative sentences an animate first nouns show a reading disruption here – a late closure garden-path effect – while other sentence types do not. For this region, models including the probability of first noun animacy and its relation to transitivity do not provide sufficient improvement in fit to balance the lost parsimony due to added parameters, whereas models including the categorical variables do. This outcome is more informative about the lack of effect of first noun animacy rather than CPTA, as the latter encodes the verb type distinction – all true non-alternating unaccusatives have very low or zero CPTA regardless of first noun animacy, while true alternating unaccusatives have some continuous value.

These findings might suggest that there are distinct mechanisms for early closure and late closure garden-path sentences. The better performance from probabilistic models at describing the results in Regions 1, 2, and 4 is consistent with the idea that early closure effects are due to probabilistic language use from many information sources in parallel, in line with probabilistic approaches to sentence processing like Levy (2008), MacDonald (1994), or Jurafsky (1996). Late closure garden-path effects may be more automatic, such that when the verb has the option of being transitive and an animate subject precedes it, then readers initially interpret the next noun as an object. This could represent a kind of "attach anyway" effect (Fodor & Inoue, 1998), in which if readers can grammatically interpret a new word within the current phrase being built in a word-by-word parse, they will do so even if it appears unacceptable. First and second noun

animacy provide sufficient information (along with verb type) to describe readers' reaction times, and probabilistic information is not necessary to capture this effect. This view would support a domain-specific effect of subject animacy for late closure garden-path effects, while early closure garden-path effects occur because of more general experience with sentence constructions.

Second, we performed exploratory regressions that may tell a more nuanced story. First, we reviewed the results for a model using only subject animacy probability, CPTA, and second noun animacy. In these analyses, both CPTA and subject animacy probability were associated with lower reading time at Region 2. This suggests that non-alternating unaccusatives had lower reading times the more likely the verb was to have the animacy that it did in the condition it appeared in. Alternating unaccusatives that had a high likelihood of a transitive clause were read faster or slower depending on how associated transitivity was with subject animacy for each verb. At Region 3, subject animacy probability was not significant, and, instead, higher CPTA correlated with longer reading time. In other words, the more likely a verb was to be in a transitive clause given the animacy of the subject noun, the stronger the late closure garden-path effect. Second noun animacy influenced the results in a way consistent with those in Chapter 2: animate second nouns led to easier reading of early closure garden-path sentences, but animate second nouns equally led to disruption for late closure garden-path sentences. In fact, higher CPTA values were associated with higher reading times with animate second nouns than inanimate.

We also reviewed models that included both probabilistic and categorical variables, although the models were reduced using a stepwise procedure. At Region 2, the

categorical and probability-based variables had a highly integrated effect on reading time. One notable exception was second noun animacy, which was only present as a main effect showing animate second nouns to lead to lower reading time (in line with the idea that animate second nouns make it easier to recognize a new clause has begun), and in an interaction with CPTA, showing that when CPTA was high, animate second nouns were associated with longer reading times. The probabilistic and categorical models showed that, for non-alternating unaccusatives, the residualized reading times showed the reverse pattern as was seen in the categorical model in Chapter 2: animate first noun sentences did not show disruption, and inanimate first noun sentences did. However, the strong negative correlation between subject animacy probability and reading time for inanimate first noun, non-alternating unaccusative sentences suggests that the animacy-thematic mismatch effect in Chapter 2 may be driven by probabilistic information.

At Region 3, there were very few interactions that ended up being included in the reduced model. The only interactions were first noun animacy and verb type, such that animate first noun sentences with alternating unaccusatives took longer to read, and the interaction between subject probability, first noun animacy, and verb type. This latter interaction indicated that inanimate first and second noun sentences and animate first and second noun sentences took longer to read when the subject animacy probability was higher. With alternating unaccusatives, this makes sense because animate first noun sentences are more likely to be transitive, thus inducing more disruption when the second noun is animate and therefore incompatible with a transitive reading. Likewise, inanimate first noun sentences will have the potential for a transitive reading when the second noun

is inanimate, and this potential may be stronger with alternating unaccusatives that prefer inanimate subjects.

Our clearest finding here is that the influence of subject animacy on non-alternating unaccusative verb early closure garden-path sentences may be related to only specific verbs. When these verbs are strongly associated with inanimate subject nouns, an animate subject noun leads to more disruption following the verb. With other non-alternating unaccusative verbs, neither animate or inanimate subjects was associated with disruption.

Limitations

It is premature to draw any conclusions from this study concerning the domain-specific or domain-general nature of animacy sensitivity, as well as for whether animacy is categorically or probabilistically defined in the mind. Our variables aren't nearly as complex as, for example, the Bayesian predictions used in Levy (2013), which were able to capture the difference between early closure and late closure garden-path sentences using only individual verb biases for transitivity. Furthermore, our experimental data does not directly reflect on neurophysiological mechanisms or ontology, but is based on behavioral data. Our findings nevertheless suggest that the models used in Levy (2013) could be updated to include animacy to better explain lexical effects in garden-path sentences. Finally, the stepwise reduced model performed slightly better than the categorical variable only model at Region 3, which may reflect the existence of more specific feature weightings in the natural processing of late closure garden-paths than either the categorical or probabilistic variables can describe by themselves. Despite these caveats, this study does provide some support for animacy as a categorical effect, rather

than a probabilistic effect, as far as its influence on late closure garden-path sentences. Likewise, this finding supports the idea that early closure garden-path effects are not categorically driven by animacy, but rather depend on readers' probabilistic associations between inanimate nouns, thematic roles, and individual verbs.

Another limitation of this study is the low number of tokens in the corpus. Some verbs had only a small number of tokens, which is a major weakness in estimates and values derived from them. In future work, it would be good to utilize the *British National Corpus,* which is a much larger corpus that is tagged for construction and included in the *Penn Treebank Project* – or ideally an American dialect equivalent – to increase our token count. With the experience and findings in this chapter, applying a similar procedure to larger corpora and perhaps more individual verbs could be streamlined as a process and allow more generalizable conclusions.

Conclusion

This study used corpus-based animacy-verb probabilities to examine early closure and late closure garden-path effects. We found that the animacy-thematic mismatch effects that influence early closure garden-path effects described in Chapter 2 are primarily a result of expectations for subject animacy. In particular, when non-alternating unaccusatives are biased toward inanimate subject nouns, that bias has a strong influence on residualized reading time that seems to account for the animacy-thematic mismatch effects observed previously. Late closure garden-path effects were better described by the categorical-only model or equally well by a reduced model in which the probability of subject animacy and the animacy of the subject and post-verbal noun influenced reading

disruption. More refined research on animacy bias and its influence on sentence processing is needed.

Chapter 4: Unaccusative and Unergative Verbs

Introduction

In this chapter, we further examine the effects of noun animacy on early closure garden-path sentences. We replicate the findings with non-alternating unaccusative verbs from Chapter 2 using a new set of stimuli, an increased number of items, and comprehension questions rather than grammaticality judgments. We also test how noun animacy influences early closure garden-path sentences with unergative verbs, which are more biased towards animate subjects. Because of COVID-19 restrictions, this experiment was done remotely online. This experiment recruited participants from a student population, from the platform *Amazon Mechanical Turk*, as well a smaller uncompensated group and a lottery group recruited via Facebook and Reddit. Our findings show consistent effects of animacy-thematic mismatch with both types of intransitive verb, although unaccusative verbs are influenced by animacy-thematic mismatch later than unergative sentences. With the *Amazon Mechanical Turk* group, unergative sentences showed animacy-mismatch effects at Region 2 and unaccusative sentences showed animacy-thematic mismatch effects at Region 3. This was slightly delayed from the pattern with the student and other groups, for which unergative sentences were influenced by animacy-thematic mismatch at Region 1 and 2 and unaccusative sentences were influenced at Region 2. Finally, the effect of second noun animacy was confirmed here, such that animate second noun sentences were consistently read more easily than inanimate second noun sentences.

Literature Review

It is well established that unergative and unaccusative (non-alternating) verbs induce different processing patterns and may involve different neurological mechanisms (Shetreet, Friedmann, & Hadar, 2010; Agnew, van de Koot, McGettigan, & Scott, 2014; Meltzer-Asscher, Mack, Barbieri, & Thompson, 2015; Sullivan, Walenski, Love, & Shapiro, 2017). It has also been established that unaccusative sentences may involve a delayed reactivation of the subject noun's semantic information (Friedmann, Taranto, Shapiro, & Swinney, 2008; Poirier, Walenski, & Shapiro, 2012; Koring, Mak, & Reuland, 2012; Koring & van der Koots, 2018). In the previous chapters, we have argued and presented evidence that these apparent processing differences may be artifactual results from experimental design: generally, animate subject nouns are used for both unaccusative and unergative verbs. Interestingly, Koring, Mak, & Reuland (2012) found that a subclass of unaccusatives (e.g., "glow," "shine") did show a similar pattern of less disruption, like unergatives, but these verbs all strongly prefer inanimate subjects and, in that study, only appeared with inanimate subject nouns.

Relevantly, a number of studies have examined the difference between unaccusative and unergative verbs in early closure garden-path sentences (Staub, 2007; Dekydtspotter & Seo, 2017), likewise finding greater difficulty for unaccusative verbs. Staub (2007) noted that three previous studies of early closure garden-path sentences used a mixture of unergative and unaccusative verbs (Adams et al., 1998; Mitchell, 1987; van Gompel & Pickering, 2001). Staub hypothesized that unergative verbs could lead to greater disruption in early closure garden-path sentences because unergatives have a potential transitive form with cognate objects (e.g., "laugh a hearty laugh") and

resultative constructions (e.g., “sneeze a hole in the wall”). Readers would attempt the available transitive construction, and disruption would result as lexical information was accessed. However, Staub found that unaccusatives, rather than unergatives, showed greater disruption at the post-verbal noun phrase, although intransitive verb types showed greater post-verbal difficulty than optionally transitive verbs like “scratch.”

Dekydtspotter & Seo (2017) also compared unaccusative and unergative verbs in early closure garden-path sentences. They hypothesized, in line with the generative grammar position (e.g., Perlmutter, 1978), that Theme roles are internal to the verb phrase and Agent or Cause roles are associated with a node external to the verb phrase. They argue that external arguments can integrate with a verb immediately to create a phrase, but internal arguments must go through movement to occupy a grammatical subject position, and that this additional requirement is the root of the processing difference between unaccusative and unergative verbs. They found disruption for both verb types at the second noun, but unaccusative verbs recovered more slowly from that disruption. Thus, both early closure garden-path experiments comparing unaccusative to unergative verbs found greater effects for unaccusative sentences. However, again, as discussed in Chapters 2 and 3, it’s notable that each of these experiments used animate first and second nouns in this experimental design.

In this chapter, we introduce a study to examine the effect of noun animacy on both (non-alternating) unaccusative and unergative verbs in early closure garden-path sentence processing. Thus, both verb types are typically intransitive, meaning there is no comparison of early and late closure garden-path effects (as in Chapters 2 and 3), but instead a comparison of two types of early closure garden-path effects, with noun

animacy manipulated. Some research on this topic has been done, as for example, Merlo & Stevenson (2001) found that in an algorithm to automatically categorize unaccusative and unergative verbs in tagged corpora, animacy was an important factor. Vernice & Sorace (2018) tested whether auxiliary selection for unaccusative and unergative verbs was affected by subject animacy in Italian, finding that unergatives were sensitive to subject animacy, but unaccusatives were not. However, our findings in Chapters 2 and 3 suggest the opposite: that unaccusative verbs may be sensitive to subject noun animacy and animacy-thematic mismatch effects. Here, we attempt to concretize those findings by comparing non-alternating unaccusative verbs to another type of intransitive (i.e., early closure garden-path effects), thus limiting variation in the data from the larger disruption caused by late closure garden-path sentences. We likewise replicate the findings for non-alternating unaccusative verbs from Chapter 2 with some improvements. This experiment uses more verbs which increases the statistical reliability of the results, and we also remove the grammaticality judgments – which may have interfered with natural reading – and replace them with comprehension questions. Relatedly, the issue of having half of the filler sentences be ungrammatical is avoided, thus ensuring that non-natural reading strategies resulting from grammaticality judgments do not influence our results. If the pattern of results in Chapter 2 for non-alternating unaccusative verbs is consistently shown here, it would suggest that the observed animacy-thematic mismatch effects are robust.

Framing the effect of animacy on two prototypically intransitive verbs – rather than on one intransitive type and one optionally transitive type, as in Chapter 2 – allows us to better examine the way that second noun animacy influences processing. A

remaining question about early closure garden-path sentences is if the second noun is initially taken as an object of the verb and then readers slow down due to the incongruity of the construction, or if readers are only reacting to the unexpected and unpunctuated end of the dependent clause. The experimental design in this chapter creates a scenario where the relationship between first and second noun animacy can influence the results. If the dependent clause has fully closed, we should expect second noun animacy to influence the results monotonically – animate first nouns should ease the recognition of a new clause, and inanimate first nouns should make it more difficult. Animate second nouns serving as a meaningful cue that a new clause subject noun is appearing supports the interpretation of early closure garden-path phenomena as difficulty predicting where the clause will end.[12]

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[12] There is another possibility. If the dependent clause has not fully closed, then the animacy of these two nouns may be subject to similarity-based interference effects, which have been found in cue-based approaches to sentence processing (Gordon, Hendrick, & Levine, 2002; Lewis and Vasishth, 2005; Van Dyke & McElree, 2006; Wagers, Lau, & Phillips, 2009; Nairne, 2010).

Unlike in purely probabilistic accounts (e.g., Levy, 2008), in cue-based approaches, there is a particular focus on accounting for memory encoding and retrieval. Cue-based models argue that there is no working memory in the classical sense, but that working memory is, instead, epiphenomenal to effects of singular attentional focus, the decay rate of activated memory, and the maintenance/retrieval of bundles of semantic of lexical/syntactic features, or cues. A consequence of this model is similarity-based interference: when syntactic or semantic cues are shared between items in memory, processing difficulty arises. For example, in a series of studies, Gordon and colleagues (Gordon, Hendrick, & Johnson, 2001; Gordon, Hendrick, & Levine, 2002; Gordon, Hendrick, & Johnson, 2004) found similarity-based interference from NP type: if both NPs are pronouns, proper names, or full definite NPs, object relative clauses take longer to read at the verb than subject relative clauses (as is usually the case), but if the two nouns are of different NP types, e.g., one is a proper name, and the other is a pronoun, the difficulty of object relative clauses is reduced or eliminated. These effects are explained through feature overwriting (Nairne, 2002; Oberauer, 2009). When accessing the bundles of features that represent a word in context (e.g., phonology, orthography, animacy,

Finally, a recent topic in general cognitive research is how well participants from online recruiting platforms like *Amazon Mechanical Turk* (MT) perform in comparison to typical recruitment pools (e.g., SONA at the University of South Carolina) and how well

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typical uses or functions, syntactic role, thematic role, etc.), as new words are encountered, overlap between features creates a weakened mental representation of the word and its meaning.

1. *It was the barber/John that saw the lawyer/Bill in the parking lot.*

2. *It was the barber/John that the lawyer/Bill saw in the parking lot.*

In 1 above, there is no similarity-based interference because none of the nouns have to be held in memory before being adopted as the subject of a verb. However, in 2, there is disruption at the verb "saw" when both nouns are of the same type – either both a name or both a noun phrase. This is referred to as retrieval interference because it occurs at the point the noun (either "the barber" or "John") needs to be retrieved from memory. Less, but still substantial, evidence supports the possibility of similarity-based interference during encoding, such that in 2, there may be disruption at "the lawyer" or "Bill", when the previous noun was of the same type (Gordon, Hendrick, & Johnson, 2001; Gordon, Hendrick, & Johnson, 2004; Hofmeister & Vasishth, 2014; Villata, Tabor, & Frank, 2018, but also Jäger, Benz, Roeser, Dillon, & Vasishth, 2015). Notably, our stimuli are more similar to 1) above than to 2), so similarity-based interference effects are possible, but not likely.

Similarity-based interference is well established between animate nouns (Fukumura & van Gompel, 2016; Warren & Gibson, 2002; Van Dyke, 2007). If early closure garden-path effects occur because readers do not recognize the intransitivity of the verb and instead automatically attempt to interpret the second noun as an object, we might expect, at either Region 2 (encoding) or at Region 3 (retrieval), to see similarity-based interference effects based on noun animacy. In other words, when the first and second nouns are both either animate or inanimate this could lead to interference or disruption regardless of verb type. Notably, however, cue-based accounts also predict animacy-thematic mismatch effects, so similarity-based interference should only be noticeable in direct comparison with either thematic match or mismatch conditions. In Chapter 2, such an effect was not possible because late and early closure garden-path sentences were being compared; here, both verbs are generally intransitive. Foreshadowing our results, we saw no similarity-based interference effects for either prototypically intransitive verbs. Instead, animate second nouns were consistently associated with faster reading and inanimate second nouns were associated with slower reading, suggesting that second noun animacy influences early closure garden-path processing – inanimate second nouns may make it harder to recognize a new clause has begun.

they compare to in-person participants. A number of studies have suggested that MT participants show greater expertise at completing tasks than student participants (Chandler, 2014; Peer, Vosgerau, & Acquisti, 2014) and that MT participants are more sensitive to small changes in experimental conditions than student participants (Hauser & Schwarz, 2016). Therefore, since our experiment allows comparison of MT participants, student participants, and volunteer participants, we might expect a different strategy to be adopted by MT participants than other groups. Notably, research has shown that remote MT participants do not differ from in-lab participants in the timing of their responses for a variety of psycholinguistic experiments (Enochson & Culbertson, 2015).

In this experiment, we recruited from multiple platforms with different compensations, although all were done remotely and online (given the ongoing COVID-19 pandemic and restrictions). We recruited from the Department of Psychology participant pool at the University of South Carolina and through MT. These groups have a direct form of compensation (either course credit or immediate financial compensation). We also recruited uncompensated participants via Facebook and Reddit, as well as lottery compensation participants from the same platforms. These two groups have less direct means of compensation. Foreshadowing our results, MT participants had a distinctive pattern of reading compared to all other groups. The course credit group and uncompensated group showed animacy-thematic mismatch effects for unergative sentences at the intransitive verb itself and at the second noun and for unaccusative verbs at the second noun. MT participants showed the same pattern, but for unergatives there was an animacy-thematic mismatch at the second noun and for unaccusatives it was at the auxiliary phrase. Also, MT participants showed a tendency for faster reading time in all

measures toward the end of the sentence, which may reflect a strategic approach to the task due to pressure to earn as much as possible. It is possible that this strategic approach is also what leads to the delay in animacy-thematic mismatch effects relative to the other groups.

Methods

Participants

A total of 503 participants took part in an online self-paced reading experiment hosted on the Ibex Farm platform (Drummond, 2020). Four different methods were used to recruit participants. First, 121 students were recruited from the USC psychology, linguistics, and English departments in exchange for course credit. Second, 232 participants were recruited via *Amazon Mechanical Turk* and compensated immediately with $3. Third, 106 participants were recruited via Facebook and completed the experiment for no compensation. Fourth, 44 participants were recruited via *Reddit* and *Facebook* through groups with an interest in psychology, linguistics, or volunteering in exchange for a chance in a lottery for a donation of $100 to a charity in their name. We might expect some differences in performance due to different compensation – participants who receive immediate monetary compensation may perform differently than those who receive delayed compensation like course credit or a lottery, who may themselves perform differently than someone completing the experiment simply to be nice. Twenty-one participants were removed because they had less than 80% accuracy on the comprehension questions, leaving a total of 482 participants whose age, location, accuracy and mean residualized reading times are shown in Table 12 below.

Table 4.1: Group data 12

Group	Total	Location	Mean age (sd) & range	Mean accuracy (sd)	Mean residualized reading time (sd)
No Compensation	102	94 US 3 Canada 1 Australia 2 UK 2 Ireland	43.3 (14.24) 24-79	0.949 (0.221)	0.000 (0.308)
Lottery	44	38 US 4 Canada 1 New Zealand 1 Australia	32.4 (12.64) 17-69	0.956 (0.205)	0.000 (0.275)
Course Credit	110	110 US	21.8 (4.29) 18-36	0.946 (0.226)	0.002 (0.306)
Amazon Mechanical Turk	226	226 US	40.9 (10.45) 24-69	0.95 (0.218)	0.003 (0.329)

Design

Four lists of experimental sentences were created. Most non-alternating unaccusative verbs were the same as used in the previous experiment. Unusual or dubious non-alternating unaccusatives like “settle” were removed from and replaced with better non-alternating unaccusative verbs (although some still ended up being included; see

"Limitations" section below). Each list contained the same 32 intransitive verbs (16 unaccusative, 16 unergative) in an initial dependent clause, followed without a comma by a passive main clause. The lists differed in the animacy of the first and second nouns, such that the full set of first/second noun animacy permutations were available (i.e., animate-inanimate, inanimate-inanimate, animate-animate, inanimate-animate). These four lists were then arranged by the second noun into two pairs of lists (i.e., one pair always had an inanimate second noun, one always had an animate second noun). Second noun animacy was a between-participant factor. Two lists were created for each level of this factor (i.e., a list of animate first nouns and a list of inanimate first nouns were created with animate second nouns, and the same lists were created for inanimate second nouns). A Latin square was applied to each of these lists such that that first noun animacy was a within-participant factor. The lists were presented so that each participant saw the same number of items in each condition. Each item was seen only once by each participant. Along with the experimental items, 32 filler items were created, and the presentation was pseudo-randomized such that every other sentence was a filler item. Each experimental item contained an early closure garden-path sentence with either an unaccusative or unergative verb. Examples of each condition are presented in Table 13 below.

Table 4.2: Sample items in all conditions

	Inanimate second noun		Animate second noun	
	Unaccusative	Unergative	Unaccusative	Unergative
Animate first noun	As the driver disappeared the vehicle was being identified at the crime scene.	As the judge frowned the charges were being recorded in the somber hearing.	As the driver disappeared the sheriff was being served at the small cafe.	As the judge frowned the criminal was being handcuffed in the somber hearing.
Inanimate first noun	As the item disappeared the vehicle was being identified at the crime scene.	As the court frowned the charges were being recorded in the somber hearing.	As the item disappeared the sheriff was being served at the small cafe.	As the court frowned the criminal was being handcuffed in the somber hearing.

Procedure

The experiment was done using the Ibex Software hosted on the Ibex Farm platform, and the data was extracted using the Ibextor package in R (Malko, 2018). Participants read and confirmed a consent form approved by the University of South Carolina Institutional Review Board, filled out survey questions on age, gender, native/primary language, and state, and read instructions. In the moving-window word-by-word self-paced reading paradigm, participants saw one word at a time; the rest of the sentence was visible, but all letters had been replaced with an "x." Participants pressed the spacebar to move forward from word to word. After each sentence, they responded to a comprehension question. Half of the questions asked a question and offered a set of multiple-choice answers. The other half asked a yes/no question about the sentence, offering "True," "False," and "I Don't Know" as options. "I Don't Know" was always coded as an incorrect answer. After completing the experiment, participants were given a completion code that they could email to the author for compensation.

Analysis

To prepare the data, we removed any response times below 100 ms or above 2000 ms, following standard practices (e.g., Linzen & Jaeger, 2016). Following practices outlined in Trueswell, Tanenhaus, & Garnsey (1994), we took the log of response time and performed a single factor mixed-effects regression with the log of word length in characters as a fixed factor and participant and the slope of log word length as random factors to minimize the influence of word length on reading time. All sentences, including fillers, were used in the residualization – and participants from all groups were included in the residualization, with the aim of better capturing the precise effect of word

length on reading time. The residuals from this model were then used as the dependent variable in linear mixed effect regressions for each region of interest in the sentence, with the residual value averaged across the words within the region. The regions are the intransitive verb, the second noun phrase, the auxiliary verbs, “was” and “being”, and the final verb plus its following preposition. Each region was analyzed separately. Each mixed-effect regression included first noun animacy, verb type, second noun animacy, and group, along with the intercepts for participant and item as random factors. The maximal random effects structure was attempted for each region, but when it failed to converge, the random effects structure was reduced to the intercept alone. Because the five samples were of different sizes, taken from different populations, and provided different motivations for the participants, each regression included all possible interactions between the five fixed effects, and a stepwise selection process (from the step () function in lme4 (Bates, Mächler, Bolker, & Walker, 2015)) was used to remove superordinate interactions that didn’t significantly alter fit; if a superordinate interaction did alter fit, then all of its subordinate interactions were automatically included. This is an attempt to maintain a model that does not contain spurious effects from the different samples but also tries to maintain adequate power. To test for significance, we performed a chi-square test of model fit with each independent variable or interaction either included or removed.

Estimated means and confidence intervals are an important part of our analysis because they represent disruption or facilitation of reading. These estimates were calculated for each group with the Bonferroni adjustment for eight estimates. Planned contrasts for the effect of first noun animacy and second noun animacy were also

calculated separately for each group with a Holm adjustment for eight hypotheses unless stated otherwise.

Hypotheses

1. Unaccusative verb sensitivity to first noun animacy: First noun animacy that does not match the thematic role assigned by the verb types should influence reading at the second noun phrase (Region 2). In other words, animate first nouns should lead to greater difficulty with unaccusatives, replicating the pattern of results found in Chapter 2.
2. Unergative verb sensitivity to first noun animacy: First noun animacy that does not match the thematic role assigned by the verb types should influence reading at the second noun phrase (Region 2). In other words, inanimate first nouns should lead to greater difficulty for unergatives.
3. Sensitivity to second noun animacy relative to first noun animacy: With all experimental conditions for first noun animacy and verb type, if the parser uses animacy as a cue that a new clause has started, animate second nouns should lead to easier recognition of the start of a new clause.
4. Group effects: *Mechanical Turk* (MT) samples have been argued to differ from student samples in that they learn the norms of tasks and surveys, while students do not (Chandler, 2014; Peer, Vosgerau, & Acquisti, 2014). MT participants have also been argued to be particularly attentive to detail and to have larger reactions than student samples to minute text manipulation (Hauser & Schwarz, 2016). Though we do not have specific predictions, we expect that the MT group will perform differently than the other three groups. It also notable that the MT group

and the uncompensated group are both on average older than the other two groups. We might conclude, then, that an effect present in those two groups but not the lottery or course credit groups stems from age-related factors.

Results

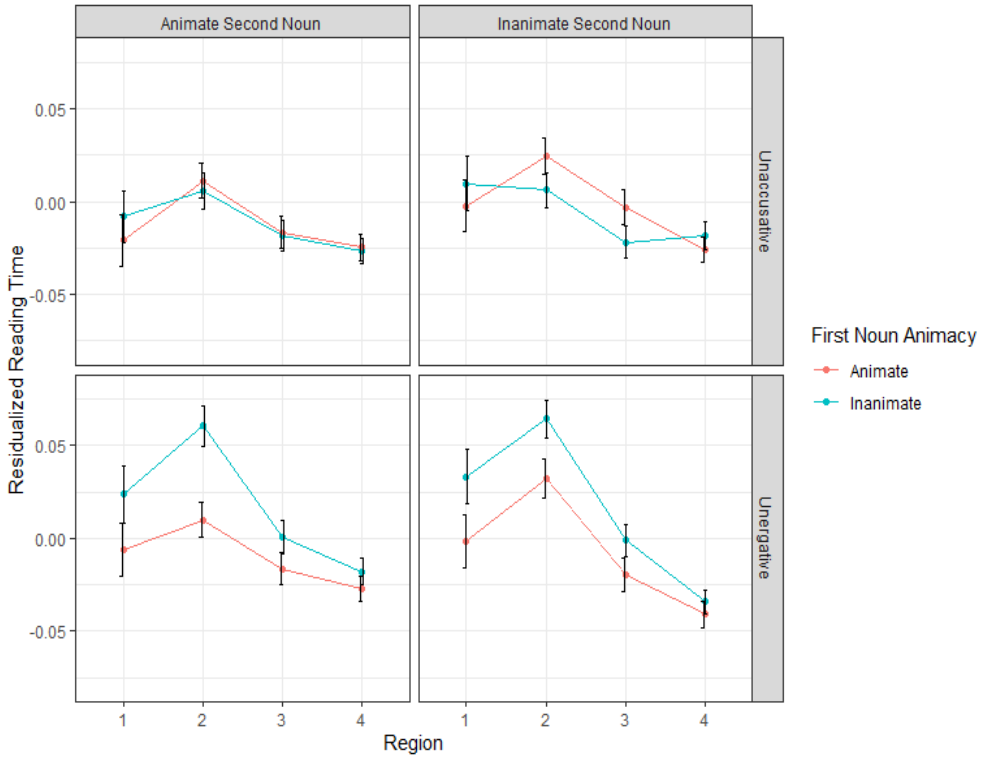

Figure 4.01: Residualized reading times across all regions, combined all groups. Residualized reading times for the eight conditions of the experiment for each region are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale. On the x-axis, 1, 2, 3, and 4 represent Region1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

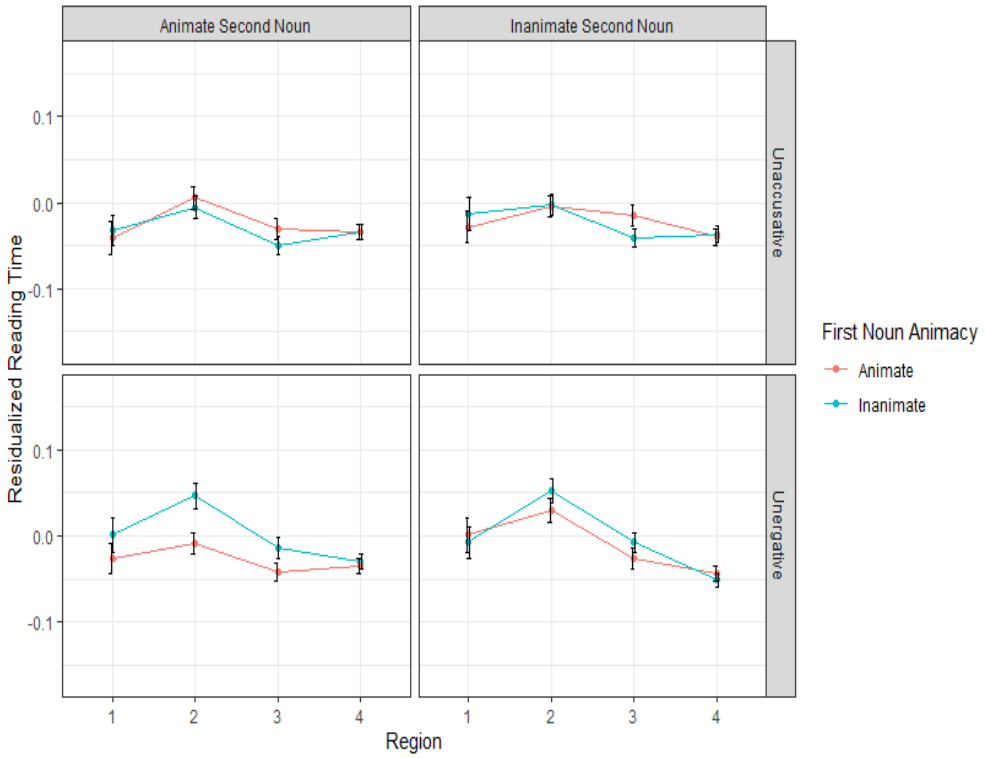

Figure 4.02: Residualized reading times across all regions, MT group. Residualized reading times for the eight conditions of the experiment for each region are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale. On the x-axis, 1, 2, 3, and 4 represent Region1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

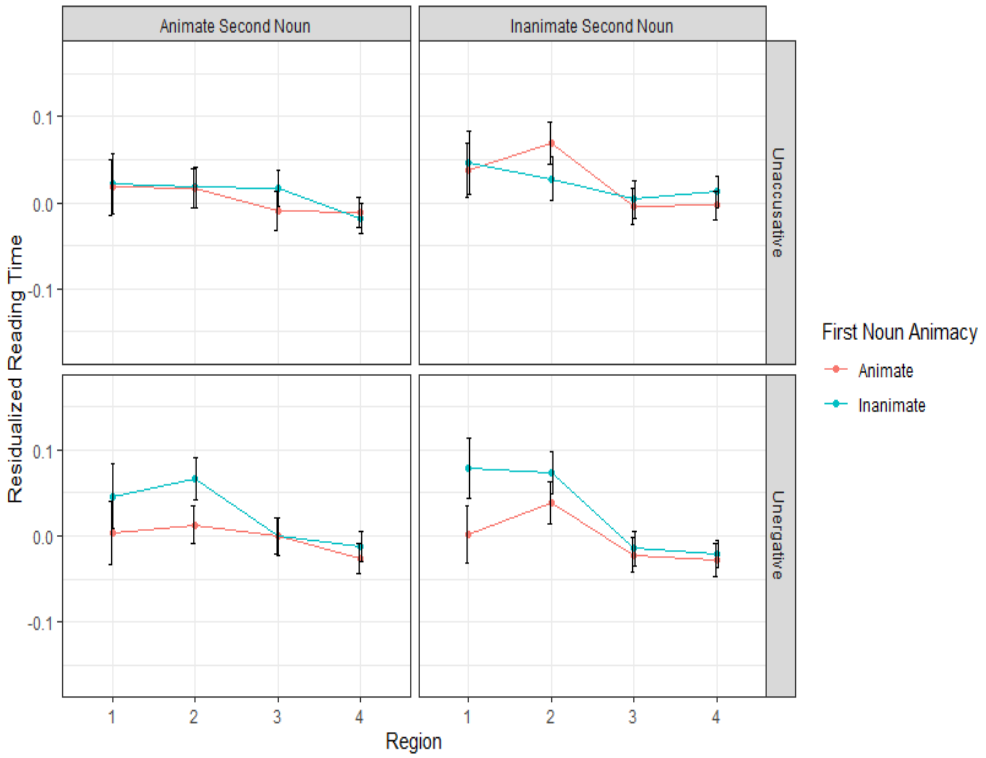

Figure 4.03: Residualized reading times across all regions, uncompensated group. Residualized reading times for the eight conditions of the experiment for each region are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale. On the x-axis, 1, 2, 3, and 4 represent Region 1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

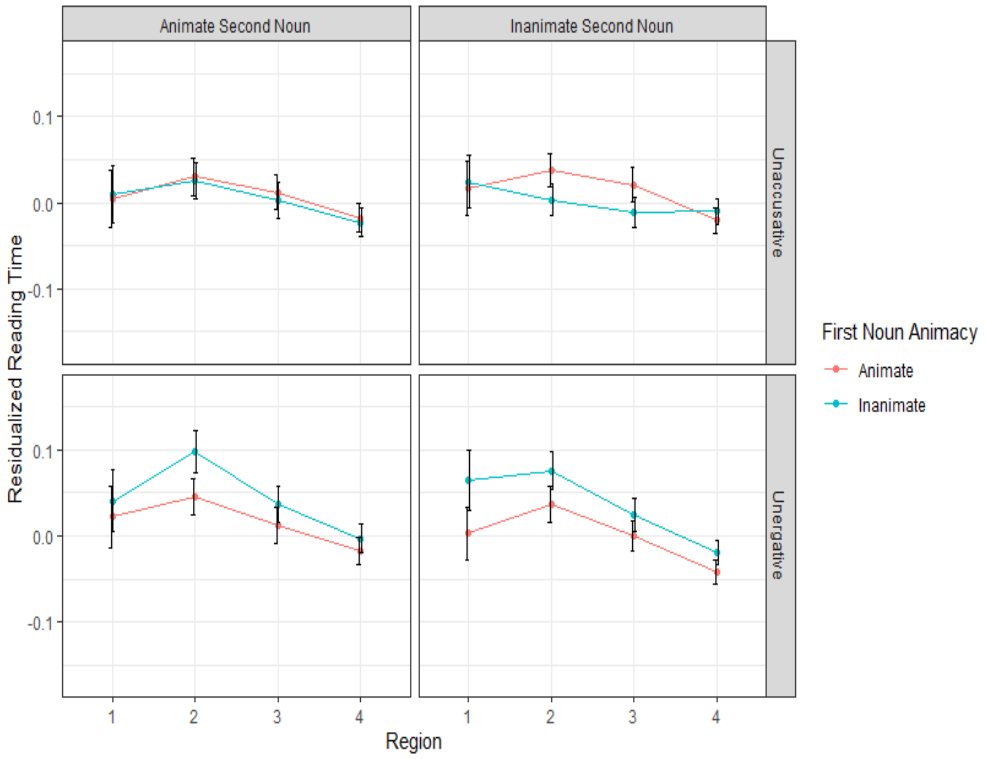

Figure 4.04: Residualized reading times across all regions, course credit group. Residualized reading times for the eight conditions of the experiment for each region are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale. On the x-axis, 1, 2, 3, and 4 represent Region 1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

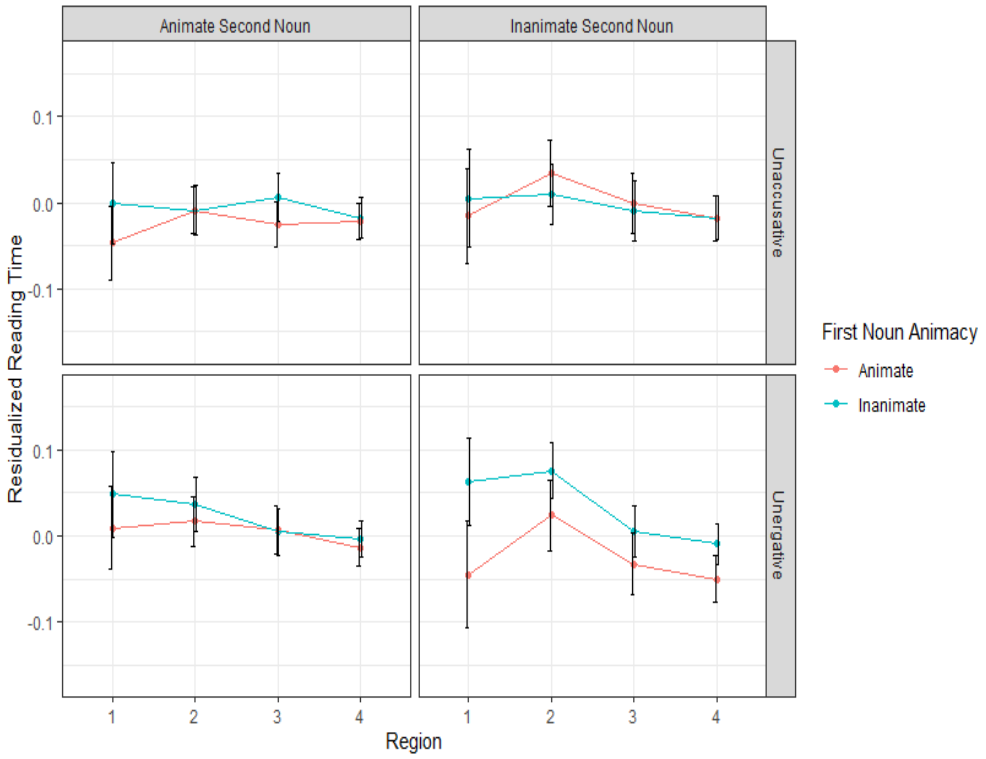

Figure 4.05: Residualized reading times across all regions, lottery group. Residualized reading times for the eight conditions of the experiment for each region are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale. On the x-axis, 1, 2, 3, and 4 represent Region 1, 2, 3, and 4 respectively. For an inanimate second noun non-alternating unaccusative sentence, 1 corresponds to "fell;" 2 corresponds to "the sign; 3 corresponds to "was being;" and 4 corresponds to "displayed on."

Overall, these results suggest that there is an animacy-thematic effect for both unaccusative and unergative verbs, although it occurs earlier and with greater intensity for unergative verbs than it does for unaccusative. Inanimate second nouns were associated with greater disruption immediately after the verb than animate second nouns, especially after an animate first noun. Figure 4.01 shows the results for all regions for all groups aggregated together and Figure 4.02-4.10 show the results for each group individually.

Region 1

All four effects and all their interactions were included in this model, as per the stepwise procedure. There was a marginally significant main effect of first noun animacy ($\chi^2(1) = 25.076$, $p < 0.001$), such that animate first nouns were read faster. There was also a significant effect of group ($\chi^2(3) = 21.737$, $p < 0.001$). There were significant two-way interactions between first noun animacy and verb type ($\chi^2(1) = 4.376$, $p = 0.036$). There was a significant four-way interaction between group, first noun animacy, second noun animacy, and verb type ($\chi^2(3) = 8.051$, $p = 0.045$). Figures 4.06-4.10 show these results for the aggregated results and for each groups' results.

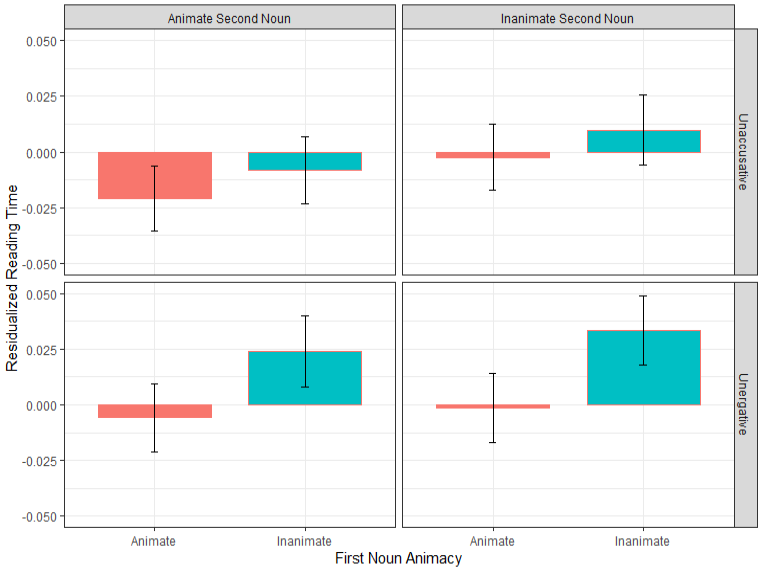

Figure 4.06: Residualized reading times for R1, all groups. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

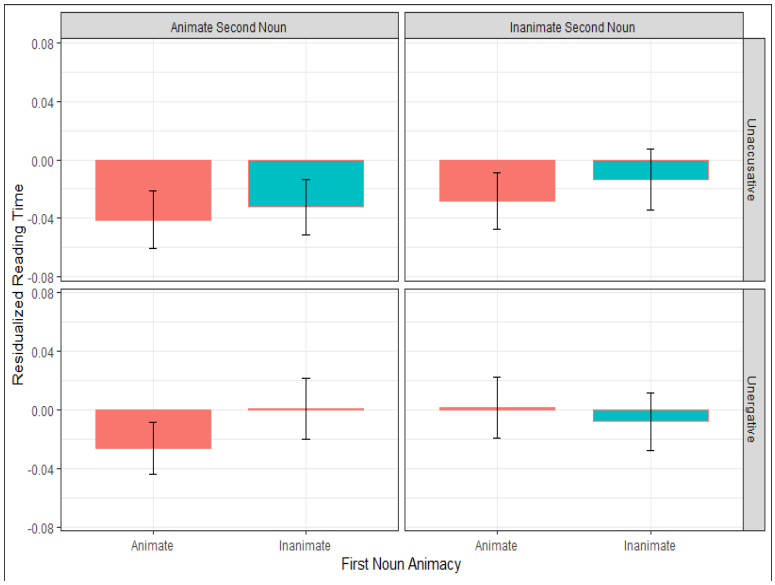

Figure 4.07: Residualized reading times for R1, MT group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

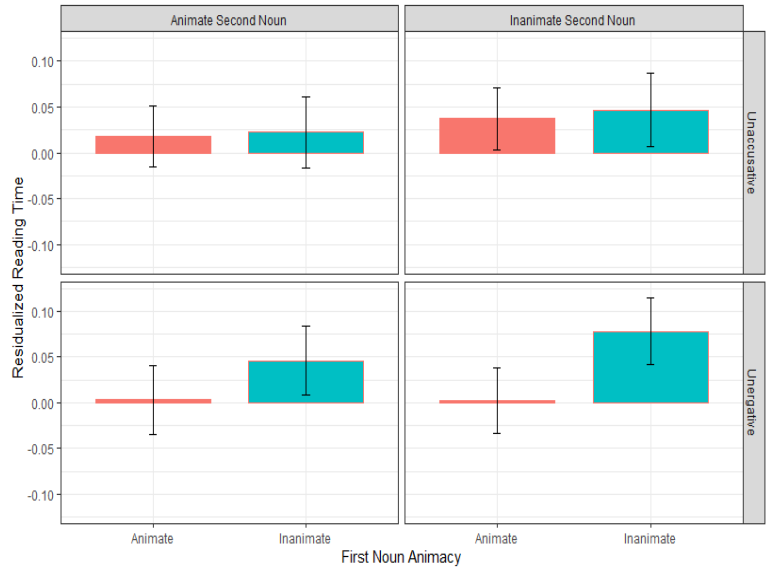

Figure 4.08: Residualized reading times for R1, uncompensated group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest

facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

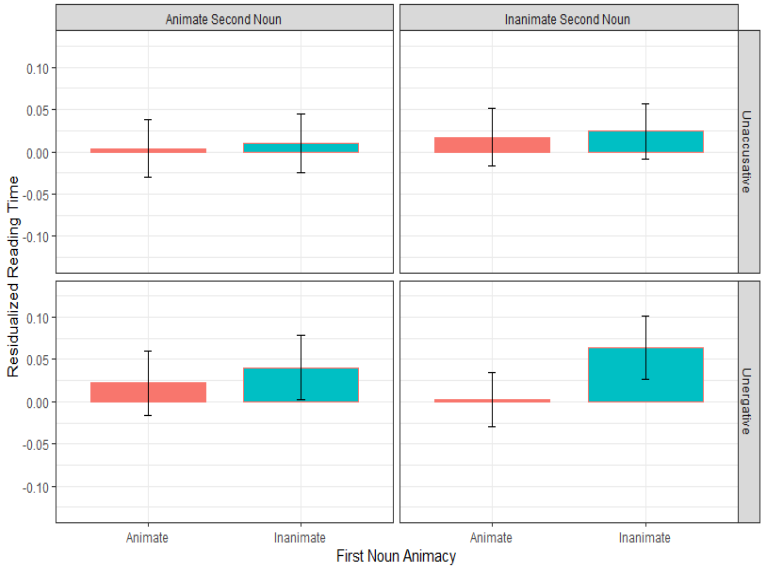

Figure 4.09: Residualized reading times for R1, course credit group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

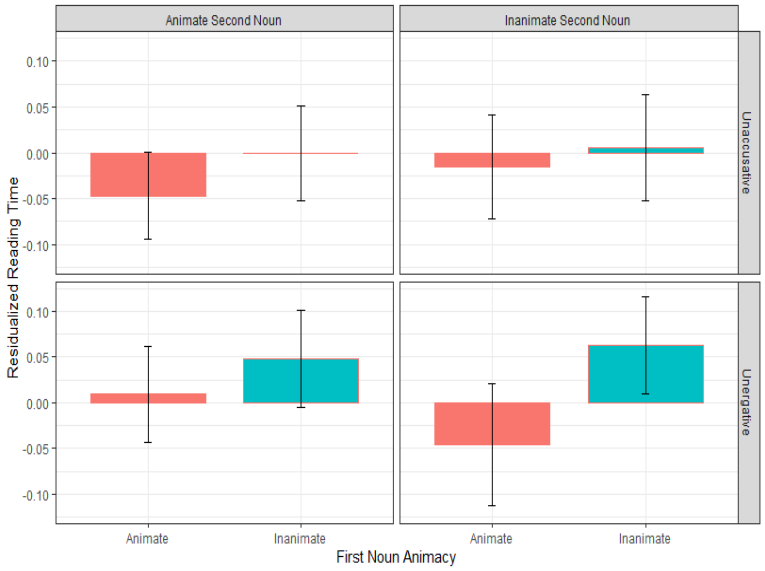

Figure 4.10: Residualized reading times for R1, lottery group. Residualized reading times for the eight conditions of the experiment are shown averaged

across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

The planned contrasts separated by group showed effects of animacy-thematic mismatch for unergative verb sentences. With unergative verbs, inanimate first noun sentences were read more slowly than animate first noun sentences when the second noun was inanimate in the uncompensated group (M =0.084, SE = 0.021, z = 3.922, $p < 0.001$), the course credit compensation group (M = 0.06, SE = 0.02, z = 3.027, p = 0.024), and the lottery group (M = 0.011, SE = 0.036, z = 3.019, p = 0.024).

Estimates of means and their confidence intervals showed varied effects. The uncompensated and the credit compensation groups showed disruptive effects of animacy-thematic mismatch for inanimate first noun sentences with unergative verbs when the second noun was inanimate (uncompensated: (M = 0.08, SE = 0.02, *95% CI:* 0.033, 0.14), course credit (M = 0.064, SE = 0.019, *95% CI:* 0.012, 0.115)). The MT group had facilitation in the animate second noun condition when the verb was unaccusative and first noun was animate (M = -0.04, SE = 0.014, *95% CI:* -0.078, 0.00).[13]

Overall, unergative sentences showed an effect of animacy-thematic mismatch in the uncompensated and course credit groups. These immediate effects are interesting, although not crucial to our hypotheses, which are focused on post-verbal regions. The results do, however, suggest that unergative verbs have an immediate effect of animacy-

[13] Since there were three potentially alternating unaccusative verbs in our set of unaccusative verbs, we performed the same regressions with those verbs excluded. At this region, the results followed exactly the same pattern as here, except that unaccusative, animate first and second noun sentences did not show facilitation in the MT group, as here (M = -0.039, SE = 0.015, 95% CI: -0.081, 0.002).

thematic mismatch. Notably, at this point in the sentence, readers have not encountered the second noun yet, so second noun animacy effects are likely only from chance.

Region 2

The stepwise procedure suggested a model with the following main effects: first and second noun animacy, verb type, and group, along with two-way interactions for verb type x first noun animacy and first noun animacy x second noun animacy. The model had six factors plus the random effects. There were significant main effects of first noun animacy ($\chi^2(1) = 21.156$, $p < 0.001$), suggesting longer reading times for animate first nouns, of second noun animacy ($\chi^2(1) = 3.91$, $p = 0.048$), suggesting longer reading times for inanimate second nouns, and of verb type ($\chi^2(1) = 8.806$, $p = 0.003$), suggesting longer reading times for unergative sentences. There was also a significant effect of group ($\chi^2(3) = 18.915$, $p < 0.001$). There was a significant interaction between first noun animacy and verb type ($\chi^2(1) = 62.991$, $p < 0.001$) and between first and second noun animacy ($\chi^2(1) = 6.946$, $p = 0.008$). Because group is not included in any interactions, all planned contrasts yield the same results for each group; however, confidence intervals differ across group from the simple effect of group – with the lottery and MT groups being faster and the uncompensated and course credit groups being slower. Figure 4.11 shows the results for all groups aggregated, and Figures 4.12-4.15 show the results for each group individually.

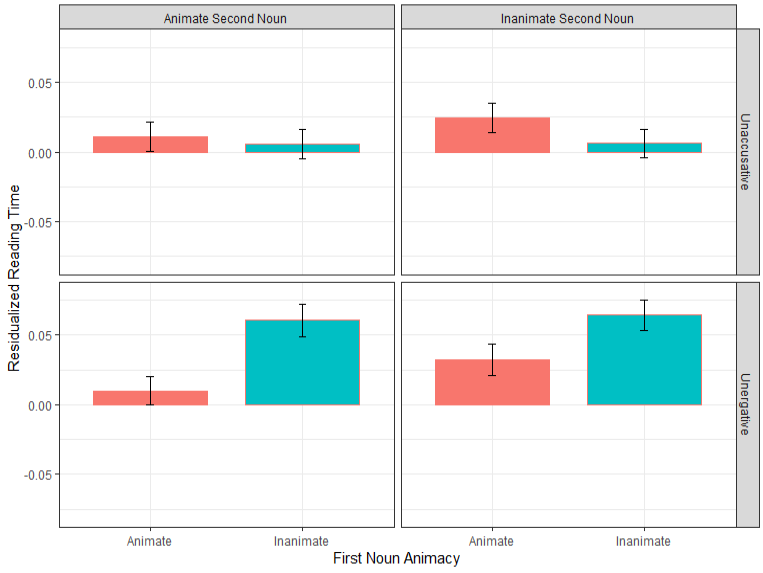

Figure 4.11: Residualized reading times for R2, all groups. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

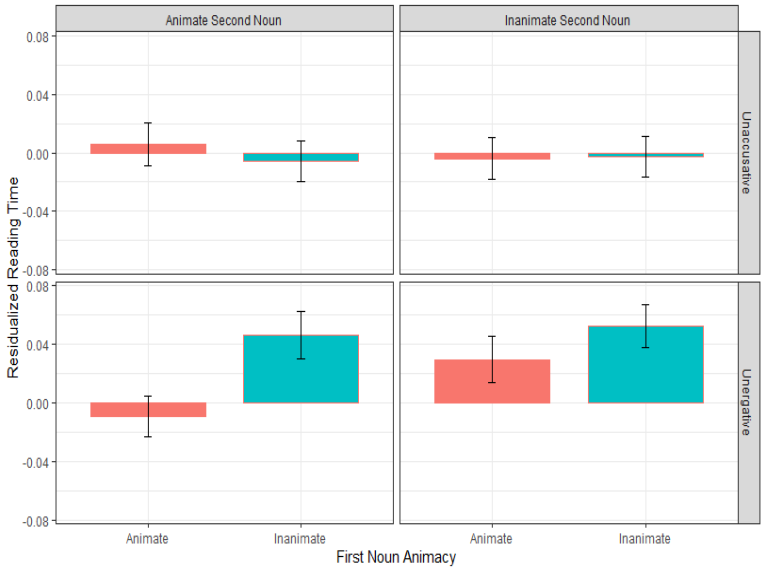

Figure 4.12: Residualized reading times for R2, MT group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

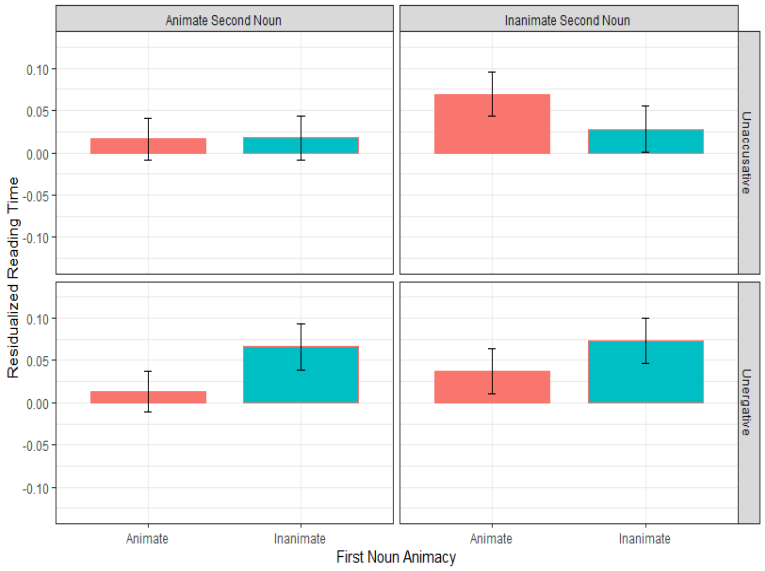

Figure 4.13: Residualized reading times for R2, uncompensated group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

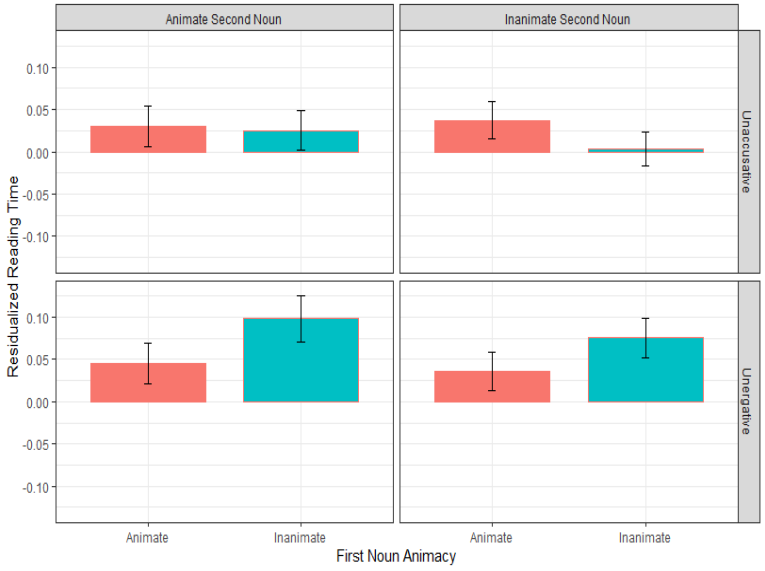

Figure 4.14: Residualized reading times for R2, course-credit group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest

facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

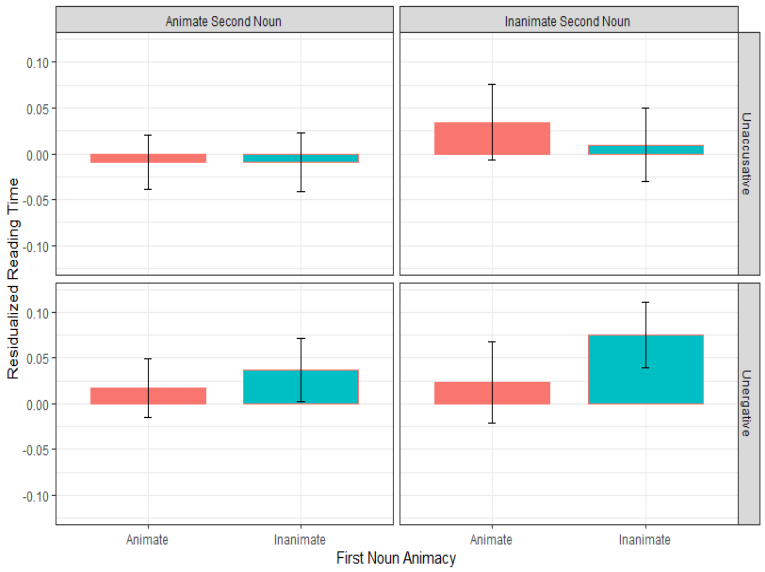

Figure 4.15: Residualized reading times for R2, lottery group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

Planned contrasts were performed. As noted above, the stepwise procedure did not include any interactions containing group. Therefore, for the planned contrasts, results from all groups were aggregated instead of analyzed separately. We again use a Holm correction for eight tests. Unergative sentences showed animacy-thematic mismatch effects. When the second noun was animate, animate first nouns were read faster than inanimate first nouns ($M = 0.05$, $SE = 0.006$, $z = 8.47$, $p < 0.001$) and when the second noun was inanimate, animate first nouns were also read faster than inanimate ($M = 0.034$, $SE = 0.006$, $z = 5.806$, $p < 0.001$). Unaccusatives also showed an animacy-thematic mismatch effect when the second noun was inanimate, such that inanimate first nouns were read faster than animate ($M = -0.012$, $SE = 0.007$, $z = -2.976$, $p = 0.017$).

However, there was no animacy-thematic mismatch effect when the second noun was animate (M = -0.002, SE = 0.007, z = -0.296, p = 1). These results support Hypotheses 1 and 2. There was also a significant effect of second noun animacy when the first noun was animate (M = -0.022, SE = 0.008, z = -2.703, p = 0.035). Because the interaction verb type x second noun animacy was not included in the model, the effect is the same for unergative and for unaccusative verbs.

Estimated means and confidence intervals from the regression model, however, could still be performed separately across group. All groups showed an animacy-thematic mismatch effect for unergative sentences. The results by group are as follows. Inanimate first noun unergative verbs were associated with reading disruption in all four groups, uncompensated (animate second noun: M = 0.076, SE = 0.011, *95% CI:* 0.046, 0.107; inanimate second noun: M = 0.078, SE = 0.011, *95% CI:* 0.047, 0.108), course credit (animate second noun: M = 0.079, SE = 0.011, *95% CI:* 0.049, 0.109; inanimate second noun: M = 0.08, SE = 0.012, *95% CI:* 0.051, 0.11), lottery (animate second noun: M = 0.056, SE = 0.013, *95% CI:* 0.02, 0.098; inanimate second noun: M = 0.057, SE = 0.014, *95% CI:* 0.02, 0.095), and MT groups (animate second noun: M = 0.049, SE = 0.01, *95% CI:* 0.023, 0.076; inanimate second noun M = 0.051, SE = 0.01, *95% CI:* 0.024, 0.077). This unanimous finding supports Hypothesis 2.

Two groups showed animacy-thematic mismatch effects for unaccusative sentences. In the uncompensated group and the course credit group, animate first noun sentences with an unaccusative verb and an inanimate second noun showed disruption (uncompensated: M = 0.04, SE = 0.011, *95% CI:* 0.01, 0.071; course credit: M = 0.043, SE = 0.011, *95% CI:* 0.013, 0.072). This supports hypothesis 1. There was also disruption

for animate first noun unergative sentences with an inanimate second noun (uncompensated: *M* = 0.043, *SE* = 0.011, *95% CI:* 0.013, 0.074; course credit: *M* = 0.046, *SE* = 0.011, *95% CI:* 0.016, 0.075) [14]. This finding does not fit in with any of our hypotheses.

Overall, this region shows unanimous evidence for animacy-thematic mismatch effects with unergative verb sentences. For unaccusative verbs, there was also some evidence for animacy-thematic mismatch. When the second noun was inanimate, there was an effect of animacy, showing that animate first noun sentences were read slower than inanimate. However, it is possible that this is, rather than an animacy-thematic mismatch effect, a result of animate noun-verb-inanimate noun sequences activating a transitive interpretation. An animate first noun leads to difficulty with an inanimate second noun, while an inanimate first noun does not. Some support for this latter position comes from the fact that, when the first noun was animate, both unergative and unaccusative sentences experienced faster reading for animate second nouns than inanimate. The effect of second noun animacy does not resemble similarity-based interference (see Footnote 11), but rather a simple effect of inanimate second nouns leading to more difficulty than animate second nouns. Because this association is significant only with animate first nouns, it also supports the idea that this effect stems from a kind of animacy template for transitive constructions. Animate second nouns may ease processing by precluding transitive interpretations.

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[14] Since there were three potentially alternating unaccusative verbs in our set of unaccusative verbs, we performed the same regressions with those verbs excluded. At this region, the results followed exactly the same pattern as here.

Region 3

Included in this model were three main effects: group, verb type, and first noun animacy – neither second noun animacy nor any interactions containing it met the criteria of the stepwise procedure. There were three interactions: group x first noun animacy, group x verb type, and group x verb type x first noun animacy. There was a marginally significant main effect of group ($\chi^2(3)$ 50.147, $p < 0.001$). There was a significant two-way interaction between group and verb type ($\chi^2(3) = 9.49$, $p = 0.024$). There was a significant three-way interaction between first noun animacy, verb type, and group ($\chi^2(1) = 35.42$, $p < 0.001$). Because second noun animacy was not in the model at all per the stepwise reduction procedure, we only tested the difference between animate and inanimate first nouns for both verb types. We nonetheless use a Holm correction for eight tests for the preplanned contrasts. The residualized values are shown for the aggregated groups in Figure 4.16 and for each group individually in Figures 4.17-4.20.

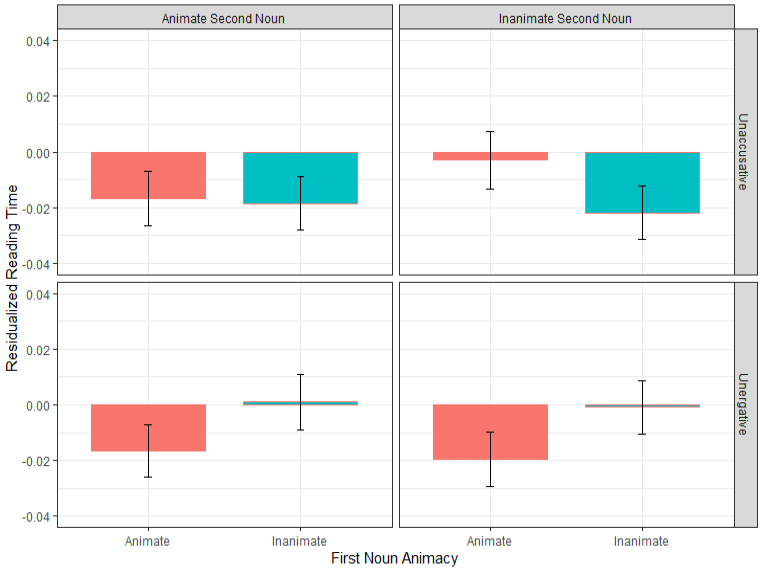

Figure 4.16: Residualized reading times for R3, all groups. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading

times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

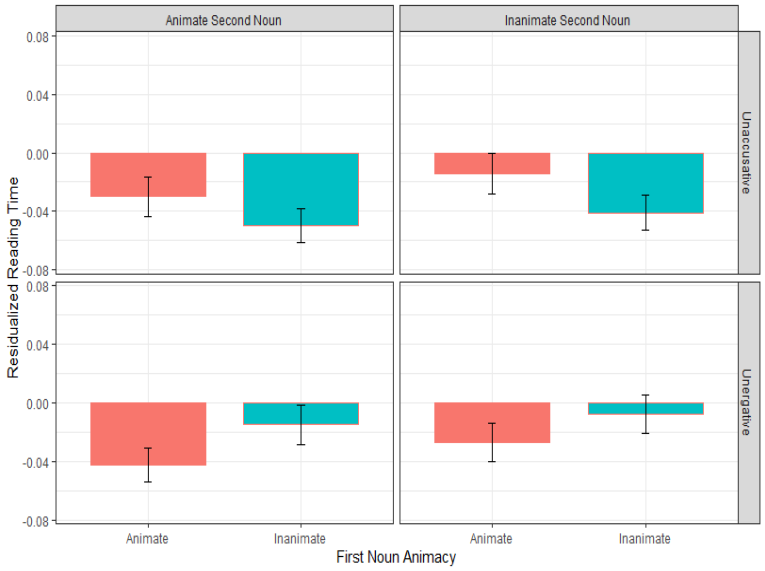

Figure 4.17: Residualized reading times for R3, MT group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

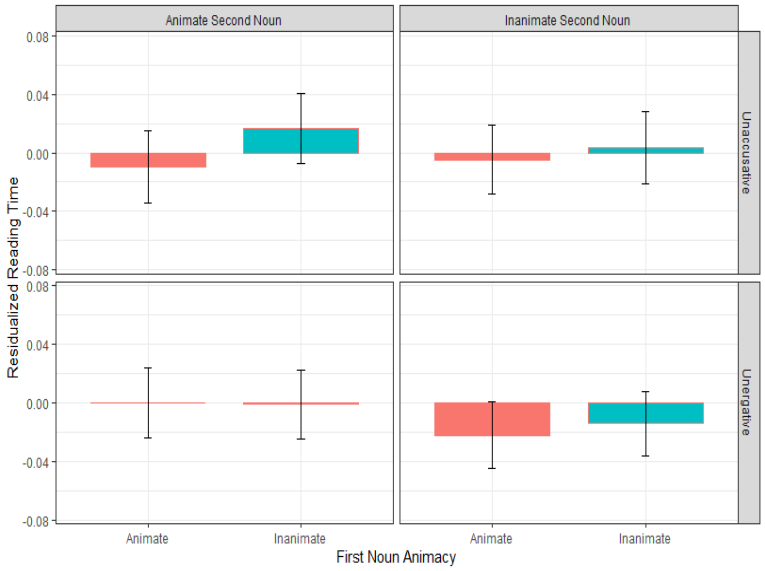

Figure 4.18: Residualized reading times for R3, uncompensated group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest

facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

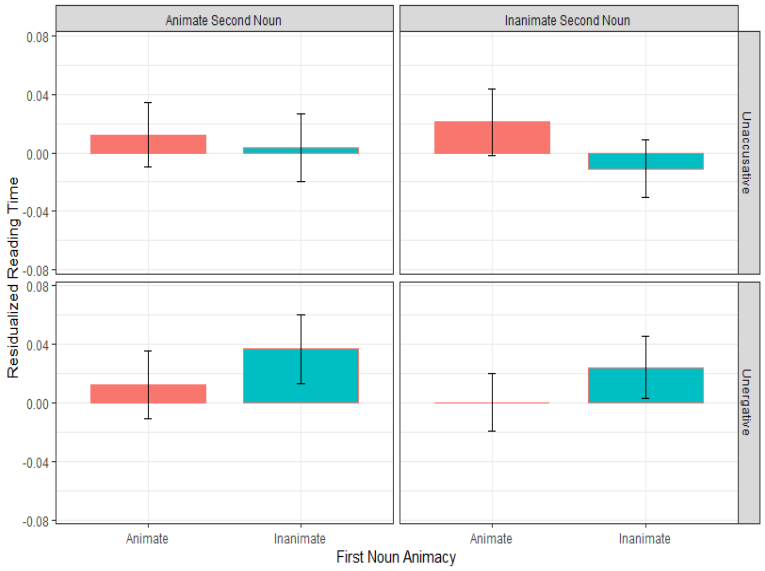

Figure 4.19: Residualized reading times for R3, course-credit group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

Planned contrasts were performed separately by groups. The MT and the course credit group showed effects of animacy-thematic mismatch. With unergative verbs, animate first noun sentences were read faster than inanimate first noun (course credit: $M = 0.0241$, $SE = 0.009$, $z = 2.662$, $p = 0.008$; MT group: $M = 0.025$, $SE = 0.006$, $z = 3.902$, $p < 0.001$). With unaccusative verbs, inanimate first noun sentences were read faster than animate first noun (course credit: $M = -0.027$, $SE = 0.009$, $z = -2.474$, $p = 0.013$; MT group: $M = -0.026$, $SE = 0.006$, $z = -4.002$, $p < 0.001$).

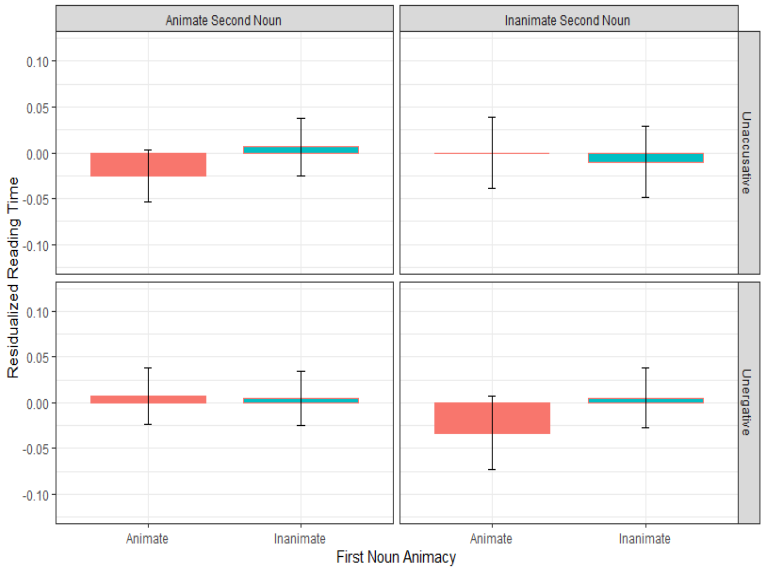

Figure 4.20: Residualized reading times for R3, lottery group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

Confidence intervals and estimated means indicated that there was disruption for inanimate first noun unergative verb sentences in the course credit group (*M* = 0.093, *SE* 0.009, *95% CI:* 0.007, 0.054). In the MT group, there was the inverse effect with the same pattern of result: all sentence conditions showed facilitation except for the inanimate first noun, inanimate second noun unergative verb sentences (*M* = -0.011, *SE* = 0.008, *95% CI:* -0.0299, 0.009). All other sentence types did show facilitation: inanimate first noun, unaccusative (*M* = -0.047, *SE* = 0.008, *95% CI:* -0.066, -0.027), animate first noun, unaccusative (*M* = -0.021, *SE* = 0.008, *95% CI:* -0.04, -0.002), and animate first

noun, unergative (*M* = -0.035, *SE* = 0.008, *95% CI:* -0.055, -0.016). These measures are Bonferroni corrected for four tests, since second noun animacy was not included.[15]

In the MT and course credit groups, we see a pattern of results that suggests animacy-thematic mismatch for both unaccusative and unergative verbs. This finding is in line with Hypotheses 1 and 2. Interestingly, we also see some evidence for Hypothesis 4. First, the MT group and the course credit group perform most similarly – the uncompensated and lottery groups do not show an animacy-thematic mismatch effect for either verb type here. Second, while the course credit group showed disruption for animacy-thematic mismatch, MT participants showed a lack of facilitation in the same pattern. This may be an effect of MT participants speeding up over the course of the sentence as a strategy to quickly complete the task while also maintaining a high accuracy rate.

Region 4

Included in the model for Region 4 were main effects of group, first noun animacy, second noun animacy, and verb type, as well as two-way interactions between group x verb type and verb type x second noun animacy. There was a significant effect of first noun animacy ($\chi^2(1) = 5.827$, $p = 0.016$), suggesting that animate first noun sentences were read more quickly, and of group ($\chi^2(1) = 82.003$, $p < 0.001$). The two-way

[15] Since there were three potentially alternating unaccusative verbs in our set of unaccusative verbs, we performed the same regressions with those verbs excluded. At this region, the results for the reduced and full version followed the same pattern, except that, for the reduced version, in the planned contrasts, the course credit group no longer showed a significant difference between animate and inanimate first noun, unaccusative verb sentences (M = -0.01, SE = 0.01, z = -0.987, p = 1). However, the MT group still showed a significant difference for first noun animacy with unaccusative verbs (M = -0.02, SE = 0.007, z = -2.801, p = 0.035).

interactions between group and verb type ($\chi^2(3) = 8.807$, $p = 0.032$) and between verb type and second noun animacy ($\chi^2(1) = 17.126$, $p < 0.001$) were significant. Figures 4.21-4.25 depict the residualized reading times aggregated over groups and for the individual groups.

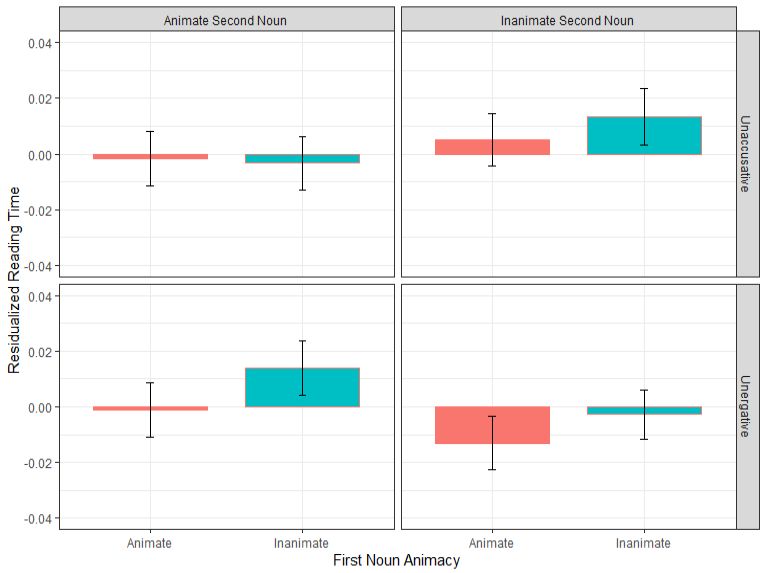

Figure 4.21: Residualized reading times for R4, all groups. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

There were no significant differences in the planned contrasts, which, in any case, could not test first noun animacy effects since it was not included in any of the interactions in the model, as the stepwise procedure showed it was itself not significant and neither were any interactions containing it.

Confidence intervals and estimated means were performed separately by group. The uncompensated group had disruption with all sentence conditions except animate

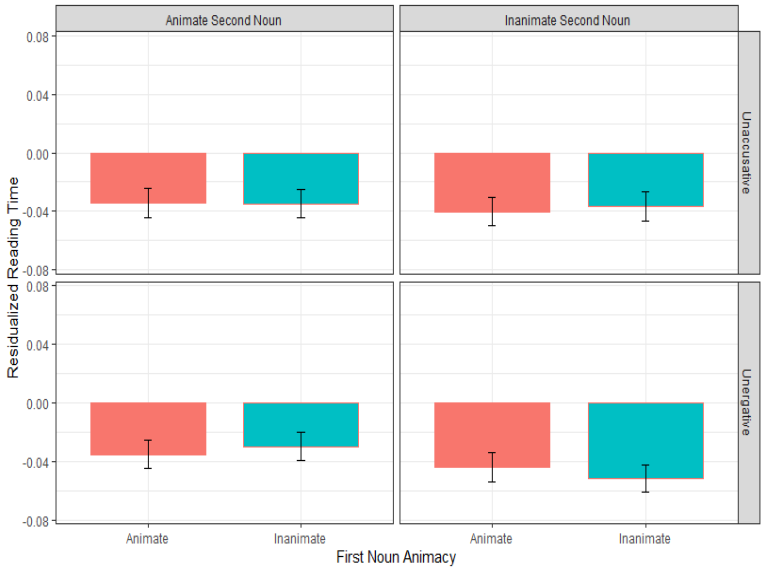

Figure 4.22: Residualized reading times for R4, MT group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

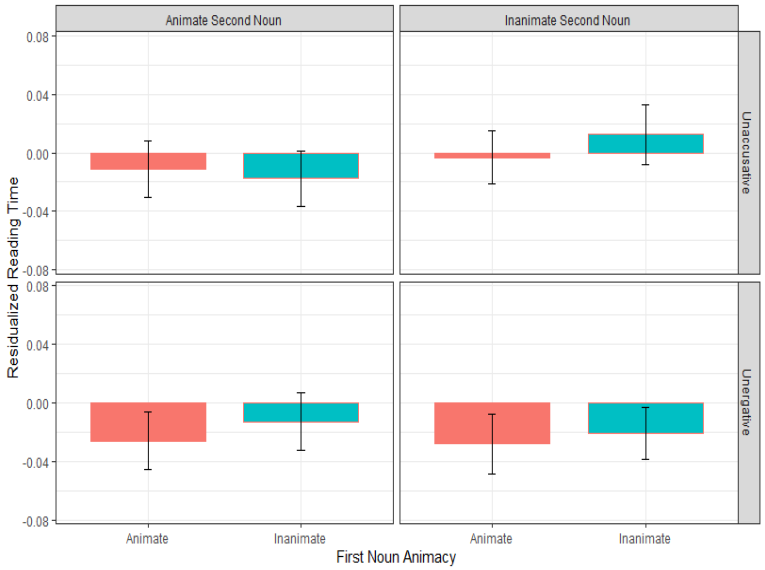

Figure 4.23: Residualized reading times for R4, uncompensated group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest

facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

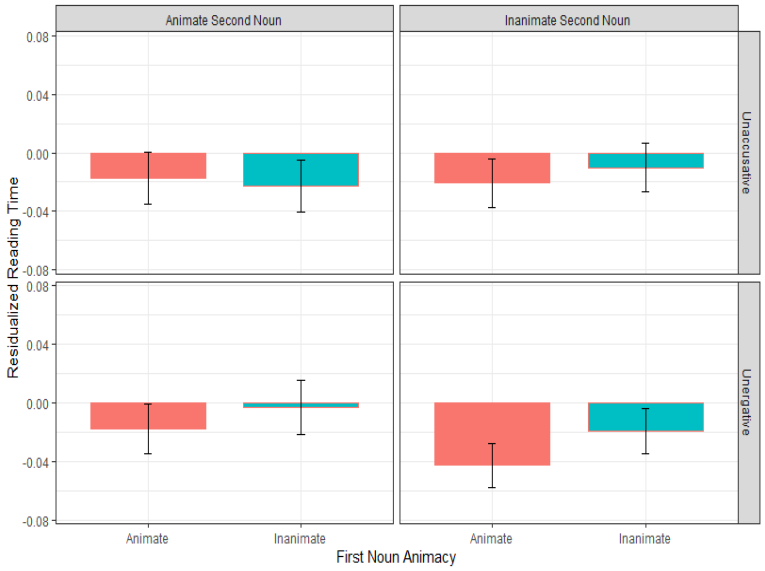

Figure 4.24: Residualized reading times for R4, course-credit group. Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length; reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

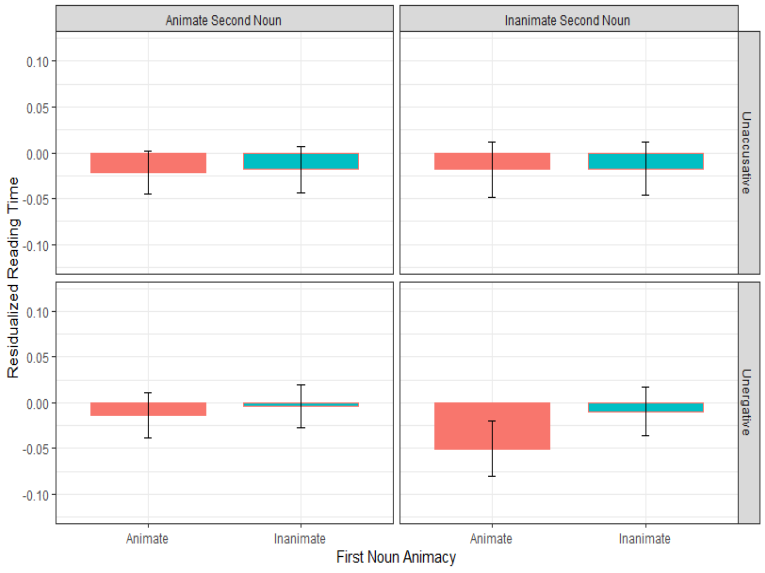

Figure 4.25: Residualized reading times for R4, lottery group.Residualized reading times for the eight conditions of the experiment are shown averaged across all groups. Zero represents no difference beyond the effect of word length;

reading times below or above the effect of word length suggest facilitation or disruption. Error bars represent confidence intervals. Graphs are shown in log scale.

first noun, animate second noun unergative sentences (*M* = 0.015, *SE* = 0.009, *95% CI:* 0.008, 0.039). The conditions with disruption were as follows: unaccusative, inanimate first, inanimate second: (*M* = 0.023, *SE* = 0.009, *95% CI:* 0.001, 0.046); unaccusative, inanimate first, animate second: (*M* = 0.046, *SE* = 0.009, *95% CI:* 0.023, 0.069); unaccusative, animate first, animate second: (*M* = 0.038, *SE* = 0.009, *95% CI:* 0.015, 0.061); unaccusative, animate first, inanimate second: (*M* = 0.049, *SE* = 0.008, *95% CI:* 0.026, 0.072); unergative animate first, animate second (*M* = 0.03, *SE* = 0.009, *95% CI:* 0.007, 0.053); unergative, inanimate first, animate second: (*M* = 0.038, *SE* = 0.009, *95% CI:* 0.015, 0.061); unergative, inanimate first, inanimate second: (*M* = 0.023, *SE* = 0.008, *95% CI:* 0.001, 0.046).

The course credit group and the MT group once again had the inverse of one another's disruption/facilitation patterns. In the course credit group, inanimate first noun, animate second noun unergative sentences (*M* = 0.028, *SE* = 0.008, *95% CI*: 0.006, 0.051) and inanimate first noun, inanimate second noun unaccusative sentences (*M* = 0.03, *SE* = 0.008, *95% CI:* 0.008, 0.053) showed disruption. In the MT group, all conditions showed facilitation except the inanimate first noun, animate second noun unergative sentences (*M* = -0.012, *SE* = 0.007, *95% CI:* -0.031, 0.006) and the inanimate first noun, inanimate second noun unaccusative sentences (*M* = -0.017, *SE* = 0.007, *95% CI:* -0.035, 0.002). Facilitation occurred in animate first noun, inanimate second noun unaccusative sentences (*M* = -0.027, *SE* = 0.007, *95% CI:* -0.046, -0.009), inanimate first noun, animate second noun unaccusative sentences (*M* = -0.028, *SE* = 0.009, *95% CI:* -0.046, -0.009), animate first noun, animate second noun unaccusative sentences (*M* = -

0.035, *SE* = 0.007, *95% CI:* -0.054, -0.017), animate first noun, animate second noun unergative sentences (*M* = -0.02, *SE* = 0.007, *95% CI:* -0.039, -0.002), inanimate first noun, inanimate second noun unergative sentences (*M* = -0.027, *SE* = 0.007, *95% CI :* -0.046, -0.009), and animate first noun, inanimate second noun unergative sentences (*M* = -0.035, *SE* = 0.007, *95% CI:* -0.054, -0.016).[16]

Although this region is not crucially important to our hypotheses, the results bear some interesting implications. First, the performance difference between groups is notable. Again, the course credit group and the MT group showed inverse results for disruption and facilitation. Also, the uncompensated group showed disruption for almost all conditions. This may be an effect of participants in the uncompensated group treating the experiment as a kind of "test" and therefore slowing down at the end of the sentence to be better able to answer the comprehension question that followed. This finding would be in line with personal communication I received from people doing the uncompensated version of the study, often asking if they had "passed" the experiment.

[16] Since there were three potentially alternating unaccusative verbs in our set of unaccusative verbs, we performed the same regressions with those verbs excluded. At this region, the results of the analyses with those verbs included and those excluded followed the same pattern, except that, for the reduced analysis, in the confidence intervals, the course credit group now did show disruption for inanimate first noun, animate second noun unaccusative verb sentences (M = 0.026, SE = 0.009, 95% CI: 0.001, 0.049) and for animate first noun, inanimate second noun unaccusative verb sentences (M = 0.031, SE = 0.009, 95% CI: 0.007, 0.054).

Discussion

Hypothesis 2 was confirmed. Inanimate first noun unergative verb sentences were associated with longer reading times than animate first noun sentences, suggesting an influence from animacy-thematic mismatch (Table 14 below). This finding was consistent across all groups. For the course credit group, this disruption started at the intransitive verb itself (Region1) and continued through the auxiliary phrase (Region 3). The uncompensated group showed the same effect from Region 1 to Region 2. For the MT group, the disruption started at Region 2 and continued to Region 3. The smallest group, the lottery group, registered disruption for inanimate first noun unergative sentences at Region 2, and this was the only significant effect for the lottery group. This finding is unsurprising, since previous research has shown that the appearance of an inanimate noun when the verb selects an animate noun is associated with disruption (e.g., Lowder & Gordon, 2014, Vernice & Sorace, 2018).

Hypothesis 1 is less substantially supported. Animate first noun unaccusative verb sentences were associated with slower reading times in the three largest groups, but not in the lottery group (Table 14 below). The uncompensated group and the course credit group showed slower reading times at the second noun (Region 2), but only when the second noun was inanimate. In the MT group and course credit group, animate first noun unaccusative sentences were associated with slower reading at the auxiliary verbs (Region 3). In the latter case, second noun animacy was not included in the model, and so it appears that the animacy-thematic mismatch effect occurs regardless of second noun

animacy[17]. The results at Region 3 appear to arise from animacy-thematic mismatch. However, at Region 2, not only is there disruption from animacy for unaccusative verbs only when the second noun is inanimate, but also unergative sentences showed the same effect: animate first nouns were associated with disruption when the second noun was inanimate.

This latter finding suggests that what appears to be unaccusative animacy-thematic disruption at Region 2 may result instead from the specific sequence of an animate noun-verb-inanimate noun that activates an expectation for a transitive structure, which leads to disruption when readers realize that the second noun is incompatible with a transitive interpretation. Slobin & Bever (1982) argue that children associate canonical word orders, like noun-verb-noun, with a typical agent-action-patient interpretation. This strategy leads children to misinterpret passive and cleft-constructions (Bever, 1970; Gertner & Fischer, 2012). Because of the salience of animacy and because children make animacy distinctions early on, it is reasonable to think that animacy is encoded in these developing canonical structures. There is also evidence that canonical representations remain and influence adult processing (e.g., Townsend & Bever, 2001).

However, these findings do not rule out – and are not even necessarily inconsistent with – an animacy-thematic mismatch effect for unaccusative verbs. If this effect is not particularly strong or only affects certain verbs (as suggested in Chapter 3),

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[17] A version of the regression model with the three-way interaction between first noun animacy, second noun animacy, and verb type included showed a significant effect of first noun animacy when the second noun was inanimate (M = -0.03, SE = 0.009, z =-3.343, p = 0.006) and a marginal effect when the second noun was animate (M = -0.021, SE = 0.009, z =-3.268, p = 0.09) for unaccusative verb in the MT group.

then it may only reach significance when it is compounded by the presence of an inanimate second noun, which is a poor cue for a new clause (discussed below). In Chapter 2, there was a marginal effect of first noun animacy when the second noun was animate, and in our current experiment the MT group had disruption regardless of second noun animacy. Our current experiments cannot distinguish between these two potential explanations. Surprisal accounts of early closure garden-path effects (e.g., Levy, 2013) can accommodate an explanation based on the additive influence of second noun animacy and animacy-thematic mismatch or an explanation specific to animate noun-verb-inanimate noun sequences and transitivity.

Table 4.2: Pattern of results for intransitive sentences

Group	Region 1	Region 2	Region 3	
Uncompensated	Thematic Mismatch	Thematic Mismatch		Unergative
		Thematic Mismatch		Unaccusative
Course Credit	Thematic Mismatch	Thematic Mismatch	Thematic Mismatch	Unergative
		Thematic Mismatch	Thematic Mismatch[18]	Unaccusative

[18] This effect was only significant when all verbs were included. However, with three potentially alternating unaccusative verbs removed, there was no longer an animacy-thematic mismatch effect at this region for the course credit group.

Lottery	Thematic Mismatch		Unergative
			Unaccusative
MT	Thematic Mismatch	Thematic Mismatch	Unergative
		Thematic Mismatch	Unaccusative

Although we did not directly compare unaccusative and unergative conditions as in Staub (2008), the pattern of animacy effects showed an interesting difference between verb types. Each group showed an earlier reaction to animacy-thematic mismatch for unergative verbs than for unaccusative verbs. This delayed disruption for uanccusative verbs draws an interesting comparison to cross-modal lexical priming research with unaccusative verbs (Friedmann, Taranto, Shapiro, & Swinney, 2008; Poirier, Walenski, & Shapiro, 2012; Koring, Mak, & Reuland, 2012; Koring & van der Koots, 2018). Cross-modal lexical priming research with intransitive verbs has found that information associated with the subject noun is reactivated immediately at the verb for both unergative and unaccusative verbs, but that unaccusative verbs incur a later priming effect at a probe located 750 ms after the intransitive verb. Typically, this finding is explained through the proposition in generative syntax that Agent subjects originate external to the verb phrase, while Theme subjects originate within the verb phrase. In this way, Agent subjects are able to directly integrate with higher nodes of the sentence, while

Theme subjects must first move out of the verb phrase and then integrate with higher nodes. This need for additional syntactic movement has been taken to indicate greater syntactic complexity for unaccusative verbs. However, as many of these studies primarily use animate subject nouns, there is a question of whether this delayed reactivation occurs because of the greater effort required to assign a non-agentive role to an animate, sentence-initial subject noun. The delayed effect of first noun animacy for unaccusative verbs relative to unergative verbs is suggestive. Although this study cannot directly address these cross-modal lexical priming effects, it does warrant future research on subject animacy in that paradigm.

Hypothesis 3 asked how second noun animacy would influence our experimental design with two early closure garden-path sentences, using unergative and unaccusative verbs. The effect of second noun animacy appears to be monotonic: animate second nouns lead to faster reading and inanimate second nouns lead to slower reading at the second noun (Region 2) and no effect at the auxiliary verb (Region 3). This pattern of results is in line with the idea that animate second nouns help deal with processing difficulty recognizing that the dependent clause has ended and a new clause has begun. There were no effects that suggested similarity-based interference played a role in reading time. This finding may be unsurprising, since our experimental sentences do not use relative clauses like those typically demonstrating similarity-based interference. However, because of the presence of two nouns in proximity that either shared or did not share the feature of animacy, it was a possibility.

Hypothesis 4 questioned what effect the recruitment platform had on processing animacy and early closure garden-path sentences. Our groups were categorized by

compensation method, although the groups also differed in other parameters – most notably age and sample size. The effect of sample size was evident. The lottery group, the smallest in sample size, only showed disruption from animacy-thematic mismatch for unergatives at Region 2. They did not register any disruption for unaccusative verbs, while all three larger groups did. The uncompensated and course credit groups performed almost identically. These groups showed effects for unergatives at Region 1 and 2 and for unaccusatives at Regions 2 and 3, while participants in the MT group showed effects for unergatives at Region 2 and 3 and for unaccusatives at Region 3. This delay may be a result of greater average age or of the MT group's pressure to complete tasks quickly and more immediate compensation[19]. However, because the uncompensated group was also older, it seems more likely that the different motivation plays a significant role. MT participants also seemed to speed up more as the sentence progressed, which course credit participants did not do and which the uncompensated group did the opposite of, slowing down toward the end of the sentence. This may be a result of more practice and focus from MT participants, who, unlike course credit participants, have many other similar tasks to perform on a given day. It may be that MT participants have developed a kind of expertise with reading tasks performed online (Chandler, Mueller, & Paolacci, 2014). The results also suggest there may be differences in psycholinguistic measurements from MT and student participant populations, despite some evidence that the two groups do perform the same (Enochson & Culbertson, 2015).

[19] We also performed a regression analysis with the MT group alone and with age included as a factor. This model showed the same pattern of results, which suggests that even with age accounted for, there is still a distinct pattern of results for the MT group.

Limitations

As in Chapter 2, there were several non-alternating unaccusative verbs included in the study that can potentially, though uncommonly, have a transitive interpretation. These verbs were “crumble,” “collapse,” and “stood.” However, in this experiment, there were few differences between models based on the full versus the reduced set of unaccusative verbs. The results for the full and reduced models are shown in Table 15. First, the unexplained facilitation for animate first noun sentences shown by the MT group with unaccusative verbs at Region 1 did not occur when the three verbs were removed. Second, for the course credit group, the preplanned contrasts showing animacy-thematic mismatch effect for animate first noun, inanimate second noun, unaccusative verb sentences was no longer present at Region 3. Finally, at Region 4, in the reduced model the course credit group showed disruption for unaccusative verbs in the animate first noun, inanimate second noun condition, the inanimate first noun, animate second noun condition. Again, these differences are minor and inessential to our hypotheses.

Conclusion

In this experiment, we asked a) whether the animacy-thematic mismatch effects observed in Chapter 2 for non-alternating unaccusative verbs would be replicated in a study using more items and employing comprehension questions rather than grammaticality judgments, and b) whether unergative verbs would also show animacy-thematic mismatch effects. Both hypotheses were confirmed. However, the timeline for disruption differed for the two intransitive verb types. Unaccusative verbs showed effects of animacy-thematic mismatch later than unergative verbs, which is a finding that may have ramifications on how we interpret the effect of unaccusativity on sentence

processing. This experiment also showed that animate second nouns ease recognition of the end of the dependent clause and are associated with faster reading times. In particular, an animate noun-verb-inanimate-noun template seemed to induce expectations of transitivity even with verbs strongly biased toward intransitivity, whereas an inanimate-noun-verb-animate-noun template was associated with easier resolution of the dependent clause structure of the experimental sentences. Overall, these findings support parallel, probabilistic approaches to sentence processing, where all available information is used to infer clausal structure incrementally through the reading of the sentence; when an interpretation that has higher likelihood must be abandoned, greater processing cost results in longer reading time.

The timeframe for reading disruption also differed for the different participant groups, which had different compensations, motivations, and average ages. Because these factors are not independent, it is premature to draw any conclusions about which of them drives the differences. Nonetheless, MT participants seemed to show delayed reactions relative to the other groups, although all groups with a sample size over one hundred were sensitive to both unergative and unaccusative sentences. In line with other research on MT participants, this suggests that MT participants are sensitive grammatical phenomena in the same way that university participants are; on the hand, the delayed disruption also suggests that MT participants may exhibit different strategies during processing.

Table 4.3: Differences in analyses

	MT group		Uncompensated group		Course-credit group		Lottery group	
	All verbs	Three verbs removed	All verbs	Three verbs removed	All verbs	Three verbs removed	All verbs	Three verbs removed
Region 1 Unacc.								
Inan.-An.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Inan.-Inan.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-An.	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Region 1 Unerg.								
Inan.-An.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Inan.-Inan.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-An.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect

Region 2 Unacc.								
Inan.-An.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Inan.-Inan.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-An.	No effect	No effect	Disruption	No effect	No effect	Disruption	No effect	No effect
An.-Inan.	No effect	No effect	Disruption	Disruption	Disruption	Disruption	No effect	No effect
Region 2 Unerg.								
Inan.-An.	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption
Inan.-Inan.	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption	Disruption
An.-An.	No effect	No effect	No effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	No effect	No effect	No effect	Disruption	Disruption	No effect	No effect	No effect
Region 3 Unacc.								
Inan.-An.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect
Inan.-Inan.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect
An.-An.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect

Region 3 Unerg.								
Inan.-An.	No effect	No effect	No effect	No effect	Disruption	Disruption	No effect	No effect
Inan.-Inan.	No effect	No effect	No effect	No effect	Disruption	Disruption	No effect	No effect
An.-An.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	Facilitation	Facilitation	No effect	No effect	No effect	No effect	No effect	No effect
Region 4 Unacc.								
Inan.-An.	Facilitation	Facilitation	Disruption	Disruption	No effect	Disruption	No effect	No effect
Inan.-Inan.	No effect	No effect	Disruption	Disruption	Disruption	Disruption	No effect	No effect
An.-An.	Facilitation	Facilitation	Disruption	Disruption	No effect	No effect	No effect	No effect
An.-Inan.	Facilitation	Facilitation	Disruption	Disruption	No effect	Disruption	No effect	No effect
Region 4 Unerg.								
Inan.-An.	No effect	No effect	Disruption	Disruption	Disruption	Disruption	No effect	No effect
Inan.-Inan.	Facilitation	Facilitation	Disruption	Disruption	No effect	No effect	No effect	No effect
An.-An.	Facilitation	Facilitation	No Effect	No effect	No effect	No effect	No effect	No effect
An.-Inan.	Facilitation	Facilitation	Disruption	Disruption	No effect	No effect	No effect	No effect

Chapter 5: Conclusion

This dissertation addressed three primary questions. First, we asked whether noun animacy guides sentence processing for non-alternating unaccusative verbs, a type of intransitive verb that always assigns a Theme to its subject noun. This question is directed at early closure garden-path effects that showed that unaccusative verbs lead to greater garden-path effects than unergative verbs (Staub, 2007; Dekydtspotter & Seo, 2017). However, these studies featured a subject noun with animacy-thematic match for unergative verbs (animate noun, Agent role) but an animacy-thematic mismatch for unaccusative verbs (animate noun, Theme role). Second, we asked whether animacy-thematic mismatch effects for early closure garden-path sentences might be driven by probabilistic associations between subject animacy and individual non-alternating unaccusative verbs – and whether these probabilistic associations between subject noun animacy and individual verbs equally affected early closure garden-path sentences (with non-alternating unaccusative verbs) and late closure garden-path sentences (with alternating unaccusative verbs). Third, we asked whether the animacy of the second noun in early closure garden-path constructions could facilitate reading as a cue for a new clause.

There were several ancillary questions also examined in this dissertation. These ancillary issues were a) whether animacy-sensitive late closure garden-path effects found in previous research (Clifton, 1993) would be replicated in an experiment using

alternating unaccusative verbs, b) whether animacy-thematic mismatch effects for unergative verbs found in previous research (Vernice & Sorace, 2018) would be replicated in an experiment using early closure garden-path sentences, and c) whether means of recruitment (*Amazon Mechanical Turk* vs student course credit vs other) would influence early closure garden-path effects.

In the concluding chapter of this dissertation, we discuss each of these topics in turn. First, we review our findings on animacy-thematic effects with non-alternating unaccusative verbs from Chapter 2 and 4, as well as the influence of second noun animacy. Next, we discuss our findings as they relate to the potential for domain-specific categorical effects of subject noun animacy, and what they show about early closure and late closure garden-path sentences (Chapter 3). After this, we review our replication studies of animacy-sensitivity for alternating unaccusatives (Chapter 2) and for unergative verbs (Chapter 4). Finally, we review differences between student populations and the popular recruiting platform, *Amazon Mechanical Turk,* before discussing potential future research directions.

Animacy and non-alternating unaccusative verbs

The main research question of this dissertation was about how animacy-thematic mismatch affects non-alternating unaccusative verbs. This effect was found in the experiments in Chapter 2 and 4. It appears that the animacy-thematic effect for non-alternating unaccusative verbs occurred across multiple experimental contexts: with grammaticality judgments and with comprehension questions, with in-lab tests and with remote online testing, and with student populations and with more general populations. We found that inanimate subject nouns helped readers to avoid early closure garden-path

effects; using animacy information, readers were able to recognize that the clause had ended even without a comma to indicate that clausal structure. This finding is in line with the view that sentence processing is guided by an opportunistic parser, which uses all available information to build expectations about the semantic and syntactic form of the sentence (e.g., MacDonald, 1994; Levy, 2008). Our finding casts some doubt on the hypothesis that unaccusative verbs are not sensitive to animacy-thematic mismatch (Vernice & Sorace, 2018) and suggests that the experimental support for the hypothesis that unaccusative verbs are simply more syntactically complex than unergative verbs may need to be revisited.

A related question is whether animacy information can help readers recognize the intransitivity of the clause. Some researchers have argued that readers do not and early closure garden-path effects are a result of an attempt to form a transitive that fails due to the delayed recognition of the verb's lexical information about being incompatible in a transitive construction (e.g., van Gompel & Pickering, 2001), while others have argued that readers do, in fact, "close" the clause and reading disruption results from how unusual it is for a clause to end in a verb without a comma (Staub, 2007; Levy, 2013).

Our findings suggest that readers do recognize the clause is intransitive – not based solely on the lexical information of the verb, but rather based on information in the clause as a whole. When the animacy of the subject noun matches the thematic role of a non-alternating unaccusative verb, it is easier to recognize that the clause will end up being intransitive. Also, the animacy of the second noun matters. For alternating unaccusative verbs with animate first nouns, sentences with an animate second noun were associated with longer reading times, because an animate second noun contradicts a

transitive reading. With unergative verbs, as well as non-alternating unaccusative verbs, animate second nouns led to faster reading than inanimate second nouns. Notably, inanimate second nouns only seemed to lead to difficulty when the first noun was animate – and this effect occurred for both unaccusative and unergative conditions. Along with animacy-thematic mismatch effects, there may also be an influence of animate noun-verb-inanimate noun as a canonical transitive clause sequence. Such an effect would not support a default transitive strategy, however, but instead an animacy-guided expectation for transitivity.

The effect of animacy on non-alternating unaccusative sentences was modulated by the strength of verb bias, based on our corpus-derived analyses. Non-alternating unaccusatives that were likely to have an animate subject did not show disruption – despite the fact that an animate noun was being assigned a Theme role. Instead, it appears that unaccusative verbs that prefer an inanimate subject are associated with reading difficulty when the subject is animate. This effect suggests that fine-grained associations exist between verbs and subject animacy probabilistically allow readers to navigate early closure garden-path sentences – and that the results are more complex than only matching or mismatching animacy to thematic roles. The capacity for noun animacy to obviate early closure garden-path effects appears to be dependent on many variables – the animacy of the first noun and the second noun, as well as the strength of association between animacy and subjecthood.

Animacy as a probabilistic vs categorical effect

Another main question in this dissertation was whether the animacy-thematic relationship in early and late closure garden-path sentences found in Chapters 2 and 4 is

better described as categorical information or as probabilistic associations between individual verbs and subject animacy. We derived two probabilistic variables from a selection of the *Penn Treebank Project* corpora: one for the simple probability of occurring with an animate or an inanimate subject noun and one for the probability of a transitive construction given the animacy of the subject noun. At Region 2, models based on these probabilistic variables performed better than categorical variables for animacy and thematic role. This suggests that early closure garden-path effects are better described by the individual verb associations with subject animacy. At Region 3, categorical models performed better than probabilistic models, suggesting that late closure garden-path effects are better described from a categorical viewpoint of animacy and thematic roles.

This result is intriguing because it supports Staub's explanation that early closure garden-path effects are driven by the difficulty of recognizing a clause ending without a comma. However, if information in the clause (like subject animacy probability) makes it easier to predict that the clause is complete, reading disruption is mitigated. Thus, if inanimate nouns are not only a cue that the clause will be intransitive for alternating unaccusative verbs, but also reenforce the expectation for an intransitive clause with non-alternating unaccusative verbs at Region 2. Late closure garden-paths, at Region 3 with animate first noun alternating unaccusative sentences are not influenced by how likely it is that the verb will appear with an animate subject or how frequently the verb appears with an animate subject or in a transitive clause. Instead, the animacy and verb type information is better descriptive of the resulting pattern. Research with animacy and cognition has suggested that animacy may be a domain-specific system, which is innate

and automatic. Thus, while early closure garden-path effects appear to be learned from specific verb associations with animacy, late closure garden-path effects may be related to an automatic sensitivity to a living/non-living distinction. While reading, people assign more attention and more expectation for action to animate (human) subject nouns. When there is a potential for interpreting animate entities as acting upon another object, readers are less influenced by probabilistic information regarding grammatical constructions than they are by an automatic tendency to assign animate nouns a causative role.

Animacy and alternating unaccusative verbs

Our study of the effect of animacy on alternating unaccusative verbs replicated the results of Clifton (1993). When paired with an animate subject, alternating unaccusative verbs led to a late closure garden-path effect – readers took the second noun to be an object and experienced reading disruption at the disambiguating verb phrase (Region 3). With an inanimate subject noun, there was an early closure garden-path effect, readers did not take the second noun to be the object of a transitive clause and instead showed an increase in reading time at the second noun. This reading time increase was diminished when the second noun was a good fit for a new clause subject and a bad fit for a grammatical object.

Animacy and unergative verbs

As expected, unergative verbs were sensitive to subject noun animacy. Animacy-thematic mismatch effects with unergative verbs led to disruption at the intransitive verb itself, earlier and stronger than animacy-thematic effects for unaccusative verbs. This result is unsurprising, since aside from the input of experimental research (e.g., Vernice

& Sorace, 2018; Lowder & Gordon, 2014), inanimate subjects for unergative clauses are intuitively anomalous and often require a metaphorical interpretation of the action.

We did not perform a corpus-based comparison of animacy associations for experiment done with unergative and non-alternating unaccusative verbs in Chapter 4. Other research has shown that corpus associations for unergative verbs is stronger than for unaccusative verbs (Merlot & Stevenson, 1998), however.

Effects of recruitment method

University students participating in the studies showed robustly similar results across the in-lab/grammaticality-judgment version of the study and the remote/comprehension-question version of the study regarding the reading of non-alternating unaccusative verb sentences. Student participants – with the same compensation and from the same age group – showed reading disruption at Region 2 when the subject noun was animate regardless of whether they were tested in the lab or online. The MT group, however, showed effects for non-alternating unaccusative verb sentences at Region 3, the disambiguating auxiliary verb phrase. In Chapter 2, we ascribed effects at this region to late closure garden-path sentences – which raises the question of whether this finding is a result of transitive expectations rather than animacy-thematic mismatch. However, there are a few reasons to believe that this is not the case. First, and most importantly, the same pattern of results occurs when we removed the unaccusative verbs that, according to the corpus sample, were potentially transitive. This alone makes a late closure effect seem unlikely. Second, two other groups – students and uncompensated – showed the same pattern of results for unergative and unaccusative verbs that the MT participants showed, only one region earlier – at Region 1 and Region

2, respectively. Since MT participants only showed animacy-thematic mismatch effects for unergatives at Region 2, it is possible to chalk up the pattern of results as simply a greater delay registering animacy-thematic mismatch. This could be caused by the different reading strategies that MT participants employed, as they read more quickly and showed, through lack of facilitation, the same results that appeared in other groups as disruption. It may also be due to the variance of age in the MT group compared to the student group. However, the uncompensated group showed a similar age range to the MT group and their pattern of results was not delayed. It seems likely that task motivation played a larger role, since all other types of participants one task, one time, but MT participants are working by the hour.

Future directions

The experiments in Chapters 2 and 4 have established a baseline of evidence for animacy-thematic mismatch effects on unaccusative verbs. When paired in an experiment with both alternating unaccusative verbs and unergative verbs, non-alternating unaccusative verbs showed a distinct pattern of results: early closure garden-path effects, which are modulated by animacy-thematic mismatch. These established effects are a good foundation for future research, which could focus directly on animacy and non-alternating unaccusative verbs.

One direction future research might take is to look directly at the effect of subject animacy in *delayed unaccusative reactivation* research, as observed in cross-modal lexical priming (e.g., Friedmann, Taranto, Shapiro, & Swinney, 2008; Sullivan, Walenski, Love, & Shapiro, 2017). In this paradigm, participants listen to a sentence and simultaneously respond to probes with a task like identifying whether an orthographic

cue is a word or not (Friedmann, Taranto, Shapiro, & Swinney, 2008) or whether a picture features something alive or not (Sullivan, Walenski, Love, & Shapiro, 2017). Some of these probes relate to the semantic material of the subject noun of the sentence, while others do not. The difference between related and unrelated probe response times indicates mental activation of the subject noun. Unergative verbs show reactivation at the intransitive verb, while non-alternating unaccusative verbs show delayed reactivation at a probe 750 ms later. This priming effect is attributed to syntactic movement, as the subject noun for unaccusatives must undergo movement, as a Theme, from inside the verb clause, to the *Spec*, C position, external to the verb phrase, in the generative grammar framework (Friedmann, Taranto, Shapiro, & Swinney, 2008).

This type of movement is distinguished from the movement in relative clauses and *Wh*-questions because, while unaccusatives (and passives) require movement to the *Spec*, C node, the former constructions require movement of an NP directly to a subject position in the sentence (Friedmann, Taranto, Shapiro, & Swinney, 2008). The connection between subject animacy and unaccusative verbs shown in this dissertation suggests that there is a possibility, in cross-modal lexical priming, that inanimate subject nouns may be able to guide parsing by acting as a cue that the single-argument movement that occurs with unaccusative verbs and therefore reduce or eliminate delayed reactivation.

Eye-tracking is another direction for future research, which would allow more fine-grained measures of cognitive processes reflected in saccadic movements during reading. The experiment for Chapter 4 was originally designed – and partially carried out – using eye-tracking instead of self-paced reading. Twenty-six participants performed

this in-lab eye-tracking experiment, using essentially the same stimuli as used in Chapter 4 (though with all animate second nouns), prior to COVID restrictions shutting down in-person testing at the University of South Carolina. Although I have not reported this partial result here, the pattern of results was similar to the remote self-paced reading. There was some evidence of animacy-thematic interference for both verb types, although unergative verb sentences showed greater and earlier disruption. Replicating these studies with eye-tracking could shed insight into whether animacy-thematic mismatch affects intransitive verbs differently at early processes, like accessing lexical material, or at later processes, like integration and revision.

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Appendix A: Experimental Items from Chapter 2

Animate First Noun, Inanimate Second Noun Alternating Unaccusative

As the thief broke the sculpture was being painted in the strange arena.

As the queen opened the lock was being destroyed in the front lobby.

As the dancer rolled the toy was being designed in the dusty garage.

As the dad dried the shirt was being ironed in the dark hallway.

As the girl closed the bank was being robbed on a dangerous street.

As the warrior swung the armor was being hidden in the distant city

As the clerk shut the gate was being repaired at the old farmhouse.

As the student grew the plant was being sheltered in the cold forest.

As the guy twisted the idea was being discussed at the large factory.

As the waiter froze the meat was being grilled in the fancy kitchen.

As the woman leaned the table was being built in the dusty warehouse.

As the lady burned the book was being praised at the yearly celebration.

As the teacher dropped the candle was being lit in the huge cathedral.

As the maid turned the chair was being brought into the dining area.

Animate First Noun, Inanimate Second Noun Non-alternating Unaccusative

As the singer vanished the piano was being played in the movie theater.

As the writer appeared the purse was being stolen at the crowded mall.

As the guard arrived the room was being decorated in the grand museum.

As the driver disappeared the wheel was being removed from the cheap car.

As the mother existed the fruit was being gathered each sunny morning.

As the guest settled the meal was being prepared at the friendly cafe.

As the doctor emerged the diamond was being viewed in the famous college.

As the soldier crumbled the treasure was being discovered in the deep cave.

As the lawyer fell the sign was being displayed on the busy highway.

As the priest died the field was being raked on the enormous farm.

As the man collapsed the building was being constructed in the new district.

As the boy glowed the experiment was being completed in the clean laboratory.

As the child floated the pool was being filled at the fine hotel.

As the king decayed the corn was being harvested in the yellow field.

Inanimate First Noun, Inanimate Second Noun Alternating Unaccusative

As the plate broke the sculpture was being painted in the strange arena.

As the box opened the lock was being destroyed in the front lobby.

As the wagon rolled the toy was being designed in the dusty garage.

As the sheet dried the shirt was being ironed in the dark hallway.

As the store closed the bank was being robbed on a dangerous street.

As the hammer swung the armor was being hidden in the distant city.

As the desk shut the gate was being repaired at the old farmhouse.

As the flower grew the plant was being sheltered in the cold forest.

As the rope twisted the idea was being discussed at the large factory.

As the bottle froze the meat was being grilled in the fancy kitchen.

As the statue leaned the table was being built in the dusty warehouse.

As the picture burned the book was being praised at the yearly celebration.

As the money dropped the candle was being lit in the huge cathedral.

As the cart turned the chair was being brought into the dining area.

Inanimate First Noun, Inanimate Second Noun Non-alternating Unaccusative

As the temple vanished the piano was being played in the movie theater.

As the number appeared the purse was being stolen at the crowded mall.

As the gift arrived the room was being decorated in the grand museum.

As the item disappeared the wheel was being removed from the cheap car.

As the garden existed the fruit was being gathered each sunny morning.

As the snow settled the meal was being prepared at the friendly cafe.

As the problem emerged the diamond was being viewed in the famous college.

As the tower crumbled the treasure was being discovered in the deep cave.

As the apple fell the sign was being displayed on the busy highway.

As the tree died the field was being raked on the enormous farm.

As the bridge collapsed the building was being constructed in the new district.

As the rock glowed the experiment was being completed in the clean laboratory.

As the ball floated the pool was being filled at the fine hotel.

As the barn decayed the corn was being harvested in the yellow field.

Animate First Noun, Animate Second Noun Alternating Unaccusative

As the thief broke the sheriff was being attacked in the strange arena.

As the queen opened the dancer was being chosen in the front lobby.

As the dentist rolled the helper was being trained in the dusty garage.

As the dad dried the neighbor was being investigated in the dark hallway.

As the girl closed the grandma was being buried at the old farmhouse.

As the warrior swung the enemy was being defeated in the distant city.

As the clerk shut the boss was being praised in the small restaurant.

As the student grew the hero was being sheltered in the cold forest.

As the guy twisted the artist was being discussed at the large factory.

As the waiter froze the fighter was being rewarded in the fancy kitchen.

As the woman leaned the accountant was being fired in the dusty warehouse.

As the lady burned the nurse was being called at the central hospital.

As the teacher dropped the salesman was being robbed in the huge cathedral.

As the maid turned the customer was being annoyed in the dining area.

Animate First Noun, Animate Second Noun Non-alternating Unaccusative

As the singer vanished the president was being kidnapped in the movie theater.

As the writer appeared the actress was being interviewed at the crowded mall.

As the guard arrived the boxer was being noticed in the grand museum.

As the driver disappeared the manager was being arrested on the fast train.

As the mother existed the nephew was being raised at the famous college.

As the guest settled the employee was being bothered at the friendly cafe.

As the doctor emerged the gentleman was being tricked at the yearly celebration.

As the soldier crumbled the spy was being discovered in the deep cave.

As the lawyer fell the journalist was being insulted on the busy highway.

As the priest died the detective was being chased in the new district.

As the man collapsed the assistant was being punished on the enormous farm.

As the boy glowed the scientist was being questioned in the clean laboratory.

As the child floated the judge was being poisoned at the fine hotel.

As the king decayed the citizen was being murdered in the yellow field.

Inanimate First Noun, Animate Second Noun Alternating Unaccusative

As the plate broke the sheriff was being attacked in the strange arena.

As the box opened the dancer was being chosen in the front lobby.

As the wagon rolled the helper was being trained in the dusty garage.

As the sheet dried the neighbor was being investigated in the dark hallway.

As the store closed the grandma was being buried at the old farmhouse.

As the hammer swung the enemy was being defeated in the distant city.

As the desk shut the boss was being praised in the small restaurant.

As the flower grew the hero was being sheltered in the cold forest.

As the rope twisted the artist was being discussed at the large factory.

As the bottle froze the fighter was being rewarded in the fancy kitchen.

As the statue leaned the accountant was being fired in the dusty warehouse.

As the picture burned the nurse was being called at the central hospital.

As the money dropped the salesman was being robbed in the huge cathedral.

As the cart turned the customer was being annoyed into the dining area.

Inanimate First Noun, Animate Second Noun Non-alternating Unaccusative

As the temple vanished the president was being kidnapped in the movie theater.

As the number appeared the actress was being interviewed at the crowded mall.

As the gift arrived the boxer was being noticed in the grand museum.

As the item disappeared the manager was being arrested on the fast train.

As the garden existed the nephew was being raised at the famous college.

As the snow settled the employee was being bothered at the friendly cafe.

As the problem emerged the gentleman was being tricked at the yearly celebration.

As the tower crumbled the spy was being discovered in the deep cave.

As the apple fell the journalist was being insulted on the busy highway.

As the tree died the detective was being chased in the new district.

As the bridge collapsed the assistant was being punished on the enormous farm.

As the rock glowed the scientist was being questioned in the clean laboratory.

As the ball floated the judge was being poisoned at the fine hotel.

As the barn decayed the citizen was being murdered in the yellow field.

Filler Sentences, ungrammatical

When over ten boats lazily entered the harbor the engines making a loud face.

As the donkey tasted the fruit was quiet in the dark jungle.

While the camel slowly walked the bird the dangerous street filled with sound.

The artist happily imagined the fence green yard landed in the long.

When the detective arrested the criminal hired an attorney with an awful reputation.

When the baseball the player threw the stadium filled with cheers and shouts.

When the breakfast prepared the two farmers had just driven to the field.

When the machine created the puzzle the experiment began the programmer.

When the truck chaotically bounced over the rocks in the back flipped over.

When the ideas confused the new employee decided the quit her job.

Over the weekend all the ants crawling beneath the new sidewalk.

An insect fought the spider was the color of a ripe tomato.

In the action movie the hero killed the victim was being rescued.

A recent story in the newspaper described the young criminal was arrested.

The evidence freshly examined by the smart officer was found to be lying.

Because the fly landed in the soup the customer was refused to eat it.

During the boring class the children reading funny comic books in secret.

During an interesting chess game the master finally won the new player.

The judge examined the tricky case never told anyone his secret.

An elephant threw the smiling monkey jumped from the scary tree.

In a few hours the explosive storm attacked by the helpless country people.

In the closet the clothes were cozily sleeping and almost by noticed them everybody.

An ancient town many tourists visited during the romantic summer in the mountains.

The magazine finished the author with only a few minutes to spare.

The boss hired the new workers spent too much time playing games.

The truck crashed by the speedy driver believed he was safe and okay.

The cabinet constantly dreamed about the dragons and stayed his friend to told home.

Every day the vegetables eagerly studied by the instructions until they remembered.

Filler Sentences, grammatical

As the infant cried the entrepreneur and the parents ran to the other room.

As the artifact eerily surprised the professor the old theory turned out to be true.

As the nurse brushed the dog the cat was being taken to the nearby hospital.

As winter blew through the air the rivers warned the crazy dictator.

As the worm hungrily devoured the chicken he cried out for help from his friends.

When the time came the wheat seeds had to be planted carefully in the dirt.

When the assistant spilled it the coffee was just beginning to cool down.

When the wolves chased the sheep ran as fast as possible into the mountain.

When the light dangerously exposed the criminal he escaped through a secret exit.

When the eagle squeezed the rabbit he stopped struggling and closed his eyes.

In the evening when the wife realized it the meal was already becoming cold and tasteless.

When the fire reached the library it was too late to save it from disaster.

When the expert spoke the words came slowly and with a lot of difficulty.

As a joke the servant hid the keys when it was time to leave.

In a single moment the kitten began to bravely battle the wild dog.

During the long winter four researchers at the small school kept the live frog.

An animal tested for hours by scientists was found to have a bad virus.

Five reporters caught by the police were just released from the harsh prison.

In a few minutes the enormous church was empty and the people went home.

On the bed some large bananas were having dinner very happily.

By the sound Samuel heard he knew his daughter was up watching television.

The lovely singer believed to be dead was found alive and well today.

An old story always considered by many to be true was actually a lie.

The salesman saw the clock was running later than he expected it would be.

The ghost barely knew the explorer who told him about the new visitors.

The professor just yesterday understood the television show was only a work of fiction.

The secretary expected the delivery but it never came to her house.

Quietly the tiger left the cage the zookeepers forgot to close last night.

Appendix B: Experimental Items from Chapter 4

Animate First Noun, Animate Second Noun Unergative

As the director whistled the artist was being discussed at the chic gallery.

As the fighter wept the enemy was being defeated in the distant city.

As the customer laughed the owner was being shamed in the fancy kitchen.

As the athlete waited the attendant was being arrested in the private gym.

As the maid squealed the princess was being annoyed in the dining area.

As the boy prayed the hero was being sheltered in the cold forest.

As the thief smiled the nurse was being called at the central hospital.

As the suspect sneered the witness was being examined in the police station.

As the secretary lied the accountant was being promoted in the shiny warehouse.

As the victim screamed the volunteer was being treated at the emergency clinic.

As the performer danced the spectator was being seated in the empty aisle.

As the husband grinned the cashier was being scolded in the grocery store.

As the prisoner howled the elder was being threatened in the rough countryside.

As the fireman coughed the boss was being followed in the dark hallway.

As the judge frowned the criminal was being handcuffed in the somber hearing.

As the guest meditated the novice was being instructed in the long hallway.

Animate First Noun, Animate Second Noun Unaccusative

As the guard arrived the boxer was being admired at the nice university.

As the driver disappeared the sheriff was being served at the small cafe.

As the writer appeared the actress was being interviewed at the crowded mall.

As the assistant glowed the scientist was being questioned in the tidy lab.

As the diplomat crumbled the spy was being discovered during the important operation.

As the child floated the mobster was being poisoned at the public pool.

As the swimmer glistened the runner was being watched at the sports event.

As the principal stood the janitor was being welcomed at the holiday party.

As the doctor emerged the gentleman was being tricked at the wild celebration.

As the man collapsed the clerk was being punished on the old farm.

As the priest died the detective was being chased in the new district.

As the leader trembled the activist was being attacked at the famous college.

As the manager thrived the gardener was being educated at the trade school.

As the king decayed the citizen was being murdered in the yellow field.

As the lawyer fell the journalist was being insulted on the busy highway.

As the singer vanished the president was being kidnapped in the movie theater.

Inanimate First Noun, Animate Second Noun Unergative

As the factory whistled the artist was being discussed at the chic gallery.

As the village wept the enemy was being defeated in the distant city.

As the restaurant laughed the owner was being shamed in the fancy kitchen.

As the garbage waited the attendant was being arrested in the private gym.

As the cart squealed the princess was being annoyed in the dining area.

As the church prayed the hero was being sheltered in the cold forest.

As the television smiled the nurse was being called at the central hospital.

As the reflection sneered the witness was being examined in the police station.

As the advertisement lied the accountant was being promoted in the shiny warehouse.

As the ambulance screamed the volunteer was being treated at the emergency clinic.

As the spotlight danced the spectator was being seated in the empty aisle.

As the room grinned the cashier was being scolded in the grocery store.

As the volcano howled the elder was being threatened in the rough countryside.

As the engine coughed the boss was being followed in the dark hallway.

As the court frowned the criminal was being handcuffed in the somber hearing.

As the temple meditated the novice was being instructed in the long hallway.

Inanimate First Noun, Animate Second Noun Unergative

As the gift arrived the boxer was being admired at the nice university.

As the item disappeared the sheriff was being served at the small cafe.

As the number appeared the actress was being interviewed at the crowded mall.

As the rock glowed the scientist was being questioned in the tidy lab.

As the defense crumbled the spy was being discovered during the important operation.

As the ball floated the mobster was being poisoned at the public pool.

As the ocean glistened the runner was being watched at the sports event.

As the office stood the janitor was being welcomed at the holiday party.

As the problem emerged the gentleman was being tricked at the wild celebration.

As the bridge collapsed the clerk was being punished on the old farm.

As the tree died the detective was being chased in the new district.

As the antenna trembled the activist was being attacked at the famous college.

As the neighborhood thrived the gardener was being educated at the trade school.

As the barn decayed the citizen was being murdered in the yellow field.

As the tower fell the journalist was being insulted on the busy highway.

As the document vanished the president was being kidnapped in the movie theater.

Animate First Noun, Innimate Second Noun Unergative

As the director whistled the atmosphere was being ruined at the chic gallery.

As the fighter wept the casket was being carried in the distant city.

As the customer laughed the menu was being prepared in the fancy kitchen.

As the athlete waited the perfume was being sprayed in the locker room.

As the maid squealed the basket was being filled in the spacious kitchen.

As the boy prayed the pumpkin was being harvested in the cold forest.

As the thief smiled the evidence was being hidden in the drafty attic.

As the suspect sneered the photographs were being examined at the police station.

As the secretary lied the policy was being discussed in the smokey room.

As the victim screamed the injury was being treated at the emergency unit.

As the performer danced the curtain was being lowered in the full theater.

As the husband grinned the tomato was being plucked in the serene garden.

As the prisoner howled the barricade was being constructed at the national border.

As the fireman coughed the furnace was being repaired in the dark basement.

As the judge frowned the charges were being recorded in the somber hearing.

As the guest meditated the doctrine was being taught in the long hallway.

Animate First Noun, Inanimate Second Noun Unaccusative

As the guard arrived the floor was being cleaned at the nice university.

As the driver disappeared the vehicle was being identified at the crime scene.

As the writer appeared the presentation was being given in the engineering department.

As the student glowed the experiment was being conducted in the tidy lab.

As the diplomat crumbled the anniversary was being celebrated in the historic province.

As the child floated the bucket was being emptied at the public pool.

As the swimmer glistened the harbor was being evacuated at the lovely beach.

As the principal stood the trophy was being displayed in the school showcase.

As the doctor emerged the uniform was being sanitized in the hospital laundromat.

As the man collapsed the anthem was being recited on the old farm.

As the priest died the grass was being mowed in the rural courtyard.

As the leader trembled the banner was being waved at the rowdy gathering.

As the manager thrived the business was being audited at the county offices.

As the king decayed the castle was being demolished in the yellow field.

As the lawyer fell the decision was being reviewed in the ominous courtroom.

As the scientist vanished the sculpture was being discovered at the excavation site.

Inanimate First Noun, Inanimate Second Noun Unergative

As the village wept the casket was being carried in the distant city.

As the factory whistled the atmosphere was being ruined at the chic gallery.

As the restaurant laughed the menu was being prepared in the fancy kitchen.

As the delivery waited the perfume was being sprayed in the locker room.

As the cart squealed the basket was being filled in the spacious kitchen.

As the church prayed the pumpkin was being harvested in the cold forest.

As the screen smiled the evidence was being hidden in the drafty attic.

As the reflection sneered the photographs were being examined at the police station.

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As the ambulance screamed the injury was being treated at the emergency unit.

As the spotlight danced the curtain was being lowered in the full theater.

As the face grinned the tomato was being plucked in the serene garden.

As the volcano howled the barricade was being constructed at the national border.

As the engine coughed the furnace was being repaired in the dark basement.

As the court frowned the charges were being recorded in the somber hearing.

As the temple meditated the doctrine was being taught in the long hallway.

Inanimate First Noun, Inanimate Second Noun Unaccusative

As the gift arrived the floor was being cleaned at the nice university.

As the item disappeared the vehicle was being identified at the crime scene.

As the number appeared the presentation was being given in the engineering department.

As the rock glowed the experiment was being conducted in the tidy lab.

As the marriage crumbled the anniversary was being celebrated in the historic province.

As the ball floated the bucket was being emptied at the public pool.

As the ocean glistened the harbor was being evacuated at the lovely beach.

As the monument stood the trophy was being displayed in the school showcase.

As the problem emerged the uniform was being sanitized in the hospital laundromat.

As the bridge collapsed the anthem was being recited on the old farm.

As the tree died the grass was being mowed in the rural courtyard. As the antenna trembled the banner was being waved at the rowdy gathering.

As the neighborhood thrived the business was being audited at the county offices.

As the barn decayed the castle was being demolished in the yellow field.

As the tower fell the decision was being reviewed in the ominous courtroom.

As the document vanished the sculpture was being discovered at the excavation site.

Filler sentences

Every evening the mayor strolled through the grass thinking quietly.

At a distance the leopard stalked the sneaky lizard that continued to escape her.

While the insect fought the bird the spider turned the color of a ripe avocado.

When ten boats lazily entered the bay the water became tumultuous.

The editor finished the magazine with only a few minutes to spare.

While the veterinarian brushed the dog the cat was being taken to the nearby hospital.

Quietly the tiger left the cage the zookeepers forgot to close last night.

When the trailer chaotically flipped the cargo in the back spilled out.

An animal tested for hours by the team was found to have a bad virus.

The foreign minister that encoded the top secret messages was handed a new mission that required going to Japan.

The clothes in the closet were cozily stored and nobody noticed them.

While the donkey chewed oats the lion was quiet in the dark jungle.

The gorgeous celebrity believed to be dead was found alive and well today.

The captain expected the shipment but it never came to her house.

Fourteen glorious doves fled and sank into the clouds just before the hawk could see them.

When the wolves chased the cattle the sheep ran as fast as possible into the forest.

While the father blindly turned away his son reached into the cookie jar again.

By the sound Samuel heard he knew his daughter was up watching the thunderstorm.

While the machine calculated the answer had already been proven.

In the few hours that the explosive blizzard was raging all the helpless country people fled.

When the baseball player threw the ball it landed high and outside.

Ten engineers who could not solve the dilemma learned that their careers were in jeopardy.

An old story that had always been considered by many to be true was actually false.

When winter began to blow through the town the advisors warned the dictator.

During an interesting chess game the new player finally outmatched the master.

While the camel slowly walked the murky street filled with sound.

A recent story in the newspaper described the young embezzler who was brought to justice.

When the time came the wheat seeds had to be planted carefully in the dirt.

After the investigation suspected the culprit he hired an attorney with an awful reputation.

The fingerprints freshly gathered by the smart officer were found to be flawed.

As a joke the servant hid the keys when it was time to leave.

Many tourists visited an ancient town in the mountains during the romantic summer.